Vol. 31. Suplemento 3. Marzo 2015
DOI:10.3305/nh.2015.31.sup3.8745

Nutrición Hospitalaria

ÓRGANO OFICIAL DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN PARENTERAL Y ENTERAL
ÓRGANO OFICIAL DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN
ÓRGANO OFICIAL DE LA FEDERACIÓN LATINO AMERICANA DE NUTRICIÓN PARENTERAL Y ENTERAL
ÓRGANO OFICIAL DE LA FEDERACIÓN ESPAÑOLA DE SOCIEDADES DE NUTRICIÓN, ALIMENTACIÓN Y DIETÉTICA

CONSENSUS MEETING ON THE METHODOLOGY OF DIETARY SURVEYS, CLASSIFICATION OF PHYSICAL ACTIVITY AND HEALTHY LIFESTYLES

REUNIÓN DE CONSENSO SOBRE LA METODOLOGÍA DE LAS ENCUESTAS ALIMENTARIAS, TIPIFICACIÓN DE LA ACTIVIDAD FÍSICA Y ESTILOS DE VIDA SALUDABLES

Editor/Editor:
Javier Aranceta Bartrina

Associated editors/Co-editores:
Gregorio Varela Moreiras and Lluis Serra-Majem

Laguardia (Rioja Alavesa)
18th & 19th September 2014

ISSN 0212-1611
9 770212 161004

Nutr Hosp. 2015;(Supl.3)31:1-292 • ISSN (Versión papel): 0212-1611 • ISSN (Versión electrónica): 1699-5198 • CODEN NUHOEQ • S.V.R. 318

Incluida en EMBASE (Excerpta Medica), MEDLINE (Index Medicus), Chemical Abstracts, Cinahl, Cochran e plus, Ebsco, Índice Médico Español, preIBECS, IBECS, MEDES, SENIOR, ScIELO, Science Citation Index Expanded (SciSearch), Cancerlit, Toxline, Aidsline y Health Planning Administration

www.nutricionhospitalaria.com

ISSN (Versión papel): 0212-1611
ISSN (Versión electrónica): 1699-5198

Nutrición Hospitalaria

IMPACT FACTOR 2013: 1,250 (JCR)

www.nutriciónhospitalaria.com

ÓRGANO OFICIAL DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN PARENTERAL Y ENTERAL

ÓRGANO OFICIAL DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN

ÓRGANO OFICIAL DE LA FEDERACIÓN LATINO AMERICANA DE NUTRICIÓN PARENTERAL Y ENTERAL

ÓRGANO OFICIAL DE LA FEDERACIÓN ESPAÑOLA DE SOCIEDADES DE NUTRICIÓN, ALIMENTACIÓN Y DIETÉTICA

Suplemento 3. Vol. 31. Marzo 2015

Edición y Administración
GRUPO AULA MÉDICA, S.L.

OFICINA
Isabel Colbrand, 10-12
Oficina 140 Planta 5.ª - 28050 Madrid
Tel.: 913 446 554 - Fax: 913 446 586
www.aulamedica.es

Dep. Legal: M-34.850-1982
Soporte válido: 19/05-R-CM
ISSN (Versión papel): 0212-1611
ISSN (Versión electrónica): 1699-5198

Suscripción y pedidos
GRUPO AULA MÉDICA, S.L.

Tarifas de suscripción:
Profesional ..... 201,87 € + IVA
Institución ..... 207 € + IVA

- **Por teléfono:**
  91 344 65 54
- **Por fax:**
  91 344 65 86
- **Por e-mail:**
  consuelo@grupoaulamedica.com

aulamédica
formación en salud

www.aulamedica.es

NORMAS DE PUBLICACIÓN PARA LOS AUTORES DE NUTRICIÓN HOSPITALARIA

Nutrición Hospitalaria

Nutrición Hospitalaria, es la publicación científica oficial de la Sociedad Española de Nutrición Parenteral y Enteral (SENPE), de la Sociedad Española de Nutrición (SEN), de la Federación Latino Americana de Nutrición Parenteral y Enteral (FELANPE) y de la Federación Española de Sociedades de Nutrición, Alimentación y Dietética (FESNAD).

Publica trabajos en castellano e inglés sobre temas relacionados con el vasto campo de la nutrición. El envío de un manuscrito a la revista implica que es original y no ha sido publicado, ni está siendo evaluado para publicación, en otra revista y deben haberse elaborado siguiendo los Requisitos de Uniformidad del Comité Internacional de Directores de Revistas Médicas en su última versión (versión oficial disponible en inglés en http://www.icme.org; correspondiente traducción al castellano en: http://www.metodo.uab.es/ enlaces/Requisitos_de_Uniformidad_2006.pdf).

La falta de consideración de estos requisitos e instrucciones producirá, inevitablemente, un retraso en el proceso editorial y en la posible publicación del manuscrito, y también puede ser causa del rechazo del trabajo.

IMPORTANTE: A la aceptación y aprobación definitiva de cada artículo deberá abonarse la cantidad más impuestos vigente en el momento de la aceptación del artículo (que será publicada en un anexo en estas normas) en concepto de contribución parcial al coste del proceso editorial de la revista. El autor recibirá un comunicado mediante correo electrónico, desde la empresa editorial, indicándole el procedimiento a seguir.

1. REMISIÓN Y PRESENTACIÓN DE MANUSCRITOS

Los trabajos se remitirán por vía electrónica a través del portal www.nutricionhospitalaria.com. En este portal el autor encontrará directrices y facilidades para la elaboración de su manuscrito. Los archivos correspondientes a texto se deberán de enviar en formato WORD. Los correspondientes a imágenes se podrán enviar en formato JPG.

Cada parte del manuscrito empezará una página, respetando siempre el siguiente orden:

1.1 Carta de presentación

- Deberá indicar el Tipo de Artículo que se remite a consideración y contendrá:
- Una breve explicación de cuál es su aportación así como su relevancia dentro del campo de la nutrición.
- Declaración de que es un texto original y no se encuentra en proceso de evaluación por otra revista, que no se trata de publicación redundante, así como declaración de cualquier tipo de confl icto de intereses o la existencia de cualquier tipo de relación económica.
- Conformidad de los criterios de autoría de todos los firmantes y su filiación profesional.
- Cesión a la revista Nutrición Hospitalaria de los derechos exclusivos para editar, publicar, reproducir, distribuir copias, preparar trabajos derivados en papel, electrónicos o multimedia e incluir el artículo en índices nacionales e internacionales o bases de datos.
- Nombre completo, dirección postal y electrónica, teléfono e institución del autor principal o responsable de la correspondencia.
- Cuando se presenten estudios realizados en seres humanos, debe enunciarse el cumplimiento de las normas éticas del Comité de Investigación o de Ensayos Clínicos correspondiente y de la Declaración de Helsinki vigente, disponible en: http://www.wma.net/s/ index.htm.

1.2 Página de título

Se indicarán, en el orden que aquí se cita, los siguientes datos: título del artículo (será obligatorio el envío del Título en castellano e inglés por parte de los autores); se evitarán símbolos y acrónimos que no sean de uso común.

Nombre completo y apellido de todos los autores (es obligatorio el envío por parte de los autores del nombre completo y los dos apellidos, no aceptándose el uso de abreviaturas y/o iniciales), separados entre sí por una coma. Se aconseja que figure un máximo de ocho autores, figurando el resto en un anexo al final del texto.

Mediante números arábigos, en superíndice, se relacionará a cada autor, si procede, con el nombre de la institución a la que pertenecen. Deberá volver a enunciar los datos del autor responsable de la correspondencia que ya se deben haber incluido en la carta de presentación.

En la parte inferior se especificará el número total de palabras del cuerpo del artículo (excluyendo la carta de presentación, el resumen, agradecimientos, referencias bibliográficas, tablas y figuras).

Se incluirá la dirección postal y de correo electrónico del/de el autor/a designado para correspondencia.

1.3 Resumen

Será estructurado en el caso de originales, originales breves y revisiones, cumplimentando los apartados de Introducción, Objetivos, Métodos, Resultados y Discusión (Conclusiones, en su caso). Deberá ser comprensible por sí mismo y no contendrá citas bibliográficas.

Se deberá de incluir la versión en castellano e inglés del resumen con idéntica estructuración. Así mismo se incluirán aquí las palabras clave en castellano e inglés. Tanto resumen como palabras claves se deben enviar en los dos idiomas. Debe recordarse que esta información en inglés aparecerá en las bases de datos bibliográficas, y es responsabilidad de los autores/as su corrección ortográfica y gramatical.

1.4 Palabras clave

Debe incluirse al final de resumen un máximo de 5 palabras clave que coincidirán con los Descriptores del Medical Subjects Headings (MeSH): http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=mesh. Como se ha indicado en 1.3 se deben de enviar las palabras clave en castellano e inglés.

1.5 Abreviaturas

Se incluirá un listado de las abreviaturas presentes en el cuerpo del trabajo con su correspondiente explicación. Asimismo, se indicarán la primera vez que aparezcan en el texto del artículo.

1.6 Texto

Estructurado en el caso de originales, originales breves y revisiones, cumplimentando los apartados de Introducción, Objetivos, Métodos, Resultados y Discusión (Conclusiones, en su caso).

Se deben citar aquellas referencias bibliográficas estrictamente necesarias teniendo en cuenta criterios de pertinencia y relevancia.

En la metodología, se especificará el diseño, la población a estudio, los métodos estadísticos empleados, los procedimientos y las normas éticas seguidas en caso de ser necesarias.

Cuando el artículo sea enviado en idioma inglés, antes de su envío a la revista, recomendamos a los autores que lo sometan a la revisión de una persona angloparlante para garantizar la calidad del mismo.

1.7 Anexos

Material suplementario que sea necesario para el entendimiento del trabajo a publicar.

1.8 Agradecimientos

Esta sección debe reconocer las ayudas materiales y económicas, de cualquier índole, recibidas. Se indicará el organismo, institución o empresa que las otorga y, en su caso, el número de proyecto que se le asigna. Se valorará positivamente haber contado con ayudas.

Toda persona física o jurídica mencionada debe conocer y consentir su inclusión en este apartado.

1.9 Bibliografía

Las citas bibliográficas deben verificarse mediante los originales y deberán cumplir los Requisitos de Uniformidad del Comité Internacional de Directores de Revistas Médicas, como se ha indicado anteriormente.

Las referencias bibliográficas se ordenarán y numerarán por orden de aparición en el texto, identificándose mediante números arábigos en superíndice.

Las referencias a textos no publicados ni pendiente de ello, se deberán citar entre paréntesis en el cuerpo del texto.

Para citar las revistas médicas se utilizarán las abreviaturas incluidas en el Journals Database, disponible en: http://www. ncbi.nlm.nih.gov/ entrez/query. fcgi?db=journals. En su defecto en el catálogo de publicaciones periódicas en bibliotecas de ciencias de la salud españolas: http://www.c17.net/c17/.

▶▶▶

1.10 Tablas y Figuras

El contenido será autoexplicativo y los datos no deberán ser redundantes con lo escrito. Las leyendas deberán incluir suficiente información para poder interpretarse sin recurrir al texto y deberán estar escritas en el mismo formato que el resto del manuscrito.

Se clasificarán con números arábigos, de acuerdo con su orden de aparición, siendo esta numeración independiente según sea tabla o figura. Llevarán un título informativo en la parte superior y en caso de necesitar alguna explicación se situará en la parte inferior. En ambos casos como parte integrante de la tabla o de la figura.

Se remitirán en fichero aparte, preferiblemente en formato JPEG, GIFF, TIFF o PowerPoint, o bien al final del texto incluyéndose cada tabla o figura en una hoja independiente.

1.11 Autorizaciones

Si se aporta material sujeto a copyright o que necesite de previa autorización para su publicación, se deberá acompañar, al manuscrito, las autorizaciones correspondientes.

1.12 Conflicto de intereses

Todos los artículos que se envíen a **Nutrición Hospitalaria** deben ir acompañados de una declaración de los posibles conflictos de intereses de cada una de las personas firmantes. De la misma manera, si no hay ningún conflicto de intereses, deberán hacerlo constar explícitamente en el artículo.

2. TIPOS Y ESTRUCTURA DE LOS TRABAJOS

2.1 Original: Trabajo de investigación cuantitativa o cualitativa relacionado con cualquier aspecto de la investigación en el campo de la nutrición.

2.2 Revisión: Trabajo de revisión, preferiblemente sistemática, sobre temas relevantes y de actualidad para la nutrición.

2.3 Notas Clínicas: Descripción de uno o más casos, de excepcional interés que supongan una aportación al conocimiento clínico.

2.4 Perspectiva: Artículo que desarrolla nuevos aspectos, tendencias y opiniones. Sirviendo como enlace entre la investigación y la sociedad.

2.5 Editorial: Artículo sobre temas de interés y actualidad. Se escribirán a petición del Comité Editorial.

2.6 Carta al Director: Observación científica y de opinión sobre trabajos publicados recientemente en la revista, así como otros temas de relevante actualidad.

2.7 Carta Científica: La multiplicación de los trabajos originales que se reciben nos obligan a administrar el espacio físico de la revista. Por ello en ocasiones pediremos que algunos originales se reconviertan en carta científica cuyas características son:

- Título
- Autor (es)
- Filiación
- Dirección para correspondencia
- Texto máximo 400 palabras
- Una figura o una tabla
- Máximo cinco citas

La publicación de una Carta Científica no es impedimento para que el artículo in extenso pueda ser publicado posteriormente en otra revista.

2.8 Artículo de Recensión: Comentarios sobre libros de interés o reciente publicación. Generalmente a solicitud del Comité editorial aunque también se considerarán aquellos enviados espontáneamente.

2.9 Artículo Especial: El Comité Editorial podrá encargar, para esta sección, otros trabajos de investigación u opinión que considere de especial relevancia. Aquellos autores que de forma voluntaria deseen colaborar en esta sección, deberán contactar previamente con el Director de la revista.

2.10 Artículo Preferente: Artículo de revisión y publicación preferente de aquellos trabajos de una importancia excepcional. Deben cumplir los requisitos señalados en este apartado, según el tipo de trabajo. En la carta de presentación se indicará de forma notoria la solicitud de Artículo Preferente. Se publicarán en el primer número de la revista posible.

EXTENSIÓN ORIENTATIVA DE LOS MANUSCRITOS

Tipo de artículo	Resumen	Texto	Tablas y figuras	Referencias
Original*	Estructurado 250 palabras	Estructurado 4.000 palabras	5	35
Original breve	Estructurado 150 palabras	Estructurado 2.000 palabras	2	15
Revisión**	Estructurado 250 palabras	Estructurado 6.000 palabras	6	150
Notas clínicas	150 palabras	1.500 palabras	2	10
Perspectiva	150 palabras	1.200 palabras	2	10
Editorial	–	2.000 palabras	2	10 a 15
Carta al Director	–	400 palabras	1	5

Eventualmente se podrá incluir, en la edición electrónica, una versión más extensa o información adicional.

*La extensión total del artículo original, una vez compuesto, con tablas, figuras y referencias, no deberá exceder cinco páginas.

**La extensión total del artículo de revisión, una vez compuesto, con tablas, figuras y referencias, no deberá exceder seis páginas.

3. PROCESO EDITORIAL

El Comité de Redacción acusará recibo de los trabajos recibidos en la revista e informará, en el plazo más breve posible, de su recepción. Todos los trabajos recibidos, se someten a evaluación por el Comité Editorial y por al menos dos revisores expertos.

Los autores pueden sugerir revisores que a su juicio sean expertos sobre el tema. Lógicamente, por motivos éticos obvios, estos revisores propuestos deben ser ajenos al trabajo que se envía. Se deberá incluir en el envío del original nombre y apellidos, cargo que ocupan y email de los revisores que se proponen.

Las consultas referentes a los manuscritos y su transcurso editorial, pueden hacerse a través de la página web.

Previamente a la publicación de los manuscritos, se enviará una prueba al autor responsable de la correspondencia utilizando el correo electrónico. Esta se debe revisar detenidamente, señalar posibles erratas y devolverla corregida a su procedencia en el plazo máximo de 4 días. En el supuesto de no remitirse las correcciones o ser enviadas fuera de plazo, **Nutrición Hospitalaria** publicará el artículo conforme a la prueba remitida para corrección.

Las correcciones solicitadas deben ser mínimas; solamente se admitirán modificaciones en relación con la sintaxis y la comprensión semántica del texto. El comité editorial se reserva el derecho de admitir o no las correcciones efectuadas por los autores en la prueba de impresión. *Aquellos autores que desean recibir separatas deberán de comunicarlo expresamente. El precio de las separatas (25 ejemplares) es de 125 euros + IVA.*

Abono en concepto de financiación parcial de la publicación. En el momento de aceptarse un artículo original o una revisión no solicitada, se facturará la cantidad que se haya estipulado en ese momento + impuestos para financiar en parte la publicación del articulo [vease Culebras JM y A Garcia de Lorenzo. El factor de impacto de Nutrición Hospitalaria incrementado… y los costes de edición también. *Nutr Hosp* 2012; 27(5)].

NOTA

Los juicios y las opiniones expresadas en los artículos y comunicaciones que aparecen en la revista son exclusivamente de las personas que los firman. El comité editorial de **Nutrición Hospitalaria** y Grupo Aula Médica declinan cualquier responsabilidad sobre los contenidos de los trabajos publicados.

El comité editorial de **Nutrición Hospitalaria** y Grupo Aula Médica no garantizan ni apoyan ningún producto que se anuncie en la revista, ni las afirmaciones realizadas por el anunciante sobre dicho producto o servicio.

Nutrición Hospitalaria

Vol. 31. Suplemento 3 • Marzo 2015

ISSN (Versión papel): 0212-1611

ISSN (Versión electrónica): 1699-5198

ISSN (Versión papel): 0212-1611

ISSN (Versión electrónica): 1699-5198

www.nutricionhospitalaria.com

Nutrición Hospitalaria

www.nutricionhospitalaria.com

ÓRGANO OFICIAL DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN PARENTERAL Y ENTERAL
ÓRGANO OFICIAL DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN
ÓRGANO OFICIAL DE LA FEDERACIÓN LATINO AMERICANA DE NUTRICIÓN PARENTERAL Y ENTERAL
ÓRGANO OFICIAL DE LA FEDERACIÓN ESPAÑOLA DE SOCIEDADES DE NUTRICIÓN, ALIMENTACIÓN Y DIETETICA

Vol. 31. Suplemento 3 • Marzo 2015
ISSN (Versión papel): 0212-1611
ISSN (Versión electrónica): 1699-5198

Nutrición Hospitalaria

SOCIEDAD ESPAÑOLA DE NUTRICION *PARENTERAL Y ENTERAL*

SENPE

AGRADECIMIENTOS

La Sociedad Española de Nutrición Parenteral y Enteral, que tiene como objetivos desde su fundación el potenciar el desarrollo y la investigación sobre temas científicos relacionados con el soporte nutricional, agradece su ayuda a las siguientes entidades, sin cuya ayuda no hubiera sido posible la realización de este proyecto.

- **SOCIEDAD ESPAÑOLA DE NUTRICIÓN COMUNITARIA**

SENC
SOCIEDAD ESPAÑOLA NUTRICION COMUNITARIA

- **FUNDACIÓN PARA LA INVESTIGACIÓN NUTRICIONAL**

fiN Fundación para la Investigación Nutricional

- **FUNDACIÓN ESPAÑOLA DE LA NUTRICIÓN (FEN)**

FEN
FUNDACIÓN ESPAÑOLA DE LA NUTRICIÓN

- **COCA-COLA IBERIA**

The Coca-Cola Company
Hidratando al Mundo desde 1886

Nutrición Hospitalaria

Vol. 31. Suplemento 3 • Marzo 2015

ISSN (Versión papel): 0212-1611

ISSN (Versión electrónica): 1699-5198

SOCIEDAD ESPAÑOLA DE NUTRICION *PARENTERAL Y ENTERAL*

SENPE

JUNTA DIRECTIVA DE LA SOCIEDAD ESPAÑOLA DE NUTRICIÓN PARENTERAL Y ENTERAL

Presidente

• MIGUEL LEÓN SANZ

Vicepresidenta

• CARMEN SÁNCHEZ ALVAREZ

Tesorera

• MERCEDES CERVERA PERIS

Secretaria

• ROSA BURGOS PELÁEZ

Vocales

• LORENA ARRIBAS HORTIGÜELA
• ROSANA ASHBAUGH ENGUIDANOS
• MIGUEL ÁNGEL MARTÍNEZ OLMOS
• CARMINA WANDEN-BERGHE LOZANO

Miembros de honor

• A. AGUADO MATORRAS†
• A. GARCÍA DE LORENZO Y MATEOS
• F. GONZÁLEZ HERMOSO
• S. GRISOLÍA GARCÍA
• F. D. MOORE†
• A. SITGES CREUS†
• G. VÁZQUEZ MATAS
• J. VOLTAS BARO†
• J. ZALDUMBIDE AMEZAGA

Coordinador de la página web

• JORDI SALAS SALVADÓ
Jordi.salas@urv.cat

Presidente de honor

• JESÚS CULEBRAS
jesus@culebras.eu

Comité Científico-Educacional

Coordinadora

• CRISTINA DE LA CUERDA COMPÉS

Secretaria

• PILAR MATÍA MARTÍN

Vocales

• CLEOFÉ PÉREZ PORTABELLA
• LAURA FRÍAS SORIANO
• CLARA VAQUERIZO ALONSO
• MARÍA DOLORES RUIZ LÓPEZ

Coordinador Grupo de Trabajo

• GABRIEL OLVEIRA FUSTER

Director de la Revista Nutr Hosp

• JESÚS CULEBRAS FERNÁNDEZ

www.senpe.com

CONSENSUS MEETING ON THE METHODOLOGY OF DIETARY SURVEYS, CLASSIFICATION OF PHYSICAL ACTIVITY AND HEALTHY LIFESTYLES

REUNIÓN DE CONSENSO SOBRE LA METODOLOGÍA DE LAS ENCUESTAS ALIMENTARIAS, TIPIFICACIÓN DE LA ACTIVIDAD FÍSICA Y ESTILOS DE VIDA SALUDABLES

ORGANIZADO POR:

• SOCIEDAD ESPAÑOLA DE NUTRICIÓN COMUNITARIA

SENC
SOCIEDAD ESPAÑOLA NUTRICION COMUNITARIA

CON LA PARTICIPACIÓN DE:

• FUNDACIÓN PARA LA INVESTIGACIÓN NUTRICIONAL

fiN Fundación para la Investigación Nutricional

• FUNDACIÓN ESPAÑOLA DE LA NUTRICIÓN (FEN)

FEN
FUNDACIÓN ESPAÑOLA DE LA NUTRICIÓN

CON LA COLABORACIÓN DE:

• COCA-COLA IBERIA

The Coca-Cola Company
Hidratando al Mundo desde 1886

Editor/Editor:
Javier Aranceta Bartrina

Associated editors/Co-editores:
Gregorio Varela Moreiras and Lluis Serra-Majem

Scientific secretariat/Secretaría científica:
Carmen Pérez Rodrigo

Nutrición Hospitalaria

Vol. 31. Suplemento 3 • Marzo 2015

ISSN (Versión papel): 0212-1611

ISSN (Versión electrónica): 1699-5198

CONSENSUS MEETING ON THE METHODOLOGY OF DIETARY SURVEYS, CLASSIFICATION OF PHYSICAL ACTIVITY AND HEALTHY LIFESTYLES

Laguardia, 18th & 19th September 2014

REUNIÓN DE CONSENSO SOBRE LA METODOLOGÍA DE LAS ENCUESTAS ALIMENTARIAS, TIPIFICACIÓN DE LA ACTIVIDAD FÍSICA Y ESTILOS DE VIDA SALUDABLES

Laguardia, 18 y 19 de Septiembre de 2014

continuación ►►►

Vol. 31. Suplemento 3 • Marzo 2015

ISSN (Versión papel): 0212-1611
ISSN (Versión electrónica): 1699-5198

Nutrición Hospitalaria

continuación ►►►

Nutrición Hospitalaria

Vol. 31. Suplemento 3 • Marzo 2015

ISSN (Versión papel): 0212-1611
ISSN (Versión electrónica): 1699-5198

continuación ►►►

Vol. 31. Suplemento 3 • Marzo 2015
ISSN (Versión papel): 0212-1611
ISSN (Versión electrónica): 1699-5198

Nutrición Hospitalaria

FOREWORD

'The true greatness of science is valued for its usefulness'
Gregorio Marañon (1887-1960)

Interest for food and nutrition population studies has followed a continuum in Spain and worldwide from the beginning of the modern era. Biomedical literature in our country gathers in the middle of the 20th century several interesting studies related to food consumption in different population groups, some of them included in the book "Nutrition studies" by Carlos Jiménez Díaz[1] and his collaborators referred to the period 1941-1943. During the Spanish Civil war and in the postwar period Francisco Grande Covián's studies on malnutrition and vitamin deficiency in the population of Madrid were also very interesting and key to understand the evolution of nutrition in Spain[2,3]. Some very relevant studies for the time were carried out by the Food and Nutrition Hygiene Section of the National School of Health, headed initially by Enrique Carrasco Cadenas and, from 1940, by Francisco Vivanco[4-8].

In 1954 The School of Bromatology was launched within the frame of the Complutense University of Madrid, with multiple research and educational activities. From this institution the first National Food Survey was started in 1956, under the direction of Professor Gregorio Varela-Mosquera, with the collaboration of FAO[8-10]. The Inventory methodology was used for data collection along with weighing the food consumed.

During this period, activities of nutritional support and assessment of the nutrition status in different groups of population were conducted, among others, by the Food and Nutrition School Service created in 1954, the General Direction for Health Services, the Service of Agrarian Extension, Social Aid, Cáritas and other non-profit entities of the time[7,8,11-14].

In 1961 the EDALNU (Educación en Alimentación y Nutrición) program was launched with the technical help of FAO and UNICEF. The aim was to distribute the food aid received throughout the whole national geography and to start projects of food and nutrition education addressed to women and families[15]. Later the EDALNU program would also elaborate more structured teaching programs and launch food consumption surveys in most of the Spanish provinces. To illustrate and as a didactic reinforcement of the educational program, several materials were published, which included "the Food Wheel", which has been in force in all informative texts up to very recent dates. A great part of these initiatives was carried out under the direction of Dr Francisco Vivanco, Dr. Juan Manuel Palacios, Dr. Abraham García Almansa and the excellent work of Dr. Consuelo López- Nomdedeu[16-21].

(*Nutr Hosp* 2015;31(Supl. 3):1-6)
DOI:10.3305/nh.2015.31.sup3.8821

From the 80s decade onwards, knowledge of food habits in the Spanish population is deepened through the surveys by INE (National Institute of Statistics)[22], Department of Agriculture and other institutions[23]. Data referred to that period are also available from FAO, OECD and other national entities[24,25].

Around the same time, different Autonomous Regions launched population nutrition surveys, as reflected in several articles in this supplement. Different research groups publish reviews on food surveys and health studies conducted in Spain in recent decades[23, 26].

During the last third of the 20th century and the beginning of the 21st it is interesting to mention the PAIDOS study (1985)[27] conducted by Spanish pediatricians to estimate the prevalence of obesity in children population. The Enkid study (Serra-Aranceta, 2000)[28] carried out on a representative sample of the children and young Spanish population, the school based nutrition intervention study PERSEO (2006-2011)[29] linked to the NAOS strategy by the Spanish Agency of Food Security and Nutrition[30]. The White Book of Nutrition in Spain, edited by Prof. G. Varela- Moreiras, from the Spanish Nutrition Foundation[31], the different nutrition surveys launched by institutions, such as ENIDE[32], ALADINO[33], ENALIA 1[34], ENALIA 2[35] and the annual reports on food consumption and food distribution published by MERCASA[36] and MAGRAMA[37].

At this moment, the ANIBES Study on "Evaluation of the Energy balance and Food Habits of the Spanish population"[38] is in a position to generate information about the determinant factors of excess body weight in Spain, high quality data on physical activity and sedentary lifestyle and will become an indispensable reference for the implementation of health promotion actions in the coming years.

In a nearby future we will also have the contributions by the ENPE study on "Nutritional Assessment of the Spanish Population" performed in a representative sample of Autonomous Regions, on the multi factorial analysis of food behavior and the different variables related[39]. This comprehensive work will contribute with data to inform the development of contents for food and nutrition education programs, evaluate and judge the need of new products and services and will draw a holistic vision of food habits in the Spanish population.

In this quick reminder of the main population nutrition studies a wide dispersion of the different methods and approaches used for data collection can be noticed. The use of different reference values, Food Composition Tables, assessment of physical activity or the way results are presented. This situation encouraged us to organize an Expert Meeting to debate in depth all the necessary points to be able to arrange future population nutrition studies, which could include assessment of food intake, physical activity, weight status classification, any other remaining related factors and other lifestyles using a validated, comparable and harmonized methodology, that would enable the advancement in the field of Nutrition and Public Health and to take part in comparative or collaborative analyses at national or international level. Though in the recent past there were at least two attempts of establishing a few general criteria on the topic that unfortunately failed[40-42], we believe in this occasion the impulse can have a longer way forward.

The scientific contents of the Expert Meeting are included in this supplement as 32 articles elaborated by 38 experts invited to the event, all of them co-authors as well of the final conclusions added at the end of this document as a summarized contribution to the final consensus of priorities.

In this supplement you will find an introductory section on the role of population nutrition studies in health planning and in health related actions prepared by the project coordinators, J. Aranceta from the University of Navarra, G. Varela- Moreiras from the University CEU-San Pablo and Ll. Serra- Majem, from the University of Las Palmas de Gran Canaria.

The first thematic section consists of a joint overview of the relevant methods of food consumption assessment: History of the methods for the assessment of food consumption (L. Morán), followed by papers on sources of information about food consumption in Spain and in Europe (JM Avila), Food records and food diaries (R. Ortega), 24 hours dietary recall method (G. Salvador), Food Frequency Questionnaires (C. Perez-Rodrigo) and Diet History method (L Moran). The second section includes a specific paper on the assessment of water and beverages intake (Ll. Serra); assessment valuation of sodium, oil and supplements intake (ML López), an overview of the modifications required to adapt existing dietary intake assessment methods in order to get valid and precise estimates from children and adolescents (I. Polanco), adults and the elderly (P. Riobó), as well as brief instruments and screening tools (C. Pérez-Rodrigo).

One of the main controversies emerges in relation to the estimates of population energy balance with precise measurements of energy intake, energy expenditure by physical activity and physiological needs (G. Varela). It is also necessary to be precise in the adjustments and bias control in food surveys (V. Arija) or the control of under- reporting or over-reporting individuals (Ll. Serra- Majem).

In this era of crisis, arises interest on the methods to classify diet quality (A. Gil) and the studies and methods to research linked to immune nutrition (A. Marcos).

At this point, we address a key element, such as reference values in relation to food intake, anthropometrical measurements and other indicators of health and nutritional status (V. Arija), along a discussion on transforming the collected data into estimates of energy and nutrient intake using Food Composition Databases: lights and shades (E. Martínez de la Victoria), and possibilities for new biomarkers of food intake (D. Corella).

This thematic section is completed by two essential issues: on the one hand, approaches to data analysis and supporting software (R. Abellana); on the other hand, methods of nutritional assessment in clinical settings. A necessary and complex procedure related to health care (C. Gómez-Candela).

One of the cutting-edge and most complex sections in this supplement, which was considered in special depth during the expert meeting working sessions, is focused on the methods of evaluation of the energy expenditure by physical activity and classification of sedentary lifestyles. Validated questionnaires (S. Aznar);

instrumental methods and new technologies (M. Gonzalez-Gros); particular aspects of the assessment of energy expenditure and food intake in sportsmen (N. Palacios), an approximation to biomarkers of physical activity (M. Gonzalez-Gros & I. Ara) and on the methods of evaluating resting energy expenditure (R. Blasco).

The last thematic section is related to other lifestyles associated to food habits, or that can influence nutritional or health status: consumption of alcohol, tobacco and other drugs (S. Belmonte); scales to assess quality of life, autonomy and mental health; screening instruments to assess food security (G. Salvador) and a very special article about the analysis of nutritional chrono-biology in food surveys (M. Garaulet).

Finally, the coordinators discuss about the usefulness and potential applications of food consumption studies assessing dietary intake, determinants of physical activity, and other lifestyles, in the area of health and in other facets of the individual and society, These contents are summarized in the Consensus Document included on the first pages of this monograph which gathers the 20 concluding remarks debated and agreed among participants.

I would like to acknowledge my colleagues in the coordination of this venture, Dr. Lluis Serra-Majem and Dr. Gregorio Varela-Moreiras, as well as the scientific secretariat Dr. Carmen Pérez -Rodrigo, for their friendship and intensive effort devoted to this project. We also acknowledge all the authors contributing to this supplement as well as all the participants attending the Experts' Meeting in Laguardia (Rioja Alavesa) for their dedication, effort and collaboration to reach the aims of this initiative. Our gratitude also to all the people who provided us with professional and human coverage for the working sessions, specially, to Coca Cola Iberia Company that, with a rigorously independent dynamics, has facilitated the publication and diffusion of this scientific material within the frame of Aula Médica publisher.

Our acknowledgement to the Spanish Society of Community Nutrition (SENC), Foundation for Nutrition Research (FIN) and Spanish Nutrition Foundation (FEN) for providing the scientific framework to host the whole process and activities.

We wish that this collaborative effort affects the advancing towards a healthier and happier society.

Javier Aranceta- Bartrina (MD, PhD)
Editor

References

1. Jiménez Díaz C. Memoria sobre el estado nutritivo de la población madrileña (1941-1943). Prólogo de José Luis Peset. *Estudios de Historia Social* 1978: 5-6: 401-465.
2. Grande Covian F, Jiménez García F. Tratamiento de la pelagra con ácido nicotínico. *Rev Clin Esp* 1940; 1: 144.
3. Del Cura MI, Huertas R. *Alimentación y enfermedad en tiempos de hambre: España, 1937-1947*. Madrid: CSIC, 2007.
4. Bemabeu Mestre J. El papel de la Escuela Nacional de Sanidad en el desarrollo de la salud pública en España, 1924-1934. *Rev San Hig Pub* 1994; 68: 65-89.
5. Bernabeu-Mestre J. El contexto histórico de la transición nutricional en España. En: Bernabeu-Mestre J, Barona JL (eds.). Nutrición, salud y sociedad. España y Europa en los siglos XIX y XX. València: Seminari d'Estudis sobre la Ciència/Publicaciones de la Universidad de Valencia, 2011: pp. 185-208.
6. Ballester R, Perdiguero E. Los estudios sobre crecimiento humano como instrumento de medida de la salud de los niños españoles (1900-1950). *Áreas: Revista internacional de ciencias sociales* 2000; 20: 161-170.
7. Villalbí JR, Maldonado R. La alimentación de la población en España desde la posguerra hasta los años ochenta: una revisión crítica de las encuestas de nutrición. *Med Clín (Barc)* 1988; 90: 127-130.
8. Sabaté F. Las encuestas de alimentación y nutrición en España. Bibliografía 1939-77. *Rev San Hig Public* 1984; 58: 1117-1132.
9. Varela G, Moreiras-Varela O, Vidal C. Niveles de nutrición en las diferentes regiones y estratos sociales. *Anales de Bromatología* 1965; 17: 163-237.
10. Rodríguez Artalejo F, Banegas JR, Graciani MA, Hernández Vecino R, Rey Calero J. El consumo de alimentos y nutrientes en España en el período 1940-1988. Análisis de su consistencia con la dieta mediterránea. *Med Clín (Barc)* 1996; 106: 161-168.
11. Servicio Escolar de Alimentación. Documenta. Cuaderno no 870. Madrid: Dirección General de Prensa; 1955.
12. De Palacios JM. Estado nutritivo de nuestros niños. Madrid: Ministerio de Educación Nacional. Dirección General de Enseñanza Primaria; 1964.
13. De Palacios JM, Vivanco F. Datos de talla y peso de 128.000 españoles. *Rev Clin Esp* 1965; XCIX (4): 230-1.
14. De Palacios JM, Vivanco F, Alonso B. Encuestas rurales de alimentación y nutrición. Moraira. *Rev Clin Esp* 1966; 102 (1): 6-18.
15. De Palacios JM. Información sobre el Programa de Educación en Alimentación y Nutrición en España. Madrid: Gobierno Español (CIBIS)-FAO-UNICEF; 1969.
16. López C. Encuesta realizada en la zona rural española sobre consumos de alimentos a nivel familiar obtenidos por el sistema de inventarios y compras. *Rev San Hig Public* 1984; 58: 119-46.
17. López C. El programa español de Educación en Alimentación y Nutrición. *Rev San Hig Pública* 1972; 46 (11-12): 951-958.
18. López C. Resumen de las tareas realizadas a través del Programa de Educación en Alimentación y Nutrición (Programa EDALNU). *Rev San Hig Public* 1973; 47 (6): 559-578.
19. Trescastro-López EM, Trescastro-López S. La educación en alimentación y nutrición en el medio escolar: el ejemplo del Programa EDALNU. *Revista Española de Nutrición Humana y Dietética* 2013; 17 (2): 84-90.
20. García A, López C. Nuestra experiencia en el programa EDALNU. *Nutr Clin Diet Hosp* 1990; 10 (4): 137-44.
21. Vivanco F, De Palacios JM, García A. Alimentación y nutrición. (2ª Ed). Madrid: Ministerio de Sanidad y Consumo, 1984.
22. Varela Mosquera G. La nutrición de los españoles. Madrid: Estudios del Instituto de Desarrollo Económico, 1971.
23. Serra-Majem L, Bautista Castaño I. La nutrición en España. En: Como vivíamos: alimentos y alimentación en la España del siglo XX. Barcelona: Lunwerg, 2007: pp. 177-195.

24. Organización de la Naciones Unidas para la Alimentación (FAO). Hojas de Balance Alimentario, 2008.

25. Bengoa JM. Nutrición internacional: Algunos momentos cruciales de su historia. *Rev Esp Nutr Com* 1996; 2(2): 64-70.

26. González Montero de Espinosa M, Marrodán MD. Contribución de las encuestas alimentarias al análisis de la nutrición en España: una revisión bibliográfica. *Revista Española de Antropología Biológica* 1996; 17: 49-62.

27. PAIDOS' 84. Estudio epidemiológico sobre nutrición y obesidad infantil. Madrid: Jomagar, 1985.

28. Serra-Majém L, Ribas Barba L, Aranceta Bartrina J, Pérez Rodrigo C, Saavedra Santana P. Pena Quintana L. Chilhood and adolescentobesity in Spain. Results of the enKid Study (1998-2000). *Med Clin (Barc)* 2003; 29, 121 (19):725-732.

29. Aranceta J, Pérez Rodrigo C, Campos Amado J, Calderón Pascual V, en nombre del Grupo Colaborativo Proyecto PERSEO. Proyecto PERSEO. Diseño y metodología del estudio de evaluación *Revista Española de Nutrición Comunitaria* 2013; , 19, 76-87.

30. Estrategia NAOS Agencia Española de Seguridad Alimentaria y Nutrición. Ministerio de Sanidad, Política Social e Igualdad, 2005 (www.naos.aesan.msssi.gob.es). (Accessed 15 January 2015).

31. Varela Moreiras G (coord.). Libro Blanco de la Nutrición en España. Madrid: FEN-AESAN-Ministerio de Sanidad y consumo, 2013. Available at: [http://www.fundacionbamberg.org/innovacion/estudios-publicaciones/estudios/estudio-dieta-total] (Accessed 15 January 2015).

32. Agencia Española de Seguridad Alimentaria y Nutrición (AESAN). Encuesta Nacional de Ingesta Dietética Española (ENIDE) 2011. [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enide.shtml.

33. Ortega Anta RM, López Sobaler AM, Perea Sánchez JM, González Rodríguez LG, Villalobos Cruz T, Pérez Farinós N, et al. Estudio Aladino. Estudio de Vigilancia del Crecimiento, Alimentación, Actividad Física, Desarrollo Infantil y Obesidad en España 2011. Madrid: AECOSAN, 2013. Available at: [http://www.observatorio.naos.aesan.msssi.gob.es/docs/docs/documentos/estudio_ALADINO.pdf] (Accessed 15 January 2015).

34. AECOSAN. "ENALIA" Encuesta Nacional de Alimentación en la población Infantil y Adolescente. Available at: [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enalia.shtml] (Accessed 15 January 2015).

35. AECOSAN. "ENALIA 2" Encuesta Nacional de Alimentación en la población adulta y mujeres embarazadas. Available at: [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enalia_2.shtml] (Accessed 15 January 2015).

36. Informe 2013 sobre Producción, Industria, Distribución y Consumo de Alimentación en España. Madrid: MERCASA, 2013. Available at: [http://www.mercasa.es] (Accessed 15 January 2015).

37. La Alimentación mes a mes en España Año 2014. Madrid: MAGRAMA, 2014. Available at: [http://www.magrama.gob.es/es/alimentacion/temas/consumo-y-comercializacion-y-distribucion-alimentaria/panel-de-consumo-alimentario/ultimos-datos/] (Accessed 15 January 2015.

38. Ruiz E, Ávila JM, Castillo A, Valero T, del Pozo S, Rodríguez P et al. The ANIBES Study on Energy Balance in Spain: Design, Protocol and Methodology. Nutrients 2015 (in press).

39. Fundación Eroski – Sociedad Española de Nutrición Comunitaria. Encuesta Nutricional de la Población Española (ENPE). Madrid: SPRIM, 2014.

40. García Almansa A, López Nomdedeu C. Experiencias de encuestas alimentarias en el programa EDALNU. En: Actas del I Simposium Nacional sobre Metodología en los Estudios de Consumo de Alimentos. Valencia: Conselleria de Sanitat i Consum, 1991.

41. Grupo de Expertos Directrices para la elaboración de estudios poblacionales de alimentación y nutrición. *Rev San Hig Public* 1994; 68 (2): 247-259. .

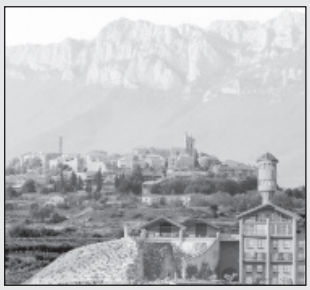
42. Serra Majem L, Román B, Ribas L.-Metodología de los estudios nutricionales. *Actividad Dietética* 2001; 12: 180-185.

Consensus document and conclusions

Methodology of dietary surveys, studies on nutrition, physical activity and other lifestyles

Documento de Consenso y Conclusiones

La metodologia de las Encuestas Alimentarias, Estudios Nutricionales, de Estimación de la Actividad Física y otros Estilos de Vida



Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):9-12
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Consensus document and conclusions

Methodology of dietary surveys, studies on nutrition, physical activity and other lifestyles

Javier Aranceta-Bartrina[1,2,3], Gregorio Varela-Moreiras[4,5], Lluis Serra-Majem[6,2,3], Carmen Pérez-Rodrigo[7]; Rosa Abellana[8], Ignacio Ara[9], Victoria Arija[10], Susana Aznar[11], José Manuel Ávila[5], Susana Belmonte[12], Raquel Blasco[13], Jesús Caldeiro[14], Lourdes Carrillo[15], Dolores Corella[16,3], María Luisa López[17], Marta Garaulet[18], Pedro Pablo García-Luna[19], Aquilino García-Perea[20], Ángel Gil[21], Carmen Gómez-Candela[22], Marcela González-Gross[23], Susana Granado de la Orden[12], Mercedes López-Pardo[24], Ascensión Marcos[25], Emilio Martínez de Victoria[21], Luis Morán[26], José María Ordovás[27], Rosa Mª Ortega[28], Nieves Palacios[9], Isabel Polanco Allué[22], Josep Mª Ramón[8], Lourdes Ribas[2], Pilar Riobó[29], Gemma Salvador Castell[30], Carmen Serrano[12], María Lourdes de Torres[31], Rafael Urrialde[32], and Salvador Zamora[18]

[1]Departament of Preventive Medicine and Public Health, University of Navarra; [2]Spanish Foundation for Nutritional Research, FIN, Barcelona; [3]CiberOBN, Instituto de Salud Carlos III, Madrid; [4]Department of Pharmaceutical and Health Sciences, Faculty of Pharmacy, CEU San Pablo University, Madrid ; [5]Spanish Nutrition Foundation (FEN), Madrid; [6]Research Institute of Biomedical and Health Sciences, Universty of Las Palmas de Gran Canaria; [7]Spanish Society of Community Nutrition (SENC), Spain; [8]University of Barcelona; [9]National Sport Council, Madrid; [10]University Rovira i Virgili, Reus; [11]University of Castilla-La Mancha, Toledo, [12]Council for Health; Community of Madrid; [13]Regional Center for Sports Medicine at the Junta de Castilla y León, Valladolid; [14]IPSOS Spain, Madrid; [15]Spanish Society of Family and Community Medicine, semFYC, Santa Cruz de Tenerife, [16]University of Valencia; [17]Spanish Society of Primary Care Medicine, SEMERGEN, Madrid; [18]University of Murcia;[19]University Hospital Virgen de Rocío, Sevilla; [20]General Council of Official Pharmacists Association, CGCOF, Madrid; [21]University of Granada; [22]La Paz University Hospital, Madrid; [23]Technical University of Madrid; [24]Spanish Nurses Association of Dietetic and Nutrition, ADENYD, Córdoba; [25]Spanish National Research Council, ICTAN-CSIC, Madrid; [26]Andalusian Society for Clinical Nutrition and Dietetics, SANCYD, Sevilla; [27]Tufts University, Boston; [28]Complutense University of Madrid; [29]Jiménez-Díaz Foundation idcsalud, Madrid; [30]Government of Catalonia, Barcelona; [31]Miguel Servet Hospital, Zaragoza; [32]Coca-Cola Iberia Madrid.

(*Nutr Hosp* 2015;31(Supl. 3):9-12)

DOI:10.3305/nh.2015.31.sup3.8745

With regard to the Consensus Meeting held in Laguardia (Spain), 17-19 September 2014, we would like to emphasize the high scientific level of the different contributions and the great personal implication of the professional participants, which has provided an extensive update of the methodology and the different factors to be considered when setting up population nutritional studies in our country. We hereby consider a synthesis of the most relevant aspects in the format of a *Consensus Document Laguardia 2015*:

1.–In population studies on nutrition, physical activity and lifestyles it is essential to know which are the objectives of interest and the available resources, to be able to decide on which valid method or methods are best suited in every circumstance.

2.–There are numerous sources of information on food consumption in Europe and Spain. However, it is necessary to continue working at European level on the standardization of data collection in order to be able to conduct more precise comparative studies and evolution trends analysis, since the development and use of new food products affects these sources to be adapted and include information about characteristics thereof.

3.–Food waste is mostly not considered in the information sources available and data collection in institutions has been largely neglected.

Correspondence: Javier Aranceta
Community Nutrition
PO Box 5199. 48080 Bilbao (Spain).
E-mail: jaranceta@unav.es

4.–All methods of dietary intake assessment have advantages and disadvantages, which must be considered when deciding which is best suited according to aims, population and resources. A combination of more than one method is recommended for nutritional surveillance studies.

5.–New technologies should help improve the quality of the available procedures, their validity and accuracy.

6.–Infant, school aged population, the elderly, groups with special needs, sportspeople and those of low socioeconomic status, among others, require specific methodological approaches according to their characteristics.

7.–Careful protocol design, selection and training of those responsible for the fieldwork, pilot study and use of agreed Food Composition Tables using documented data, updated and representative of the food consumed in the study site, are key points in the process.

8.–Nutritional studies should include measured data on energy expenditure through physical activity, and thus primarily assess energy balance in the study group.

9.–The assessment of physical activity and quantifying of sedentary lifestyle should be performed using the combination of instruments and self-assessment questionnaires that are considered most suitable according to objectives, population and resources. It should be considered that quantifying energy expenditure through physical activity questionnaires can raise certain inaccuracy and an overestimation of results.

10.–Different categorizations of physical activity level should be assessed depending on aspects such as gender, age, socioeconomic status and educational level, among others. Furthermore, the pattern of behaviour should be analysed, including factors such as type, duration, frequency and intensity of physical activity performed.

11.–In all studies including food consumption assessment there are people that under-report or over-report on their food intake. This problem is even more important in certain population groups, and it should be considered when designing the project and processing the data to relieve its impact on the results.

12.–Food and beverage consumption assessment should consider social aspects related to intake, including “when”, “where”, “what”, “how” and ”with who”.

13.–It would be desirable to have validated scales of food insecurity assessment that allow detection of the difficulties that families and individuals can experience or be experiencing to access a varied, sufficient and adequate diet. This section is especially important in disadvantaged environments and in periods of crisis.

14.–The assessment and quantification of physical activity is related to more individual aspects, which makes evaluation more specific than in the case of food consumption surveys.

15.–For the assessment of nutritional status of individuals or populations specific tools are required for use in clinical, healthcare and institutional settings or population level.

16.–Screening instruments may be useful to identify individuals or groups at nutritional risk or malnutrition in Primary Health Care and other care settings. The development of self-assessment tools is also interesting.

17.–Assessing the quality of the diet, nutritional status and different related biomarkers require selecting reference values and standard evaluation criteria.

18.–The measurement of anthropometric data allows the estimation of body composition of an individual, but the complexity of these indicators makes it essential to consider the body mass index, waist circumference and percentage body fat values as a whole and not as single components, allowing for the necessary adjustments according to age group or physiological state. When used in combination the accuracy of weight status classification will be much higher.

19.–Studies that comprehend anthropometric data, food intake, level of physical activity and

other related variables facilitates that these multidisciplinary factors can be addressed globally, and experts from different areas of knowledge of health sciences are involved in determining processes, quantification and assessment of the data.

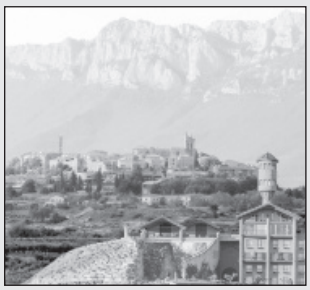
20.–It is necessary to promote periodically this type of scientific meetings with experts on monographic topics of interest in the field of nutrition, physical activity and health. The selection of participants should allow a rigorous and multidisciplinary approach, taking care of a physical and human atmosphere that fosters communication, content exchange and discussion. The future challenge is to evaluate the impact of this consensus meeting on improving the quality and comparability of nutrition information in Spain and associated lifestyles.

FOOD AND BEVERAGE CONSUMPTION ASSESSMENT: METHODS AND CONTROVERSIES

EVALUACIÓN DEL CONSUMO DE ALIMENTOS Y BEBIDAS: MÉTODOS Y CONTROVERSIAS

"Consensus Meeting on the Methodology of Dietary Surveys, Classification of Physical Activity and Healthy Lifestyles"

"Reunión de Consenso sobre la Metodología de las Encuestas Alimentarias, Tipificación de la Actividad Física y Estilos de Vida Saludables"



Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):15-21
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Controversies about population, clinical or basic research studies related with food, nutrition, physical activity and lifestyle

Javier Aranceta Bartrina[1,2,8], Carmen Pérez Rodrigo[3], Goiuri Alberdi Aresti[4], Gregorio Varela Moreiras[5,6] and Lluis Serra-Majem[2,7,8]

[1]Departamento de Medicina Preventiva y Salud Pública. Universidad de Navarra, Pamplona, Spain. [2]Fundación para la Investigación Nutricional (FIN), Parc Científic de Barcelona, Barcelona, Spain. [3]Fundación FIDEC. Bilbao, Spain. [4]School of Medical Sciences, University of Aberdeen, Institute of Medical Sciences, Aberdeen, Scotland, UK. [5]Department of Pharmaceutical and Health Sciences, Faculty of Pharmacy, CEU San Pablo University; Madrid, Spain. [6]Spanish Nutrition Foundation (FEN), Madrid, Spain. [7]Instituto de Investigaciones Biomédicas y Sanitarias, Universidad de Las Palmas de Gran Canaria, Las Palmas, Spain. [8]CiberOBN, Instituto de Salud Carlos III, Madrid, Spain.

Abstract

Nutritional studies including food and beverage consumption assessment are needed for different purposes in the field of nutrition, food supply monitoring, toxicology or in the context of intervention strategies that include changes in eating behaviors. Different methods have been used, each with strengths, weaknesses, biases and limitations that must be considered when choosing the most appropriate in each case. The development of new technologies offers exciting developments to improve the validity and accuracy of these methods, as well as their efficiency and commodity. The characteristics of the individuals under study, its environment and the resources available should be considered as well.

(*Nutr Hosp* 2015;31(Supl. 3):15-21)

DOI:10.3305/nh.2015.31.sup3.8746

Key words: *Food consumption assessment. Validity. Precision. New technologies.*

CONTROVERSIAS SOBRE LOS ESTUDIOS POBLACIONALES, CLÍNICOS O DE INVESTIGACIÓN BÁSICA RELACIONADOS CON LA ALIMENTACIÓN, NUTRICIÓN, ACTIVIDAD FÍSICA Y ESTILOS DE VIDA

Resumen

Los estudios nutricionales que incluyen análisis del consumo de alimentos y bebidas son necesarios con diferentes finalidades de interés nutricional, alimentario, toxicológico o en el contexto de estrategias de intervención que incluyen la modificación de conductas alimentarias. Se han venido utilizando diferentes métodos, cada uno con ventajas, inconvenientes, sesgos y limitaciones que deben considerarse al elegir el más adecuado en cada caso. El desarrollo de las nuevas tecnologías ofrece avances interesantes para mejorar la validez y precisión de estos métodos, así como su rápidez y eficiencia. También debe tenerse en cuenta las características de los individuos objeto del estudio, su entorno así como los recursos disponibles.

(*Nutr Hosp* 2015;31(Supl. 3):15-21)

DOI:10.3305/nh.2015.31.sup3.8746

Palabras clave: *Consumo alimentario. Evaluación. Validez. Precisión. Nuevas tecnologías.*

Correspondence: Javier Aranceta.
Community Nutrition
PO Box 5199. 48080 Bilbao (Spain).
E-mail: jaranceta@unav.es

Abbreviations

AECOSAN: Agencia Española de Consumo, Seguridad Alimentaria y Nutrición.
AMPM: Automated Multiple Pass Method.
EC: European Community.
EFSA: European Food Safety Authority.
FAO: Food and Agriculture Organization of the United Nations.
FIVR: Food Intake and Voice Recognizer.
MAGRAMA: Ministerio de Agricultura, Alimentación y Medio Ambiente.
TADA: Technology Assisted Dietary Assessment.
ANIBES: Antropometría, Ingesta, y Balance Energético en España.
ENPE: Estado Nutricional de la Población Española.
ENIDE: Encuesta Nacional de Ingesta Dietética.
PREDIMED. Prevención con Dieta Mediterránea.
PERSEO: Programa piloto Escolar de Referencia para la Salud y el Ejercicio contra la Obesidad.
NHANES: National Health and Nutrition Examination Survey.

Introduction

Health status is influenced by different genetic, individual and environmental factors that in variable proportionality interact with well-being, the morbidity/mortality and the vital projection towards future generations.

Under this assumption, knowledge and analysis of food habits, physical activity, energy balance and other lifestyle factors can be of great help in nutritional epidemiology studies and in processes of health-planning, development of dietary recommendations or when dealing out health plans.

Regarding these studies and their findings, doubts and controversies arise depending on the complexity and diversity of the methodologies to be used, the criteria employed to set cut-off points, or the normality ranges of different variables; or, more frequently the doubts are concerned with the insufficient quality data obtained during field-work interviews.

Most of the information collected in such studies belongs to the intimate personal domain of people, such as their eating habits, their shopping, cooking or eating manners, time-schedules, daily life style and other personal characteristics[1]. Sometimes methodological aspects might be placed into question, such as the tools used for nutritional assessment or other aspects related with the variability of intake, but in most cases, there are two important blocks of uncertainty:

- Incomplete or biased information on dietary intake, amount of physical activity or other lifestyle factors. We often think on memory lapses, but there are reasons about masking the reality, due to an urge for approval of habits and social desirability, or even due to saturation induced by too long and poorly motivating interviews.

- One of the aspects that are more difficult to assess is related to physical activity: time spent, type or intensity. The use of validated questionnaires is only a first estimate, and instrumental aids such as accelerometers are very expensive to be used in large scale studies and require specialized personnel for proper interpretation.

In this regard, one of the characteristics of most population studies is a large percentage of energy miss-reporters, but also for some specific food groups, nutrients, or self-reported physical activity and a lack of specification of the energy balance of the individuals and groups under study[2].

With these limitations seems very risky to use the results obtained in a study to modify sustainably the current diet, to generate recommendations and to plan actions towards public health.

Based on this strategic approach it seems necessary to encourage the implementation of representative surveys of food use reality and its determinants, where the evaluation of physical activity, culinary habits and individual sensitivity on sustainable production, ecological and emotional balances, are blocks of variables considered for an operational analysis.

Purpose and interest of food consumption studies

In general, the studies related to food and beverage intake have multiple streams of application, ranging from institutional commitment for monitoring food intake or shopping basket to a more commercial interests linked with marketing strategies and market analysis[1].

Some of these areas of application are summarized in the following sections (table I):

1.- Nutritional interest

- Estimation of the adequacy of the food and nutrient intake to the Recommended Dietary Intake and Dietary Guidelines in each region or country. For example, the recent studies carried out in Spain such as the ANIBES study[3], the ENPE project[4] or the ENIDE study[5].

- Evaluation of the relationship between diet-nutritional status-health: nutritional epidemiology. In this section we consider for example the recent contributions of the PREDIMED study in Spain[6].

- Assessment Tool for evaluating nutrition education programs, nutritional interventions and food fortification programs, for instance, some of the phases of the PERSEO project[7].

Table I
Aims and uses of food consumption studies

Food and Nutrition Plans	*Nutrition interest*	*Toxicological aspects of food supply*
Food supply and distribution. Examples: Food Balance Sheets Household Budget Surveys	Nutrient inadequacy. Nutrition and Health Surveys: Regional surveys (Catalonia, Basque Country, Canary Islands, Madrid, Valencian Region, Andalusia…) National surveys ENIDE (Spain), NHANES (USA), Germany, Austria, Finland, France, Ireland, Netherlands, United Kingdom, Australia, New Zealand…	Total Diet studies EU Menu
Food production and distribution. Examples: Ministry of Agriculture surveillance	Epidemiological research about diet- nutrition- health status. Example: PREDIMED…	
Food regulation, food fortification and nutrition education	Evaluation of nutrition intervention programs, policies.and guidelines	

2.- Food and Nutrition Planning

- Analysis of the production and availability of food in a region or country (FAO Food Balance Sheets)[8].
- Analysis of supply and distribution of food and beverages (Household Budget Surveys[9], MAGRAMA[10,11] or MERCASA[12] surveys in Spain).
- Food and Nutrition Surveillance Programs (AECOSAN)[13].
- Food regulation, food fortification and nutritional education projects as some of those led by AECOSAN on salt content of some foods.

3.- Toxicological aspects of food supply

- Total Diet Studies to determine trace elements and contaminants in food. Several regions have developed such studies, as also did AECOSAN recently[14].
- EU Menu, project coordinated by the European Food Safety Agency (EFSA) aiming to promote the collection of data on food consumption in European countries with standardized procedures, in order to assess the exposure and risk analysis more accurately and efficiently. It will collect data about the European population menu between 2012 and 2017.

Some common concerns in nutritional studies

There are many elements to consider in all population studies, from the selection of the sample to the interpretation of the results, but one of the limiting factors is related with the validity and reliability of the selected methodology for data collection on food intake. Table II summarizes frequent issues and controversies related to food consumption and nutrition surveys.

From the available methods and their variants, the procedure chosen usually depends on the purpose, budget, resources and characteristics of the sample group. In all cases, our ultimate goal is to determine the usual intake of the individuals and groups under study[15].

Knowledge of the usual and real intake is a demanding goal. The application of different complementary supportive methods based on food records will be required, such as, one or more 24-hour recalls or the Automated *Multiple Pass* Method (AMPM). The latter one is a computerized method used to systematically collect the reminders of food eaten in 24 hours by telephone or face-to-face interview. Other methods include food frequency questionnaires and even diet history questionnaires. Based on the information collected, appropriate statistical analysis will help to model usual intake and provide estimates closer to real intake.

Data collection is key in this process. Planning the adequate strategy for data collection is as important as choosing the appropriate method and protocol, preparing the suitable arrangements to involve trained and qualified personnel. They can motivate respondents to collaborate and get them to contribute as best the quality and complete information as possible.

Table II
Issues and controversies in food and nutrition studies

Issue	*Controversy*
Validity	Cost-effectiveness Estimation of usual intake Appropriate method according to aims and resources Harmonization – comparability of data Energy balance Underreporting- Overreporting
Portion size	Food models and replicas Photograph models New technologies
Special foods and additions	Bread Salt Water and beverages Fats and oils Supplements
Respondent burden	Influence eating behavior Response rate
Special population groups	Cognitive ability Surrogate response
Energy and nutrient intake estimates	Food composition databases Suitable software- platforms
Biomarkers	Energy and nutrient intake Physical activity Omics
Physical activity	Questionnaires Accelerometry New technologies
Data analysis	Response rate Bias and adjustments

This work requires the support of validated tools for the interpretation of weights and portion sizes as well as a appropriate use of new technologies as means to save this information in a quick, precise and easy manner. This is undoubtedly one of the key points of nutritional studies.

EFSA work-teams have suggested a methodological approach to make a consistent data collection and nutritional assessment in order to obtain reliable data and hence be able to compare the data collected in surveys conducted in different countries as well as provide the possibility to combine efforts and data from different countries in the European Community (EC)[16,17].

Portion size models and dietary intake assessment

As mentioned earlier, the portion size and weight estimations of food intake are limiting factors in nutritional studies. We are interested in gathering all information on the consumption of food and drinks in a given period of time, but also, we may want to assess the portion of sizes and weights of foods consumed and food ingredients.

Different kinds of food models have been used in food and nutrition surveys since the Nutrition Survey of Canada in 1974. In that survey, sizes and thicknesses of cardboard, calibrated containers and other gadgets were used as food models to estimate the portion sizes of foods consumed. Other procedures include food replicas, household measures (plates, spoons, glasses, cups...) and even modeling with fingers and hands. Currently, photographic models and technology based aids are the most widely used resources[18]. Photographic models are suitable for being specifically designed for each study, considering four or more volumetric references for food or food group[19-23]. The description of the average servings consumed as small, medium, large or very large can also be useful, depending on the level of the information required.

These days, web pages, laptops, tablets or mobile phones with specific applications are frequently used for this purpose. Sometimes, images are recorded to display the choice of food in catering or during the process of buying in small shops or supermarkets or even to support food records[21-28].

Technology Assisted Dietary Assessment (TADA) system is one of such new technological applications,

which involves capturing photos with the mobile before and after food consumption. These photos are tagged with supporting details to estimate the portion size and subsequent automatic analysis from a link to a database of food composition analysis[29].

The Food Intake and Voice Recognizer (FIVR) system allows us to capture images with the mobile and simultaneously record comments about the prepared dishes to be consumed. The information is processed with the estimation of food portion sizes and volumes. The end result is a dietary study with automated nutritional assessment[30].

The sensor system e-button, for ubiquitous evaluation, allows image capturing and logging of data for a day or a set period. This method is based on the use of a device with sensors and a recording camera that allows for a real-time collection of information from environmental factors, food shopping, food intake, cooking techniques used, physical activity, leisure time activities, and consumption of drinks or other substances. It is a process of great interest in the future of telemedicine and health research[31].

Main difficulties in estimating dietary intake

Dietary assessment is a complex procedure. All foods, fresh or processed, need a special attention to get a more precise picture and avoid the leak of any details to the overall assessment. However, there are some elements of the diet are particularly difficult for accurate quantification.

Water and beverages

The estimated consumption of water and other drinks require special attention and the use of specific validated questionnaires. Many people have trouble remembering their water and overall beverages intake and its variability further complicates the assessment of the usual intake. Use of biomarkers and urine output are recommended.

Alcoholic beverages

The assessment of alcohol intake in alcoholic beverages users requires a thorough interview about this particular product, starting from the time of getting up to bedtime and even at night-times. This section should be completed at the end of the interview with a sensible approach and empathy.

Salt intake

Assessment of salt and total sodium intake is a difficult challenge. Information can be derived from the buying and spending of salt in a given time period by the number of users in each family. Information on the use of extra salt at the table and/or contribution of salt marked with lithium. We can draw on 24 hour urine collection for the determination of sodium and particularly, we can draw on a good food composition table or on a duplicate portion analysis system.

Intake of oil and other added fats

Quantification of oil consumption individually or in a group have varying degrees of difficulty depending on culinary techniques, added oil, type of oil, or the ratio between oil availability and intake, among others. A homogenous criteria needs to be placed for allocating oil consumption depending the type of dish and food volume and wherever possible it should be accompanied by the use of biomarkers.

For fat spreads the recipe will be used, home servings or quantities allocated according to the size of the receiving surface.

Bread

In some situations, bread is a food of difficult characterization. We will need to know the sizes and weights of the most used breads in each region, along with the weight and size of the loaves and alike. Photographic models, home measures and the usual shopping will help in quantifying bread consumption.

Other critical variables

Along with the complexity of assessing the diet as a whole and some foods or products in particular, various challenges arise regarding the relationship between the respondent and the interviewer throughout the fieldwork process. This issue will be discussed with particular thoroughness in some sections of this monograph. This is about getting a good rate of valid responses on a well selected theoretical sample. Adapt the whole dynamic of the process to encourage the participation and collaboration of respondents and nonetheless conduct an adequate analysis of the nonresponse rate.

Other added peculiar features should be noted in some groups such as the elderly, children, disabled, homeless, immigrants or people affected by illness, etc. Also in cases of surrogate responses.

Some studies have important limitations based on low response rates, important under-response subgroups and the use of low quality or difficult to compare food composition tables.

Some biases are related with the lack of quality information on nutritional supplements or dietetic products intake. Also bias can be related with the use of just few days for intake analysis or periods that do not allow integrating seasonal or monthly variability.

Instrumental assessment: anthropometry and physical activity

Some nutritional studies and almost all the studies aimed at assessing nutritional status incorporate a relatively extensive section on anthropometric measurements. This section requires a large technical training, approved/homologated instrumentation, calibration and daily quality controls. The preceding work before a study begins will allow achieving a high level of training in making measurements, along with the decision of the cut-off points and the reference values to be used.

As explained earlier, a key points related to the investigation of physical activity and caloric expenditure of each study participant. The use of validated questionnaires will be aided by incorporating modern instruments and new technologies such as specific applications in connection with accelerometers, pedometers and other technical utilities[32].

The relevance of incorporating haematological and biochemical indicators, other biological tests or genetic determinants will be discussed by the research team depending on the objectives of the project and the characteristics of the study group. Finally, Ethics Committees will be an added guarantee of balance in our overall proposals.

Other lifestyles

In this preliminary review on the various factors to consider in the development of population studies on nutritional status, we cannot forget to include smoking, alcohol, medicaments and other drugs, along with accurate indicators of mental health/well-being and quality of life.

From the modelled framework of the Mediterranean Diet we will not forget the chronobiological aspects, time and environment dedicated to each meal, sustainability criteria, characteristics of food production, the balance of remains, leftovers and other anthropological variables related to diet.

All of them are factors related with and determinants of dietary habits and health status. These data, in varying degrees, will be of great use for our future proposals of intervention initiatives and nutrition education.

References

1. Aranceta J. Nutrición Comunitaria (3ª edición). *Barcelona: Elsevier-Masson* 2013
2. Archer E, Hand GA, Blair SN. Validity of U.S. *Nutritional Surveillance: National Health and Nutrition Examination Survey Caloric Energy Intake Data* 1971–2010. PLoS ONE 2013; 8(10): e76632. doi:10.1371/journal.pone.0076632
3. Ruiz E, Ávila JM, Castillo A, Valero T, del Pozo S, Rodriguez P et al. The ANIBES Study on Energy Balance in Spain: Design, Protocol and Methodology. *Nutrients* 2015 (in press)
4. Fundación Eroski – Sociedad Española de Nutrición Comunitaria. Encuesta Nutricional de la Población Española (ENPE). *Madrid: SPRIM* 2014
5. Agencia Española de Seguridad Alimentaria y Nutrición (AESAN). *Encuesta Nacional de Ingesta Dietética Española (ENIDE)* 2011. [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enide.shtml
6. Prevención con Dieta Mediterránea (PREDIMED). [http://www.predimed.org/]
7. Aranceta J, Pérez Rodrigo C, Campos Amado J, Calderón Pascual V, en nombre del Grupo Colaborativo Proyecto PERSEO. Proyecto PERSEO. *Diseño y metodología del estudio de evaluación Revista Española de Nutrición Comunitaria* 2013; , 19, 76-87
8. FAO. Food Balance Sheets Avaible at:[http://www.fao.org/economic/ess/hojas-de-balance-de-alimentos/es/]
9. INE. Encuesta de Presupuestos Familiares (EPF). INEbase. Available at: [www.ine.es] (Accessed 15 January 2015)
10. La Alimentación mes a mes en España Año 2014. Madrid: *MAGRAMA*, 2014. Available at: [http://www.magrama.gob.es/es/alimentacion/temas/consumo-y-comercializacion-y-distribucion-alimentaria/panel-de-consumo-alimentario/ultimos-datos/] (Accessed 15 January 2015)
11. Del Pozo de la Calle S, García Iglesias V, Cuadrado Vives C, Ruiz Moreno E, Valero Gaspar T, Ávila Torres JM, Varela Moreiras G. Valoración Nutricional de la Dieta Española de acuerdo al Panel de Consumo Alimentario. *Madrid: Fundación Española de la Nutrición (FEN)- MAGRAMA* 2012. Available at: [http://www.fen.org.es/imgPublicaciones/30092012125258.pdf] (Accessed 15 January 2015)
12. Informe 2013 sobre Producción, Industria, Distribución y Consumo de Alimentación en España. *Madrid: MERCASA* 2013. Available at: [http://www.mercasa.es] (Accessed 15 January 2015).
13. AECOSAN. Evaluación de riesgos. Datos de consumo alimentario. Available at: [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/seccion/datos_consumo.shtml] (Accessed 15 January 2015)
14. Estudio de Dieta Total. *Madrid: AESAN-Fundación Bamberg* 2007. Available at: [http://www.fundacionbamberg.org/innovacion/estudios-publicaciones/estudios/estudio-dieta-total] (Accessed 15 January 2015)
15. Serra Majem Ll, Aranceta Bartrina J (eds). Nutrición y salud pública: Métodos, bases científicas y aplicaciones. 2 ed. *Barcelona: Elsevier- Masson* 2006.
16. European Food Safety Authority; General principles for the collection of national food consumption data in the view of a pan-European dietary survey. *EFSA Journal* 2009; 7(12):1435. [51 pp.]. doi:10.2903/j.efsa.2009.1435
17. Gavrieli A, Naska A, Berry R, Roe M, Harvey L, Finglas P et al. Dietary monitoring tools for risk assessment. *EFSA supporting publication* 2014: EN-607, 287 pp.
18. Gibson RS. Principles of nutritional assessment (2nd edition). *New York: Oxford University Press* 2005
19. Islam NG, Dadabhoy H, Gillum A, Baranowski J, Zimmerman T, Subar AF, Baranowski T. Digital Food Photography: dietary surveillance and beyond. *Procedia Food Science* 2013; 2: 122 – 128
20. McCabe-Sellers, B. Advancing the art and science of dietary assessment through technology. *J Am Diet Assoc* 2010 Jan;110(1):52-4. doi: 10.1016/j.jada.2009.10.014.
21. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim SP, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *Int J Epidemiol* 2012;41:1187–1203
22. Subar AF, Crafts J, Zimmerman TP, Wilson M, Mittl B, Islam NG, et al. Assessment of the accuracy of portion size reports using computer-based food photographs aids in the development of an automated self-administered 24-hour recall. *J Am Diet Assoc* 2010;110: 55-64.
23. Toobert DJ, Strycker LA, Hampson SE, Westling E, Christiansen SM; Hurley TG, Hébert JR. Computerized portion-size estimation compared to multiple 24-hour dietary recalls for

measurement of fat, fruit, and vegetable intake in overweight adults. *J Am Diet Assoc* 2011;111: 1578-1583.
24. Millen BE. Dietary behavior assessment: historical and recent innovations. *J Am Diet Assoc* 2010 Aug;110(8):1166-9. doi: 10.1016/j.jada.2010.05.011.
25. Ngo J, Engelen A, Molag M, Roesle J, García-Segovia P, Serra-Majem L. A review of the use of information and communication technologies for dietary assessment. *Br J Nutr* 2009; 101 (Suppl 2): S102–S112.
26. Stumbo PJ, Weiss R,.Newman JW, Pennington JA, Tucker KL, Wiesenfeld PL, Illner AK, Klurfeld DM, Kaput J. Web-enabled and improved software tools and data are needed to measure nutrient intakes and physical activity for personalized health research. *J. Nutr* 2010; 140: 2104–2115
27. Kirkpatrick SI, Reedy J, Butler EN, Dodd KW, Subar AF, Thompson FE, McKinnon RA. Dietary assessment in food environment research. A systematic review. *Am J Prev Med* 2014;46(1):94–102.
28. Serra-Majem L. Food availability and consumption at national, household and individual levels: implications for food-based dietary guidelines development. *Public Health Nutr* 2001;4(2B):673-676.
29. Stumbo PJ. New technology in dietary assessment: a review of digital methods in improving food record accuracy. *Proceedings of the Nutrition Society* 2013, 72, 70–76
30. Food Intake and Voice Recognizer (FIVR) Available at: [http://www.viocare.com/index.aspx]
31. Sun M; Fernstrom JD, Jia W, Hackworth SA, Yao N, Li Y. et al. A wearable electronic system for objective dietary assessment. *J Am Diet Assoc* 2010 Jan;110(1):45-7. doi: 10.1016/j.jada.2009.10.013.
32. Plasqui G, Bonomi AG, Westerterp KR. Daily physical activity assessment with accelerometers: new insights and validation studies. *Obes Rev* 2013 Jun;14(6):451-62. doi: 10.1111/obr.12021. Epub 2013 Feb 7.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):22-28
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Historical overview of diet assessment and food consumption surveys in Spain: assessment methods and applications

Luis Juan Morán Fagúndez[1], Alejandra Rivera Torres[1], María Eugenia González Sánchez[1], Mari Lourdes de Torres Aured[2], Mercedes López-Pardo Martínez[3] and José Antonio Irles Rocamora[4]

[1]Sociedad Andaluza de Nutrición Clínica y Dietética (SANCYD). [2]Unidad de Dietética y Nutrición. Hospital Universitario Miguel Servet. Zaragoza. [3]Unidad de Gestión Clínica de Endocrinología y Nutrición del Hospital Universitario Reina Sofía. Facultad de Medicina y Enfermería de Córdoba. [4]Unidad de Gestión Clínica de Endocrinología y Nutrición Hospital Universitario Virgen de Valme. Sevilla.

Abstract

The food consumption assessment methods are used in nutrition and health population surveys and are the basis for the development of guidelines, nutritional recommendations and health plans, The study of these issues is one of the major tasks of the research and health policy in developed countries.

Major advances nationally in this area have been made since 1940, both in the reliability of the data and in the standardization of studies, which is a necessary condition to compare changes over time.

In this article the history and application of different dietary surveys, dietary history and food frequency records are analyzed.

Besides information from surveys conducted at a national level, the main data currently available for public health planning in nutrition comes from nutritional analysis of household budget surveys and food balance sheets, based on data provided by the Ministry of Agriculture.

(*Nutr Hosp* 2015;31(Supl. 3):22-28)

DOI:10.3305/nh.2015.31.sup3.8747

Key words: *Dietetics. Diet Surveys. Food Habits. Diet Records. History.*

REVISIÓN HISTÓRICA DE LA VALORACIÓN DE LA INGESTA Y ESTUDIOS DE CONSUMO ALIMENTARIO EN ESPAÑA: MÉTODOS DE VALORACIÓN Y APLICACIONES

Resumen

Los métodos de valoración del consumo de alimentos, son utilizados para evaluar la salud nutricional de la población y sirven de base para la elaboración de guías, recomendaciones nutricionales y planes de salud, y el estudio de estos temas constituye una de las grandes tareas de la investigación y de las políticas sanitarias en los países desarrollados.

Los principales avances en este área en nuestro país se han realizado a partir de 1940, avanzándose tanto en la fiabilidad de los datos, como en la estandarización de los estudios, lo que es una condición necesaria para poder comparar los cambios ocurridos a lo largo del tiempo.

En este artículo se analizan la historia y aplicación de las diferentes encuestas dietéticas, de la historia dietética y de los Registros de frecuencia de alimentos.

Además de la información procedente de algunas encuestas realizadas a nivel nacional, los principales datos de que disponemos actualmente para planificación en salud publica Nutricional, proceden de la explotación nutricional de las encuestas de presupuestos familiares y de las hojas de balance alimentario, basadas en datos proporcionados por el Ministerio de Agricultura.

(*Nutr Hosp* 2015;31(Supl. 3):22-28)

DOI:10.3305/nh.2015.31.sup3.8747

Palabras clave: *Dietética. Encuesta dietética. Hábitos alimentarios. Registro dietético. Historia.*

Correspondence: Luis Juan Morán Fagúndez.
Sociedad Andaluza de Nutrición Clínica y Dietética (SANCYD).
Pagés del Corro nº 80, 3º 41010. Sevilla.
E-mail: luisjmoran@ono.com

Eating is a primary need for humans and assessment of food consumption and diet both individually and collectively, has raised interest for a long time.

Initially the study of diet focused on the distinction between foods that favored survival and those who were harmful to health or poisonous, experiences based on trial and error. The empirical knowledge acquired at the high cost of many lives among our ancestors has been incorporated and passed down from generation to generation as a valuable knowledge in the cultural heritage of civilizations.

The study of diet, not only to survive but to maintain good health, came later. Etymologically the word "diet" comes from the Greek DAYTA, meaning 'way of life'. It is accepted as a synonymous to diet, which refers to 'set and amounts of foods or food mixtures commonly consumed'. It can also mean food choices made by healthy, ill or convalescing people, in certain circumstances, in eating, drinking and sleeping[1].

Information about diet is available before writing appeared. However it was not until the last 200 years when major developments took place in food consumption assessment, applying the scientific method. Nowadays the study of these issues is one of the major tasks of research and health policies in developed countries.

This article reviews the attempts to study food consumption from its initial steps to date. We have also reviewed the use of the methods and techniques in major Public Health interventions.

Ancient Times

For millions of years humanity fed on what people could find around, without any scientific knowledge about food, the first aim of feeding for humans was to satisfy hunger. Survival of human groups was conditioned by access to food[2].

The original habitats of our ancestors mainly consisted of forests and wood areas in a tropical-like climate. Dental morphology analysis shows that the feeding of primates 12 million years ago was particularly frugivorous, including fresh and dried fruits, leaves, stems, seeds, etc.[3]. The subsequent climate changes on our planet changed the landscape and food distribution which in turn, conditioned the evolution of species. With the settlement and the emergence of the first civilizations, human left behind nomadic hunter-gathering and gave way to a diet based on foods produced.

Probably the first dietary experiment, with documented evidence, is described in the Biblical story of Daniel, which took place 600 years a.C , when David rejected a diet based on delicate viands and wine offered by King Nebuchadnezzar of Babylon. In return, David managed to persuade the cook to feed himself and his colleagues with a diet rich in legumes and change the wine for water during ten days. After these ten days, they saw the satisfying appearance of these young people and were allowed to continue on the same diet. Even three years later, the king himself noticed that they were ten times better than all the magicians and enchanters in his kingdom. Perhaps this was the beginning of the assessment of "Scientific" truths, although at that time knowledge was scarce and confusing: trust in magic began to decrease.

Primitive humans had guidance only based on self-experience and therefore it should not be surprising that many misconceptions prevailed. Traditional beliefs gave illness a divine character as a "punishment from the gods". Hippocrates (460 years a.C.) was the first person who firmly confronted these superstitions was. He offered a rational view, relating the development of medicine with the development of nutrition; he believed that diseases were the result of vital habits, food and the environment[4]. However, although Greeks and Romans considered appropriate to use diet in the treatment of diseases, they didn't know exactly which foods were useful or why. But at that time we have knowledge of one of the first data on food consumption in the population. At the time of the Republic of Ancient Rome, trade of basic foods like wheat, was controlled with known prices regulation and quantities stored in their warehouses, or consumed by the population.

The period since the fall of the Roman Empire (year 476 a.C.) until the Middle Ages was the period of the spread of Christianity, and not much attention to medicine or science was given[2].

The experimental method

To our knowledge, Hippocrates was the first one who modified the old concepts related to food; but it was not until the beginning of the Christian Age the experimental method was developed. Galen, a Greek physician (130 a 200 d. C) learned from animal experiments and dissections in human cadavers that food is fragmented into particles small enough to be absorbed in the stomach. He revealed the functions of kidney and bladder and demonstrated that arteries carry blood, ending the common understanding at the time that they carried air. He gave a powerful impetus to the experimental method as a necessary element in the study of medicine. However, over the next ten centuries after his death little progress was made in this field and his writings were considered as the last word on the matter for almost 1200 years[4].

Sanctorius (1561 -1636), Italian physician, recorded his own weight, all food he ate and all products of excretion from his own body for several weeks. He was probably the first one who began the study of human nutrition and his book published in Leipzig in 1614 can be considered the first one on the study of human basal metabolism[4].

Since then, new progress in medicine came; William Harvey (1578 – 1657) showed blood circulation; the

French René Réamur (1683 -1757) showed digestion as a chemical process and the existence of acid in the gastric juice, the Russian Pedro Iván Pavlow (1849-1936), published his work 'Lectures on the Work of the Digestive Glands'. Chemistry made big progress during the XIX Century. Gastric juice was identified as hydrochloric acid, and also the presence of another agent responsible for the dissolution of food, the pepsin enzyme (1835).

Another remarkable advance in the world of nutrition was the discovery of metabolism. In the 18th century, Antoine Lavoisier was the first one to measure metabolism in humans. His work was continued by scientists like Liebig, Voit and Rubner[3]. Lavoisier showed that in science it is essential to measure weights and all measures accurately. His experiments provided the basis for understanding the metabolic processes occurring in the human body and thereafter he was assigned the title of 'Father of Nutrition'[4].

In the early nineteenth century three kinds of food materials were known: saccharides, oilseeds and albumin. The same elements later called carbohydrates, fats and protein. In the mid-nineteenth century, a more critically view study started and also research on how they were formed in the body, where they came from and whether they were or were not necessary in the diet[4].

The study on minerals (iron, calcium and phosphorus) began, as well as vitamins, whose history is probably the longest, even though it was the last group of nutrients studied.

Current time

Currently the health of populations is addressed through a new approach, it is Nutrition in Public Health, and nowadays is one of the major tasks of research and health policy in developed countries and it will probably continue to do so over the coming decades.

During the first two or three decades of the last century, the deficit and infectious diseases were the leading cause of mortality, but in the middle of the twentieth century chronic diseases took over. From this moment, diet had a role in maintaining health and reducing the risk of chronic diseases, such as heart disease and cancer, which formed the basis of most of the research being carried out. Subsequently diet was reaffirmed through clinical epidemiology and laboratory as one of the most important factors involved in the etiology of these diseases[5].

Dietary assessment methods are key tools to inform this area, among other dietary surveys, diet history and food frequency questionnaires.

Dietary surveys

They were first used in the 1930s, in studies aimed to describe the nutritional status of populations.

The "24 hours recall " method was mentioned by Burke in 1938[5], presenting it as a basic method to teach mothers to collect dietary intake of their children. But since the results were not calculated in terms of energy and nutrients, Wiehl has often been cited as the first researcher who used this method in a study of dietary deficiencies among industrial workers in 1942. It has been one of the most common methods in national studies, among others countries like Canada, USA (NHANES I, II, III), Spain, Mexico and South and Central American countries.

Diet History

Diet history was first used in 1947 by Burke et al., to measure the usual intake. The technique was structured in 3 parts: 1. Interview about the usual pattern of intake of the individual respondent, estimating quantities by household measures. 2. A questionnaire on a detailed list of foods to clarify the overall pattern of intake and verify the information obtained in the first part (cross-check) and 3.- 3 days food record with estimates of portions consumed[6].

Food Frequency Questionnaires.

Wiehl developed in 1960 a short questionnaire for qualitative classification of dietary habits. The diet records used by Heady were intended to show that the frequency of food consumed was greater than the total weights of the same foods. It was based on a self-administered questionnaire strictly based on the frequency of food consumption.

Stephanik and Trulson found in 1963 that a food frequency questionnaire discriminated between groups defined by ethnicity, but it was not considered useful to calculate nutrient intake. Also in 1963, JH Abramson studied the limitations and possible uses of food frequency questionnaires concluding that "its use in epidemiological studies is useful as a simple and inexpensive tool, although not very accurate"[7]. Marr in 1971 -1973 proposed various methods for assessing the intake[8].

In 1985, Walter Willett developed a food frequency questionnaire known as the "Harvard FFQ" that includes information on portion sizes as part of the description of the food, rather than a separate list[9].

Currently, there are new designs for food frequency questionnaires that address specific population groups, such as children[10] or elderly[11, 12]. There are also questionnaires focused on the characterization of food or nutrients, such as calcium or zinc[13].

The need for further research and improve the methodology of individual questionnaires for the assessment of dietary intake deserves a renewed effort and maximum impetus[13].

Situation in Spain

Currently the main sources of information on food consumption in our country come from both knowledge of food availability, based on food balance sheets (FBS), and the analysis of nutritional data derived from the household budget surveys (HBS) and other surveys conducted nationwide.

If we make a historical tour from 1900 to date, we can notice how both the reliability of the data, and the standardization of studies have progressed, a necessary condition to compare changes over time. In the evolution of these sources of information, we can clearly distinguish two stages: pre- and post- 1940.

The first stage, from the late nineteenth century until 1940, is characterized by scarcity and poor homogeneity of the information available. Information sources are the Ministry of Agriculture and surveys at provincial or regional level. Some historians like Simpson and Cusso have analyzed these data conducting a retrospective reconstruction of those years[14, 15].

Among the difficulties they found, the poor reliability of tithing in many areas after the Independence war, and the lack of a register or good information acreage. Production estimates are based on the 'Censo de Frutos y Manufacturas' and the Agricultural Advisory Board (JCA)[16].

Among the studies after 1900, highlights that conducted by pharmacist J. Giral "Food supply from a hygienic and social view," 1914, one of the classics of the nutrition transition in Spain. It is based on documents and works of the extra-parliamentary commission for transforming consumption tax, and provides information on the estimated calorie intake, albumin, carbohydrates and fat as well as the consumption of various food groups in 6 populations with different economic income. The differences, especially in protein for poor families were evident[17].

Carrasco Cadenas in the Department of Food Hygiene and Nutrition, National School of Health, conducted several studies to determine the average regular diet of Spaniards, from the quantities consumed of each food throughout the country, following methodology recommended by the International Committee of Experts in Geneva and Rome 1932 Committee. With the method of food survey highlights the work of pharmacists Francisco Jiménez and Manuel Jiménez, 1934, conducted in the province of Jaén. They studied 3592 cases in 70 villages, based on the familiar feeding cards following the methodology recommended by the Hygiene committee of the League of Nations. They recorded everyone ordinary food, in quantities of bread, meat, eggs, etc., as well as epidemiological and anthropometric data. Most animal protein intake was constant in middle and upper classes. Higher consumption of fish was observed in working classes, especially salted cod[18].

During the early years of the 1940s, Francisco Jiménez García and Francisco Grande Covián, from the National Institute of Food Hygiene, published in Spanish Clinical Journal a series of clinical studies about the deficiency diseases in the population of Madrid during the war and the period after the war. We can learn details about this decade through the study of nutrition in Madrid during the Spanish War, 1937 to 1939[19,20].

From 1940 onwards, in order to inform about eating habits of the Spanish population over a number of years, the most important contribution is the nutritional analysis of the data from household budget surveys, conducted in a collaboration between the National Institute Statistics and the National Institute of Nutrition for the years 1958 , 1964 to 1965, 1980 to 1981 and 1991.

The first standardized data on food availability are the HBA, appearing since 1940 and continue up to date. The Food and Agriculture Organization, United Nations (FAO) and The Organization for Economic Co-operation and Development (OECD) produce these reports from data provided by the Ministry of Agriculture. The FBS provide information about the amount of food that enters the domestic market, available for consumption. The calculation of food availability is a synthesis in which data from numerous statistical sources are integrated.

More recently, Rodriguez Artalejo made the first systematic reconstruction of food and nutritional history of Spain in the last fifty years, re-analyzing data from the Ministry of Agriculture, from 1940 to 1988. These new FBS for Spain also incorporate the sources cited and information from the International Olive Oil Council, the Vertical Olivo Trade Union, the National Association of Fish Powder Producers and the National Wheat Service. The changes occurred especially since the sixties, coinciding with the acceleration of economic development[21].

Among the surveys from 1940, highlights that by G. Varela, 1961, based on data from the National Statistics Institute (INE). Subsequently nutritional analysis of data derived from household budget surveys (HBS) has provided information of food consumed per person per day in physical quantities of food purchased by households.

Since 1987 the Panel of Food Consumption in Spain was conducted by the Ministry of Agriculture, Food and Environment (MARM, former MAPA). From 1987 until 2005 published yearly, the volume "Food in Spain".

Subsequently, the Ministry, under the Framework Cooperation Agreement signed with the Spanish Nutrition Foundation (FEN), followed a step further by deciding a more complete nutritional analysis of the data obtained, leading to the volume "Rating Spanish Diet According to the Food Consumption Panel", from 2000 to 2006. The latest edition of 2012 valued data for the years 2007 and 2008. The figures refer to consumption within households, hotels/restaurants and institutions.

Finally, the ENKID Study can be mentioned among child population surveys conducted.

Applications of food consumption assessment methods.

Food consumption assessment methods are an essential tool in determining food intake in populations. They are useful for assessing and monitoring nutritional health, allowing to observe trends and changes in consumption patterns. This information will serve as a basis for the development of guidelines, recommendations and nutritional health plans and policies for the organization of agricultural prices and food and nutrition. Also, to execute actions for the prevention and control of non-communicable diseases and, sometimes, to regulate the advertising of industrialized foods.

In this section we review some of these basic documents in the field of Public Health, such as Recommendations and Guidelines, the development of Health Plans and actions on the Disease-Related Malnutrition

Recommendations and Guidelines

Documents dating from the 40s to the 60s of 20th century are known and they are the precursors of current dietary guidelines; but not until 1970 guidelines appeared, some of them in a pyramid shape, published by the competent authorities and state agencies in each country. The first one was published in Sweden in 1974. In the United States, the first guidelines were published in 1980 (Food Based Dietary Guidelines) and they are reviewed every five years. In January 2005, some of the foundations of the new pyramid are specified; the latest revision is from 2010 and the next, currently under development, will be published in 2015. Perhaps the best known is the 1992 United States Department of Agriculture version revised and updated in 2005 and called 'My Pyramid', where the importance of exercise is reflected and which was later replaced by 'My Plate' in 2011[22].

FAO and WHO during the Rome meeting in 1992, made a statement in which they urged all countries to adopt strategies to promote health through food and make dietary guidelines to guide the population. In 1996 they developed a report describing the methodology for setting standards and proper use of these guidelines based on food consumption[23, 24].

The Spanish Society of Community Nutrition (SENC) sponsored by the World Health Organization made a document in the shape of a pyramid and pioneer in our country, where the nutritional status of the population is reviewed, nutritional goals are defined and food guidelines for the population are disclosed. The Food Guideline, published in 1992, follows the model promoted by the National Nutrient Database for Standard Reference (USDA), which reflected the latest nutritional science. Until the publication of the new pyramid, the Food Guideline was the only nutrition guide for consumers. In subsequent years a spread work of the food pyramid was made, being used by many institutions and agencies at national, regional and local level and it was included in nutrition publications and textbooks. Later in 2001, following the 4th Congress of the SENC in Bilbao, the 2nd edition of the Dietary Guidelines was published, incorporating recommendations for different population groups and diseases. In 2004 the SENC publishes the "Guideline for Healthy Eating" in collaboration with the "Spanish Agency of Consumer Affairs, Food Security and Nutrition" (AECOSAN)[25].

In addition to the Food Pyramid other graphic resources for nutrition education of the population have been suggested, as the Food Wheel, an educational resource that was widely used in the 70s and 80s promoted in Spain by the EDALNU program of the Ministry of Health and involved health professionals and education professionals. In 2005[26] the Spanish Society of Dietetics and Food Science (SEDCA) retook this symbol and updated it with the collaboration of the Alfonso X el Sabio University of Madrid and the Madrid regional government[27].

More recent data on the Spanish diet should be kept in mind when planning future action on Nutrition[28, 29].

Health Plans

At the International Conference on Nutrition (ICN) held in December 1992, 159 countries unanimously adopted a World Declaration and Plan of Action for Nutrition where the strong commitment of all participating governments was to eliminate hunger and all forms of malnutrition before the end of the twentieth century. The new global statement CIN and Plan of Action for Nutrition[23], adopts new targets to combat malnutrition by 2000 as nutritional predicting and detecting short-term or acute problems; specify populations groups for short term SOS campaigns; long-term programs development; close monitoring of changes in the situation; to organize programs and evaluate the impact of the interventions and development programs.

In the past few years a comprehensive plan for mother and child, infant and child nutrition has been developed, it was voted and adopted by the 194 member countries of WHO in 2012, during the 65th World Health Assembly. This plan includes six goals related to nutrition to be achieved by 2025. In June 2014 the World Health Organization (WHO) published its proposed Action Plan on Food and Nutrition for the period 2015-2020[24].

At the last International Conference on Nutrition of FAO in Rome in November 2014 a framework is proposed with 60 objectives to be achieved by 2025 which compliance will be monitored every two years by FAO and WHO[23, 24]. The program advocates, among other challenges, to reduce by 40 % the number of children under 5 suffering from stunting, 50% the number of anemias suffered by women in reproductive age and

by 30% the number of babies born weighing less than healthy[23]. It also sets as objectives, a 50% increased in rates of breastfeeding in the first six months of life and a 30% decrease in the consumption of salt, sugar, animal fats and trans fats.

As can be seen, the objectives are aimed for people to obtain a correct nutritional status, in situations of abundance and scarcity. Another innovation is the creation of a website as a teaching tool about the proper food intake and dietary guidelines, and trying to unify the messages made by nutritional educators, which sometimes can be confusing[23, 30]. This nutrition web currently has a collection of dietary guidelines from more than 100 countries, including Spain.

Disease-Related Malnutrition (DRM)

All references made so far refer to guidelines or protocols facing the population understood as healthy; but one of the issues that most concern in recent decades is related to the Disease-Related Malnutrition (DRM) because it constitutes a health problem of high prevalence and high costs. It affects about 30 million people in Europe. In this aspect, the Spanish Society of Parenteral and Enteral Nutrition (SENPE) is the one who has taken the initiative and lead the studies on this issue, as being part of the European Society for Clinical Nutrition and Metabolism (ESPEN), endorses the recommendations of the European Nutrition for Health Alliance (ENHA) on Nutritional Risk Assessment in Europe.

Malnutrition is a common problem at all levels of healthcare, from primary to specialized care and also in geriatric care centers. Its incidence in hospitals is 40% and in nursing homes exceeds 60%. Malnutrition increases morbidity, mortality, hospital admissions and length of stay. These high numbers logically imply an increased use of health care resources. According to (ENHA) in Europe there are 20 million people suffering from malnutrition . This is a universal problem, which was recognized by the Europe Council in 2003.

The +Nutridos Project is a Strategic Plan, or "Action Plan to Combat Malnutrition in Spain" which includes the following points: Training in nutrition; assessment of disease-related malnutrition; Nutritional therapy in primary care centers , hospitals and nursing homes defining degrees of intervention; nutritional care monitoring and treatment; registration of diagnosed patients with disease-related malnutrition; Evaluation of results in health[30, 31]. One approach of the project is 'to invest in early nutritional care, is investing in health' and at the same time, saving costs.

The 2008-2013 Strategy "Together for Health" raised in the European Parliament urges Member States to develop , together with regional and local authorities, initiatives in the field of education to the population , specific training , research and good clinical practice. The ENHA has promoted the "Optimal Nutritional Care for All" (ONCA), strategy debated in Brussels in 2014 by several delegations of member countries, which takes over from the previous and on which will work from now on.

These strategic lines continue the recommendations proposed by the European Council in the "Resolution on Food and Nutritional Care in Hospitals ", released in 2003 and other initiatives such as the "Prague Declaration" of June 2009.

In 2011 the 'Consensus on Multidisciplinary Approach of Malnutrition in Spain' appeared at the Ministry of Health signed by representatives of more than 35,000 healthcare professionals represented in 22 scientific associations, the Spanish Foundation for Nutrition and The Patient Forum. With all these strategies, they pretend DRM to be a priority of the health system, as similar strategies have been made before for obesity.

The Swedish physician Arvid Wretlind, by 1961 said: "Malnutrition in the villages is a sign of poverty, in hospitals is a sign of ignorance."

Conclusions

Consumption quantification and eating habits has awaken interest from the time of Hippocrates and been related to the individual health.

Since the 30s and 40s of the twentieth century this effort by collecting food consumption data begins to be standardized in the form of questionnaires, in a time when the deficit and infectious diseases were the leading cause of mortality.

With the relief brought about by the chronic diseases from the mid-twentieth century, the methods to evaluate dietary intake take a position better oriented to health maintenance and to reduce the risk of chronic diseases.

Currently, they constitute an essential tool in determining food intake in populations groups. They are useful for assessing and monitoring the nutritional health of the population allowing to observe trends and changes in consumption patterns, this information serves as a basis for the development of guidelines, recommendations and nutritional health plans, and for the organization of agricultural price policies and food and nutrition. They are also useful to measure the prevention and control of no communicable diseases and sometimes regulating propaganda of industrialized food.

However, more research and the improvement of the methodology of individual questionnaires are needed for their faithful applicability to the realities of food consumption.

References:

1. Pinto JA , Carbajal A. La dieta equilibrada, prudente o saludable. Nutrición y Salud 1. Dirección General de Salud Pública

y Alimentación. Consejería de Sanidad y Consumo de Madrid. *Madrid* 2006.
2. Anderson. Nutrición y dieta de Cooper. *Mcgraw-hill Interamericana de España, s.l. 17º Ed* 1980.
3. Salas-Salvadó J, García-Lorda P, Sánchez JM. La alimentación y la nutrición a través de la historia. *Editorial Glosa* 2005
4. Lowenberg-Wilson .Los alimentos y el hombre. Editorial Limusa Wiley. *México* 1970.
5. García Closas R. Historia de la Nutrición en Salud Pública. En: Nutrición y Salud Pública. Métodos, Bases científicas y aplicaciones. Editorial Masson, S.A. *Barcelona* 1995.
6. Burke BS. The dietary history as a research tool. *Am Diet Assoc* 1947, 23:1041-1046.
7. Abramson JH. Slome C. Kosovsky C. Food Frequency Interview as an Epidemiological Tool. *Am J Public Health Nations Health* 1963 July; 53[7]: 1093–1101.
8. Marr JW. Individual dietary surveys: purposes and methods. *World Rev Nutr Diet* 1971; 13:105-64.
9. Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J, Hennekens CH, Speizer FE. Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol* 1985 Jul; 122[1]:51-65.
10. Parrish LA, Marshall JA, Krebs NF, Rewers M, Norris JM. Validation of a food frequency questionnaire in preschool children. *Epidemiology* 2003; 14:213-7.
11. Dumartheray EW, Krieg MA, Cornuz J, Whittamore DR, Lovell DP, Burckhardt P et al. Validation and reproducibility of a semi-quantitative Food Frequency Questionnaire for use in elderly Swiss women. *J Hum Nutr Diet* 2006; 19:321-30.
12. Quandt SA, Vitolins MZ, Smith SL, Tooze JA, Bell RA, Davis CC, et al. Comparative validation of standard, picture-sort and meal-based food-frequency questionnaires adapted for an elderly population of low socio-economic status. *Public Health Nutr* 2007; 10:524-32.
13. Martin-Moreno M, Gorgojo L. Valoración de la ingesta dietética a nivel poblacional mediante cuestionarios individuales: sombras y luces metodológicas. *Rev Esp Salud Pública* 2007; 81[5]: 507-18.
14. Simpson, J. La agricultura española (1765-1965): la larga siesta. *Alianza, Madrid* 1995, 1997
15. Cussó, X. "El estado nutritivo de la población española, 1900-1970". *Historia Agraria* 2005: 36, 329-58.
16. Documentos y Trabajos de la Comisión Extraparlamentaria para la Transformación del Impuesto de Consumos. Imp. de Sucesora de M. Minuesa de los Rios .*Madrid* 1906.
17. Giral Pereira J. La ración alimenticia desde los puntos de vista higiénico social. pag 350. Editor Adrian Romo. *Madrid* 1914 .
18. Bernabeu-Mestre J, Barona Vilar JL, Del Cura MI et al. "La alimentación como problema sanitario: nutrición y salud pública en la España de la primera mitad del siglo XX". En: VIII Congreso de la Asociación de Demografía Histórica [Recurso electrónico] : 30 mayo, 1 y 2 de junio 2007, Maó (Menorca). *Madrid : ADEH* 2007
19. Grande Covián, F., La alimentación en Madrid durante la Guerra. Estudio de la dieta suministrada a la población civil madrileña durante diecinueve meses de guerra: Agosto 1937 a Febrero 1939., *Publicación de la Revista de Sanidad e Higiene Pública* 1939.
20. Jiménez García, F., Grande Covián, F., Sobre los trastornos carenciales observados en Madrid durante la Guerra. I. Los cuadros clínicos presentados con más frecuencia y su clasificación. *Rev Clin Esp* 1940, 1, :313-318
21. Rodríguez Artalejo F, Banegas JR, Graciani MA, Hernández Vecino R, Rey Calero J. El consumo de alimentos y nutrientes en España en el periodo 1940-1988. Análisis de su consistencia con la dieta mediterránea. *Med Clin. (Barc)* 1996;106:161-168.
22. U.S. Department of Agriculture, U.S. Department of Health and Human Services [Internet].América: U.S. Government Printing Office; c2014citado [17/12/14] History of Dietary Guidelines for Americans Disponible en http://www.cnpp.usda.gov/DietaryGuidelines.htm
23. FAO: Organización de las Naciones Unidas para la Alimentación y la Agricultura [Internet]. Europa: FAO; c2014 citado [17/12/14]. Food based dietary guidelines. [aprox.8 pantallas]. Disponible en https://dietery-guidelines@fao.org
24. OMS: Organización Mundial de la Salud [Internet] citado [17/12/14]. [aprox.24 pantallas] Plan de Acción sobre Alimentación y la Nutrición para el periodo 2015-2020.Disponible en https://who.int/es
25. SENC: Sociedad Española de Nutrición Comunitaria [Internet].España: SENC; citado [17/12/14]. [aprox.10 pantallas] Elaboración de guías de la alimentación saludable Disponible en https://nutricioncomunitaria.com.
26. MSSSI: Ministerio de Sanidad, Servicios Sociales e Igualdad [Internet].España citado [17/12/14]. [aprox.30 pantallas]Nutrición y hábitos saludables Disponible en https:// aesan.msssi.gob.
27. SEDCA: Sociedad Española de Dietética y Ciencias de la alimentación. [Internet].España: SEDCA; citado [17/12/14]. [aprox.5 pantallas] La nueva rueda de los alimentos Disponible en https://nutricion.org
28. Marrodan MD Montero P, Cherkaoui M. Transición Nutricional en España durante la historia reciente. *Nutr Clin Diet Hosp* 2012; 32 (supl. 2): 55-64.
29. Varela-Moreiras Gregorio, Ruiz Emma, Valero Teresa, Ávila José Manuel, Pozo Susana del. The Spanish diet: an update. Nutr Hosp. [revista en la Internet]. [citado 2014 Dic 28]. Disponible en: http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0212-16112013001100002&lng=es.
30. Norte Navarro A. I., Ortiz Moncada R. Calidad de la dieta española según el índice de alimentación saludable. Nutr Hosp. [revista en la Internet]. 2011 Abr [citado 2014 Dic 28] ; 26(2): 330-336. Disponible en: http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0212-16112011000200014&lng=es.
31. SENPE: Sociedad Española de Nutrición Parenteral y Enteral [Internet]. *España: SENPE-Fundación ABBOTT* 2012. citado [17/12/14]. [aprox.17pantallas] Programa Más Nutridos. Cuaderno nº1. Plan de eficiencia nutricional. Herramientas de cribado nutricional para Hospitales, Residencias y Comunidad. Disponible https://
32. SENPE: Sociedad Española de Nutrición Parenteral y Enteral [Internet]. *España: SENPE-Fundación ABBOTT* 2014. citado [17/12/14]. [aprox.20pantallas] Programa Más Nutridos. Cuaderno nº 2. Hacia la desnutrición cero en centros hospitalarios. Disponible en https://senpe.com/MASNUTRIDOS/Presentacion+Nutridos+socios+SENP.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):29-37
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Sources of information on food consumption in Spain and Europe

Susana del Pozo de la Calle[1], Emma Ruiz Moreno[1], Teresa Valero Gaspar[1], Paula Rodríguez Alonso[1] and José Manuel Ávila Torres[1]

[1]*Fundación Española de la Nutrición. Spain.*

Abstract

Estimation of food consumption and nutrient intake is a topic of growing interest. Currently, both in Europe and in Spain, there are numerous sources of information on food consumption, that we provide information on different levels: national, household and individual, all of them are useful, but including some limitations, mainly arising from the lack of accurate data on food purchased but not consumed.

The data obtained allow, among other things, meet dietary habits, explore the food quality, study the energy and nutrient intake and / or assessing exposure to food risks.

Among the existing sources in Spain can highlight two surveys especially useful: the Household Budget Survey of the National Statistics Institute (INE) and Food Consumption Panel Ministry of Agriculture, Food and Environment (MAGRAMA). Both provide for many years food consumption but, lately, only in households.

Both European and Spanish would be necessary to improve the usefulness of the data, standardize the type of survey used and could be comparable between them.

(*Nutr Hosp* 2015;31(Supl. 3):29-37)

DOI:10.3305/nh.2015.31.sup3.8748

Key words: *food consumption, Spain, Europe*.

FUENTES DE INFORMACIÓN SOBRE EL CONSUMO ALIMENTARIO EN ESPAÑA Y EUROPA

Resumen

La estimación del consumo de alimentos y la ingesta de nutrientes es un tema de creciente interés. Actualmente, tanto en Europa como en España, existen fuentes de información sobre el consumo de alimentos, que nos ofrecen esta información a distintos niveles: nacional, familiar o individual, todas ellas son de gran utilidad, pero incluyen algunas limitaciones, principalmente derivadas de la falta de datos precisos sobre los alimentos comprados pero no consumidos.

Los datos obtenidos permiten, entre otras, conocer los hábitos alimentarios, explorar la calidad de la alimentación, estudiar la ingesta de energía y nutrientes y/o evaluar la exposición a riesgos alimentarios.

Entre las fuentes existentes en España se pueden resaltar dos encuestas de especial utilidad: la encuesta de presupuestos familiares del Instituto Nacional de Estadística (INE) y el panel de consumo de alimentos del Ministerio de Agricultura, Alimentación y Medio Ambiente (MAGRAMA). Ambas proporcionan desde hace bastantes años la información relativa al consumo de alimentos pero, últimamente, sólo en hogares.

Tanto a nivel europeo como español sería necesario, para mejorar la utilidad de los datos, estandarizar el tipo de encuestas utilizadas, para ser comparables entre ellas.

(*Nutr Hosp* 2015;31(Supl. 3):29-37)

DOI:10.3305/nh.2015.31.sup3.8748

Palabras clave: *Consumo de alimentos. España. Europa.*

Abbreviations

HBS: Household budget surveys.
AECOSAN: Spanish Agency for Consumer Affairs, Food Safety and Nutrition.
EFSA: European Food Safety Authority.
FAO: Food and Agriculture Organization of the United Nations.
EFG: European Food Groups.
FEN: Spanish Nutrition Foundation.
UE: European Union.
HBS: Household Budget Survey.
INE: National Statistics Office.
COICOP: Classification of Individual Consumption by Purpose.
MAGRAMA: Ministry of Agriculture, Food and Environment.

Correspondence: José Manuel Ávila Torres.
Fundación Española de la Nutrición.
Gral. Álvarez de Castro, 20 1ª pta.
28010 Madrid, España.
E-mail: jmavila@fen.org.es

Background

There are many factors that influence in the health of the population, some of them such as age, sex, race,

etc. cannot influence, but there are others, among which is the consumption of food if modified. Therefore, there is growing interest in learning about food consumption of the population.

Food intake is regulated in humans by many factors, other than nutritional ones, that together determine their choice and therefore food habits. Food habits are the result of more or less conscious, collective in most cases and always repetitive behavior, which leads to selecting, preparing and eating a particular food or menu as a part of their social, cultural and religious customs and which is influenced by multiple factors (socioeconomic, cultural, geographic, etc.).

Along time various tools have been used, more or less correctly, to achieve this goal. Information can be obtained at three different levels, which depend on the consumer unit: national, family or individual and the methodology in the collection of food consumption data (Fig. 1).

National surveys: The estimated supply of food for human consumption is performed by the technique of *food balance sheets* with national statistics on production, imports, exports, food etc. Food balance sheets present a comprehensive picture of the pattern of a country's food supply during a specified reference period.

The estimates are based on an inventory of available food for the inhabitants of a country. Considering the production and imports of food and making deductions export losses in storage or transportation and employment purposes other than human consumption (animal feed, seeds for farming, industrial uses, etc.) is obtained by dividing by the census of the country, an indirect estimate of the average availability per person per day.

Food and Agriculture Organization of the United Nations (FAO) published the first food balance sheets in 1949 that included the periods 1934-38 and 1947-48, and has since made numerous publications periodicals on the subject[1].

To know food consumption can also make *dietary surveys* that provide a quantitative and qualitative assessment of a food or food group in an individual during a given period of time.

Household surveys: Household budget surveys (HBS) control of all food consumed by the family is usually done for a week or, in the case of a collective dining room, for the time necessary to cover an entire period of menus. In the collective dining room all meals or only some of them can be made. In them the consumer unit is the household (institution or homogeneous group). HBS are periodically conducted by the National Statistical Offices of most European countries.

The technique consists of measuring all foods which are in the larder at the beginning and end of the study, adding daily entries: shopping, gifts, etc. and all those outlets which are not intended for consumption of respondents.

Subsequently, a homogeneous distribution among all the diners is performed. Often the respondent group presents quite homogeneous characteristics, for example, when it comes to school meals or nursing homes. In others, however, as in a family the composition can be very heterogeneous.

In 1945, at the First Session of the FAO (Quebec), indicated that they should start making dietary surveys, globally, to collect data on food consumption, food habits, nutritional status, the prevalence of malnutrition and deficiency diseases. The importance of consumer studies based on HBS as additional information to food balance sheets was also mentioned[2].

Individual survey: There are many methods to study individual food intake. Some of them studying current intake, *prospective* as weighing method, and other studying past intake, *retrospective* as food frequency questionnaire, 24-hour recall, diet history, that we provide information on the individual consumption.

The weighing method can be used in surveys in which very accurate data on food intake of individuals or groups are desired. Because of its expense that method is restricted to small samples. The estimated food record is a little less accurate but is especially suitable for individual surveys and a larger sample is possible than with the weighing method.

The 24-hour recall was conceived by Burke the late 1930s and developed by Wiehl in the early 1940s[3], who used it the first time in 1942. It is one of the most used

	Method	Find out differences between
National surveys	Food Balance Sheets	Countries and regions worldwide
Family surveys	Household budget surveys	Country, locality, seasonal, household
	Household surveys: shopping basket	
Individual surveys	The weighing method	Geographics, seasonal and demographics subgroup and individuals
	Food frequency questionnaire	
	24-hour recall	
	Diet history	Temporary and demographics subgroup and individuals

Fig. 1.—Sources of information. Dietary surveys.

techniques for its simplicity. Purpose: obtain detailed information about all foods and beverages consumed on a given day. The participant recalled the food and beverage intake for the past 24 hours (and possibly dietary supplements). Food quantities were assessed by using of household measures, food models, pictures, or the brands.

The classic version of a diet history was developed by Burke in 1947 and quantitatively assesses an individual intake and eating habits[3]. Allows to know the usual diet of a person generally used as reference period remember the last month.

The method consists of three components:

1. Frequency of food consumption refers to the last month (a list of foods and beverages for which usual frequency and amount are queried).
2. Detailed questions about usual patterns of eating, organized by meal.
3. A self-administered 3-day food record or alternatively a 24-hours recall. The food list and the 3-day food record are used only as cross-checks to modify information gathered during the meal pattern interview.

Both recall and diet history give fairly reliable mean results of the nutrient intakes of groups of individuals, but they are less suitable for surveying the food consumption of individuals. An advantage of diet history over recall is that it provides data on the normal food consumption, which is of importance in epidemiological investigations in particular.

Although the results are not quite as accurate as those obtained by the weighed or estimated food records, they give a good general idea of the diet. An advantage of the method is that the sample is large, although it cannot always be representative. With and without stock inventories it can be used also for studying the intake of people living in institutions. The interview methods are the cheapest ones for collecting food consumption data of large population groups selected at random.

The choice of data at national, household or individual levels will depend on the objectives of the work for which these data are used.

Therefore, we propose to make a description of the current status of the different sources of information on food consumption in Spain and Europe describing its limitations, controversies and applications.

Interest

Knowledge of food consumption in Europe and Spain will be useful in different ways. Their usefulness will be influenced by the level at which this data is collected.

At state level these studies can be useful in formulating nutrition policy, planning adequacy of supply, production, food distribution and regulation of food products.

They will also have an important nutritional interest because they are allowed to know the intake of energy and nutrients and compare this with the reference values or recommendations. This data will help identify individuals or populations, inadequate intakes for deficiencies or excesses, and identify risk groups among the study population. They allow to know food habits, consumption of fortified foods and explore the quality of food. In this sense also be possible to evaluate intervention and nutrition education programs. Therefore, we can perform a map of nutritional status. It will be possible to evaluate the risks and exposure to dietary intake of toxic substances pollutants or food additives.

On the other hand, are very important in public health. This will allow to investigate the relationship between diet, health and nutrition states and thereby improve the health status of the population and prevent disease. To know global and regional food consumption patterns and trends is useful to promote healthy diets and lifestyles to reduce the global burden of noncommunicable diseases because there are a positive correlations between foods and different diseases.

These studies also allow us to estimate the daily consumption of a particular food or beverages.

Controversy

There is a great discussion regarding the usefulness of dietary surveys because of biases produced by different methods used, since no method gives an exact image of what it consumes a population or an individual, because all have limitations.

Therefore, it is important that each study using the most appropriate method will depend on the purpose of the work, sample the type of information, accuracy, etc., and thus get a proper map of food consumption at all times.

For this reason, it is preferable to use an instrument that collects dietary data with the least bias possible.

Limitations

When speaking of limitations, we must distinguish between the different methods used to obtain food consumption, because each has distinct features as well as strengths and limitations.

National surveys: when studying consumption nationally use food balance we only indicate the quantities of food available for human consumption at the national level do not indicate what is actually consumed. It is not considered possible losses along the food chain, storage, transportation, preparation, etc., not food intended for animal use are taken into account.

On the other hand, do not provide data on the difference in the diet consumed between different regions or in different months.

When speaking of family or individual level to obtain detailed information about access to food in the home or individual food consumption can be long and expensive, and require a high level of technical capability for both the collection and the analysis of data.

HBS: Provide us with information on the consumption of food at home, so do not provide us the consumption of each individual.

Individual surveys: these surveys are complicated when the respondent has a large number of foods in his diet or take many intakes outside the home or take many packaged foods which there is no known their composition. Other problem is the underreporting, depending on age, gender and / or cultural level of the sample can result in over or underestimation of intake and some of these populations may have more problems performing surveys. Currently have developed a study, ANIBES, which aims to minimize this problem, has used new technologic with the possibility for "real-time" recording at eating events.

On the other hand, there are some foods that are difficult to register in a dietary survey, among them we can highlight: water, oil, bread, salt and alcohol.

Another common limitation to all individual surveys is the degree of abandonment that can be produced by the sample during the study.

Because of these limitations is important to remember that data gathered using these instruments are prone to measurement error (the difference between the true value of a parameter and the value obtained from the reported dietary intake). Knowing how to deal with measurement error is critical.

Actual status

Europe

Currently there are different sources of information about food consumption in Europe. Among them we can highlight:

FAO: *FAOSTAT* Food and Agriculture Organization of the United Nations Statistics Division. Provides time-series and cross sectional data relating to food and agriculture for some 200 countries. Presents a comprehensive picture of the pattern of a country's food supply during a specified reference period. The Food Balance Sheets domain covers: production, trade, feed and seed and waste, other utilization: food availability, elements covered: quantities, calories, proteins and fats[4].

Nutrition assessment. *Nutrition Country Profiles*. FAO publishes Nutrition Country Profiles which provide a comprehensive review of the food and nutrition situation in developing countries[5,6].

DAFNE: Data Food Networking system - The DAFNE databank is based on information collected in the context of HBS. HBS are periodically conducted by the National Statistical Offices of most European countries in country-representative samples of households. The methodology followed is uniform enough to allow between countries comparisons following minimal adjustment only[7,5].

European Nutrition and Health Report 2009. The aim of the European Nutrition and Health Report 2009 is to provide a comprehensive view of the health and nutrition status in the European Union (EU)[8,5].

EFCOSUM: The aim of EFCOSUM was to define a method for monitoring food consumption in nationally representative samples of all age-sex categories in Europe in a comparable way. Additionally, the project aimed to indicate how to make existing food consumption data comparable and available to the health monitoring system (HIEMS)[9,5].

EFCOVAL: European Food Consumption Validation. Aims to further develop and validate a trans-European food consumption method to be used for estimating the intake of foods, nutrients and potentially hazardous chemicals within the European population[10,5].

The European Prospective Investigation into Cancer and Nutrition (EPIC) study is one of the largest cohort studies in the world, with more than half a million (521.000) participants recruited across 10 European countries and followed for almost 15 years.

EPIC was designed to investigate the relationships between diet, nutritional status, lifestyle and environmental factors, and the incidence of cancer and other chronic diseases.

This study used a classification system of international food, distributing food to 17 different levels and is recommended in many studies. EPIC SOFT software was developed.

PANCAKE: Pilot study for the Assessment of Nutrient intake and food consumption among kids in Europe, the aim was to develop, test, and evaluate tools and procedures for a future harmonized pan-European food consumption survey (EU Menu) among infants, toddlers, children (upto ten years), and breastfeeding women[11,5].

SENECA: Survey in Europe on Nutrition and the Elderly. A Concerted Action. This study was an international, multi-centric longitudinal cohort study from 1988, in an attempt to analyze these factors in various food cultures of Europe in elderly people[12,5].

To obtain these food consumption is necessary to have **identification systems, classification and description of food**.

LanguaL the International Framework for Food Description. It is an automated method for describing, capturing and retrieving data about food. Since 1996, the European LanguaL Technical Committee has administered the **thesaurus** who provides a standardized language for describing foods, specifically for classifying food products for information retrieval.

LanguaL is a multilingual thesaural system using facetted classification. Each food is described by a set

of standard, controlled terms chosen from facets characteristic of the nutritional and/or hygienic quality of a food, as for example the biological origin, the methods of cooking and conservation, and technological treatments[13,5].

Many different systems to systematically define food items are available. It is important to remember that classification is a point of view and it is necessary to think that level is to conduct the study to find out what classification system used (individual, HBS or food balance sheets).We can classify foods in relation to many aspects as may be:

- Food additives (CIAA, Codex Alimentarius GSFA)
- Pesticides (Codex Classification of Foods and Feeds, CCPR)
- Contaminants (Codex Classification for Contaminants and Toxins, GSC)
- EC Common Nomenclature, PRODCOM (Eurostat), World Trade, Organization, ...
- Global Product Classification (GS1 GPC, GSDN Food and Beverage Extension)
- European Food Groups (Cost Action 99/EFCOSUM) and EFSA Food Categorization (Concise European Food Consumption Database)
- Food Composition Databases (EuroFIR classification)[14,5].

And many other classifications

At the European level can be highlighted:

Eurocode 2 food classification: To serve as a standard instrument for nutritional surveys in Europe and to serve the need for food intake comparisons[15,5].

EFG European Food Groups includes 33 groups: The European Food Groups (EFG) classification system was developed, as a project of COST Action 99/ Eurofoods, in an attempt to evaluate the level of food description and classification that would permit international comparisons of the results of available food consumption and food availability surveys. In order to formulate the EFG system, several classification schemes used for recording food intake at the international and national classification schemes were compared: International - FAO Food Balance Sheet, WHO GEMS/ FOODS regional diets, DAFNE classification system for HBS data, and Eurocode 2 core classification (levels 1 and 2); National - French National Food Consumption Survey (1999), Dutch National Food Consumption Survey (1998), and British National Food Survey. In the process of comparing food intake data from various European countries, it became evident that such comparisons are feasible only when results are expressed at the raw ingredient level. Since the DAFNE classification system groups food items at the raw level, it was one of the international classification schemes used to create the EFG food grouping system[16,5].

CIAA and EUROFIR food classification. These terms are for classification only[15].

FoodEx2 - In an effort to introduce standardized food nomenclature across pan-European data collection activities, a Working Group including EFSA staff and external experts was established to develop a suitable .Food classification and description system FoodEx 2, new system of classification and coding of foods that allow the use of consumption data from different countries of the EU[17,5].

In the EU, there is no requirement regarding the collection of data on food consumption of individual character. However, there are national dietary surveys in many European that provide valuable information for use in national policies and are critical for assessing the nutritional status countries. Among the national surveys in countries of the European Union carried out in recent years are:

Germany (14–80 years old, 2008)
Austria (18-65 years old, 2008)
Finland (25-74 years old, 2008)
France (3-79 years old, 2007)
Ireland (>18 years old, 2008)
Holland (7-69 years 2010)
UK (>1.5 years old, 2010)[18].

Spain

Bases previously discussed can be used to meet food consumption in Spain, but also find specific sources for the country.

Different valuable dietary surveys have been conducted in Spain. Briefly, the first Food Consumption Survey was performed in 1956 under the National Health Survey. Among them:

INE (National Statistics Office),**The Household Budget Survey (HBS):** the survey provides annual information on the nature and destination of consumption expenses, as well as on a range of features relating to household living conditions.

Consumption expenses refer both to the monetary flow into the home for paying for specific final consumption goods and services, and to the value of goods received for self-consumption, self-supply, payment in kind, free or subsidized food and rent of the dwelling in which the household lives (where it is owned or it is granted by other households or institutions). Expenses are recorded at the time of acquisition, irrespective of whether payment is in cash or in instalments.

The sample size is approximately 24,000 households per year. Each household remains in the sample for two consecutive years, with half of the sample renewed each year.

Since its implementation in 1958, there has been an alteration in the different types of surveys that tried to collect the information needed at each moment.

The survey provides estimates of annual consumption for the entire country and the Autonomous Communities, and of consumption in physical amounts of certain food goods for the country as a whole[19].

The HBS has representativeness by municipalities, geographic, population, basket, shopping areas, establishments, for items, price trends should be similar to the rest of the items they represent, should be consumed regularly, easily observable prices with reasonable assurance of continued market.

The choosing criteria the establishments is the most frequented and largest sales volume in each establishment cannot pick up on the same day, more than one price per item and an establishment should not concentrate a large number of observations prices. The sample establishments are not part restricted and should provide continuity of sales items. The classification used to collect expenses is COICOP, which is the national adaptation of the international classification used by Eurostat for budget surveys (COICOP/HBS), and which is structured in twelve groups:

Items are added into subclasses, these classes, subsequently into subgroups, and last subgroups into groups.

The structure consists of 12 categories or groups, 37 subgroups, 79 classes and 126 subclasses, which include a total of 489 items. The number of items has been changing since the beginning, in 1936 the basket was between 95 and 139 items[19].

The results of this survey can be accessed through the INE websitehttp://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t25/p458&file=inebase.

The processing of data from this survey gave rise to National Food and Nutrition Survey (ENNA 1, 2 and 3) which includes the conversion into energy and nutrients from food purchased in households the Spanish population[20].

Ministry of Agriculture, Food and Environment MAGRAMA: **Food Consumption Panel:**

The Food Consumption Panel, conducted for over 25 years (since 1987) by the Ministry of Agriculture, Food and Environment MAGRAMA, has as one of its goals the study of food consumption in households and commercial establishments and social restoration in Spain and represents a very detailed food shopping map in Spain[21].

The sample size in 2013 was 12,000 households which daily pointed their shopping with an optical reader. The choice of this sample is random with a two-stage method. In the first stage, survey points were selected based on population size for each of the regions. In the second, the collaborators is selected on each of the chosen points.

In 2011, there was a change census which was first used the panel to show food consumption data from the year 2013. In that year coexisted both censuses. The extra-household panel consumption was modified in 2012, showing weight/year, volume/year, units/year per capita, to show the impact of the different products studied and the evolution of these.

As in the previous case the results of the consumer panel can be viewed on the website of MAGRAMA (http://www.magrama.gob.es/es/alimentacion/temas/consumo-y-comercializacion-y-distribucion-alimentaria/panel-de-consumo-alimentario/ultimos-datos/).

Traditionally MAGRAMA published their results in an annual text entitled "Food in Spain" which was annexed a section that valued nutritionally diet "diet food", but since 2000 the data have been treated since the Spanish Nutrition Foundation who has done various publications:

- Nutritional Assessment of the Spanish diet according to the Food Consumption Panel.
- Consumption evaluation enriched / fortified foods in Spain through the Food Consumption Panel (Spanish Nutrition Foundation. FEN).

National Health Survey of Spain by the Ministry of Health Social Services and Equality in collaboration with the National Institute of Statistics, collects health information on the resident population in Spain (21,508 households). It is a five-yearly research that allows to know many aspects of the health of citizens at national and regional level, and to plan and evaluate interventions in health care. Among the information collected is food consumption[22].

At national level, the current AECOSAN (Spanish Agency for Consumer Affairs, Food Safety and Nutrition) recently carried out:

ENIDE National Survey of Dietary Intake (2009-2010). AECOSAN has performed a nutritional assessment of the Spanish adult population, the objective was to determine food consumption in Spain and, more specifically, to determine the patterns of dietary intake in the Spanish adult population of both sexes[23].

ENALIA It is a food survey involving children and adolescents aged 6 months to 17 years of all the Autonomous Communities. It is an individual survey, which identifies the exact type and quantity of food consumed, which is essential to assess the nutrient intakes and for scientific research on exposure to other chemicals through food[24].

ENALIA 2 (children and adolescents / adults and elderly).This study, continuation of Enalia survey, includes adults between 18 and 75 years from all the Autonomous Communities and a group of pregnant women. It is an individual survey, which identifies the exact type and quantity of food consumed, which is essential to assess the nutrient intakes and for scientific research on exposure to other chemicals through food[25].The latter updates the reference survey in Spain in children and young people (2-24 years old) called **EnKid**, and the **AVENA** study, a multicenter nutrition survey in Spanish adolescents**.**

At regional level, other valuable and representative surveys have been conducted: The Region of Madrid, which has been recently updated by FEN (**ENUCAM** Survey of eating habits in the Region of Madrid), Catalonia (**ENCAT.** Evaluation of the state nutritional of Catalan towns 2002-2003. Evolution of eating habits and

food consumption and nutrient Catalonia (1992-2003)), the Region of Valencia (**Nutrition Survey of the Community of Valencia**), Galicia (**Survey on the eating habits of the adult population of Galicia,** 2007), Basque Country (**EINUT-1**. Nutrition Survey of the Autonomous Community of the Basque Country), Andalusia (Nutritional Survey of Andalusia) among others.

Other surveys are **UNINUT** (Study of eating habits and lifestyles of Spanish university), **ANIBES** (Study on Energy Balance in Spain) (in press), **ENRICA:** Survey of Nutrition and Cardiovascular Risk in Spain, Survey **of Child Nutrition Community of Madrid, SUN Project, PREDIMED**: "Effects of the Mediterranean diet on the primary prevention of cardiovascular diseases".

Perspectives

European Food Safety Authority (EFSA) promotes and coordinates data collection standardized food consumption and is working with Member States to develop harmonized surveys on food consumption in the European Union. Thereby the studies are comparable, allowing use at the community level. Thus, EFSA has published a guide to conducting surveys in a European context and other documents on classification and coding of foods in addition to the database "Comprehensive Food Consumption Database" with detailed data from individual surveys in several countries EU.

In this sense it has been developed "The food classification and description system FoodEx 2", a new system of coding and classification of foods that allow the use of consumption data from different EU countries for different purposes: risk assessment, nutritional studies and any other needs that may arise in the future.

The EU Menu is a project aimed at harmonizing data collection on food consumption across Europe. Co-ordinated by EFSA, and in close co-operation with Member States, it will allow the collection of comparable food consumption data across the EU.

Although national dietary surveys are already conducted in many European countries, it is not currently possible to carry out EU-wide analysis or country-to country comparisons on food consumption due to differences in how information is collected.

The EU Menu aims to provide standardized information on what people eat in all countries and regions across the EU. It will allow more efficient and accurate exposure assessment and support risk managers in their decision making on food safety. It will also assist policy makers in assessing the nutritional status of population groups, setting targets regarding healthy diets and monitoring progress over time. In that way, the EU Menu will contribute to safer food and healthier diets for European citizens.

In February 2010 members of EFSA's Advisory Forum signed a declaration supporting the establishment of a pan-European food consumption survey[26].

Applications

Knowledge of food consumption either national, household or individual surveys may have numerous applications: identifying food patterns and sources of nutrients, explore the quality of food and evaluate the dietary exposure to risks. It can also be used to meet the nutritional status, although it is not possible to have an accurate idea exclusively from dietary data, the results of the dietary survey do allow to have intakes on the possibility that a person or a group at risk for having inadequate intakes of energy and nutrients.

Once you know food consumption, it becomes intake of energy and nutrients through the databases of food composition and subsequently compared with those recommended for judge the adequacy of dietary intakes. In addition, the calculation of different indices of quality diet can have a global idea of nutritional status, judged by diet and these data can be used to update the current recommendations of energy and nutrients.

Transform food consumption into energy and nutrients to assess the nutritional status of the individual or group study is the most used application from the FEN.

The sources used by FEN are HBS and more recently Food Consumption Panel. Both provide food consumption in weight/year, volume/year or units/year measurements and transformation in g/person per day is done: discounting an inedible portion all food and performing a "correction" in the case of vegetable oils (-20%).

The first was used for the realization the "National Study of Nutrition and Food (ENNA 1, 2 and 3)" and the second "Food Diet" (MAGRAMA), "Nutritional Assessment of the Spanish diet according to consumer Panel (2008 and 2012)" and "Evaluation of the use of enriched/fortified in Spain through food Consumption Panel". table I provides a summary of the characteristics of both sources and table II shows the strengths and weaknesses.

Recommendations

There are numerous sources of information on food consumption, but the diversity of designs and data collection methods of the studies difficult to evaluate and compare them. Therefore, it is necessary to work at European level in the standardization of data collection, since the complexity both individually and in population nutrition studies, requires models agreed questionnaires and tools to facilitate the identification of information collection, for this is precisely comparable across countries.

In relation to individual surveys should continue working on the use of technologies to easily record the intake at the time of consumption.

Regarding the Spanish data, the coexistence of two databases (Food Consumption Panel, HBS) contribu-

Table I
The Household Budget Survey (HBS) and Food Consumption Panel

	Food Consumption Panel	*The Household Budget Survey*
Beginning	1987	1939
Frequency	Annual	Quarterly
Population scope	Households, hotel industry/restoration and institutions	Family homes, commercial areas and establishments (excluding institutions)
Geographic scope	Peninsula, Baleares y Canarias	National territory
Sample size	12.000 households	24.000 households
Criteria breakdown	Geographic areas and autonomous Household socioeconomic status Habitat size Family size Age and activity of responsible for purchasing Presence ofchilds	Autonomous Community Province Size of the municipality Household composition Household Income Level Educational level of the main breadwinner Quarter Survey
Number of foods	130 food staples disaggregated in 416 inputs (quantified by weight)	187 foods 66 (quantified by weight)

Table II
Strengths and weaknessesin the Household Budget Survey (HBS) and Food Consumption Panel

	Strengths	*Weaknesses*
Food Consumption Panel	Consolidate Annual Representative Includes a large amount of food Reliable information Allows study the evolution of feed Data freely distributable	No studied Ceuta and Melilla Since 2011 not collect kg / person per day in catering and institutions Food waste is not evaluated Not allowed value according to age or sex Database change Not include energy and nutrient content (unless Evaluation of food consumption and dietary patterns in Spain by the Food Consumption Survey) Provides information on a group but does not show the real value of each individuals
Household Budget Survey	Consolidate Quarterly Weighted Includes database changes International classification (COICOP) Representative Entire country Reliable information Allows study the evolution of feed Data freely distributable	No includes all food quantified by weight They exclude institutions Food waste is not evaluated Not allowed value according to age or sex Not include energy and nutrient content (unless National Food and Nutrition Survey ENNA) Provides information on a group but does not show the real value of each individuals

tes greatly to show a good picture of feeding of the Spanish people, however, as in Europe, it must follow a set of coding and classification of unique foods, to make better comparisons.

References

1. Cotier, J and Morón, C. Hojas de balance de alimentos. EN: FAO. Producción y manejo de datos de composición química de alimentos en nutrición. FAO, 1997.
2. Food and agriculture organization of the united nations. FAO. Report of the conference of FAO. First Session. FAO. Quebec: 1945.
3. Manjarrés, LM. Métodos para precisar la recolección de la ingesta dietética. *Perspectivas en nutrición humana* Vol. 9, nº 2, pp. 155-163, Julio-diciembre 2007.
4. Food and agriculture organization of the united nations.FAOSTAT.http://faostat3.fao.org/faostat-gateway/go/to/browse/FB/FB/E. [Accessed: September 29, 2014].
5. Beltrán, B; Carbajal, A; Cuadrado, C; García-Diz, L; Goñi, I; Sierra, JL. Encuestas dietéticas. Innovadieta. https://www.ucm.es/innovadieta/encuestas. [Accessed: December 17, 2014].
6. Food and agriculture organization of the united nations. FAO. Evaluación nutricional. Perfiles Nutricionales. http://www.fao.org/food/evaluacion-nutricional/perfiles-nutricionales-por-paises/es/. [Accessed: September 29, 2014].
7. DAFNE. Data Food Networking. DAFNE. 2005. http://www.nut.uoa.gr/dafnesoftweb/. [Accessed: September 29, 2014].

8. Elmadfa I, Freisling H, Nowak V, Hofstädter D, Hasengger V, Ferge M, et al. *European Nutrition and Health Report* 2009. Vienna: Karger, 2009.
9. EFCOSUM group.European Food Consumption Survey Method. Final Report. Report, TNO Nutrition and Food Research. 2001.
10. EFCOVAL. Efcoval. European Food Consumption Validation. 2010. http://www.efcoval.eu/. [Accessed: Septiembre 29, 2014].
11. PANCAKE- Pilot study for de assessment of nutrient intake and food consumption among kids in Europe. The PANCAKE consortium. EN-339. Supportin Publications, 2012.
12. Del Pozo, S, Cuadrado, C and Moreiras, O.Cambios con la edad en la ingesta dietética de personas de edad avanzada. Estudio Euronut-SENECA 348-352. *Nutr Hosp* 2003, Vol. XVIII (6).
13. Danish Food Informatics. LanguaL™ - the International Framework for Food Description. 2014. http://www.langual.org/. [Accesed: September 30, 2014].
14. Ireland, J and Moller, A. Strengths and weaknesses of existing food classification systems. Parma, Italy: EFSA Scientific Colloquium on Food Classification, 2010.
15. Unwin, I; Møller, A. EUROCODE 2. Food Coding System. Febrero 3, 1999. http://www.ianunwin.demon.co.uk/eurocode/index.htm. [Accessed: September 30, 2014].
16. The LanguaL 2013 Thesaurus- Systematic Display. 2013. http://www.langual.org/langual_thesaurus.asp?termid=A0690&haschildren=True&owner=A0356&openstr=A0724_A0361_00000_B1564_J0107_A0356_A0690_A0289. [Accessed: September 30, 2014].
17. EFSA (European Food Safety Authority). The food classification and description system FoodEx 2 (draft-revision 1). Supporting Publications 2011:215. [438 pp.]. Available online: http://www.efsa.europa.eu/en/supporting/pub/215e.htm.
18. AECOSAN. Agencia Española de Consumo Seguridad Alimentaria y Nutrición.Consumo de alimentos en Europa http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/alimentos_europa.shtml. [Accessed: September 29, 2014].
19. Estadística, INE. Instituto Nacional de. INEbase. 2014. http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t25/p458&file=inebase. [Accessed: october 1, 2014].
20. Varela, G;Moreiras, O; Carbajal, A; Campo, M. Estudio nacional de nutrición y alimentación 1991 (ENNA 3). Tomo I. Ingesta de alimentos, energía y nutrientes. Adecuación a las ingestas recomendadas. Tendecias de consumo en los últimos 30 años. s.l. : Instituto Nacional de Estadística. 1995. (ISBN: 84-260-2973-6). 352 pp.
21. Del Pozo, S; García, V; Cuadrado, C; Ruiz, E; Valero, T; Ávila, JM; Varela, G. Valoración de la dieta española de acuerdo al panel de consumo alimentario. Fundación Española de la Nutrición. 2012.
22. Ministerio de Sanidad, Servicios Sociales e Igualdad. Encuesta Nacional de Salud de España 2011/12. 2014. https://www.msssi.gob.es/estadEstudios/estadisticas/encuestaNacional/encuesta2011.htm. [Accessed: October 2, 2014].
23. AECOSAN. Agencia española de consumo seguridad alimentaria y nutrición. ENIDE: Encuesta nacional de ingesta dietética (2009-2010). Resultados sobre datos de consumo. 2014. http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enide.shtml. [Accessed: october 2, 2014].
24. AECOSAN. Agencia Española de Consumo Seguridad Alimentaria y Nutrición. "ENALIA" Encuesta Nacional de Alimentación en la poblaicón Infantil y Adolescente. 2014. http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enalia.shtml. [Accessed: october 2, 2014].
25. AECOSAN: Agencia Española de consumo seguridad alimentaria y nutrición. "ENALIA 2" Encuesta Nacional de Alimentación en la poblaicón adulta y mujeres embarazadas. 2014. http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enalia_2.shtml. [Accessed: october 2, 2014].
26. EFSA (European Food Safety Authority). EU Menu. http://www.efsa.europa.eu/en/datexfoodcdb/datexeumenu.htm. [Accessed: November 5, 2014].

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):38-45
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Dietary assessment methods: dietary records

Rosa M. Ortega[1], Carmen Pérez-Rodrigo[2] and Ana M. López-Sobaler[1]

[1]*Departamento de Nutrición y Bromatología I (Nutrición), Facultad de Farmacia, Universidad Complutense de Madrid.*
[2]*Fundación FIDEC, Bilbao. Spain.*

Abstract

Dietary records or food diaries can be highlighted among dietary assessment methods of the current diet for their interest and validity. It is a prospective, open-ended survey method collecting data about the foods and beverages consumed over a previously specified period of time. Dietary records can be used to estimate current diet of individuals and population groups, as well as to identify groups at risk of inadequacy. It is a dietary assessment method interesting for its use in epidemiological or in clinical studies.

High validity and precision has been reported for the method when used following adequate procedures and considering the sufficient number of days. Thus, dietary records are often considered as a reference method in validation studies. Nevertheless, the method is affected by error and has limitations due mainly to the tendency of subjects to report food consumption close to those socially desirable. Additional problems are related to the high burden posed on respondents. The method can also influence food behavior in respondents in order to simplify the registration of food intake and some subjects can experience difficulties in writing down the foods and beverages consumed or in describing the portion sizes. Increasing the number of days observed reduces the quality of completed diet records. It should also be considered the high cost of coding and processing information collected in diet records. One of the main advantages of the method is the registration of the foods and beverages as consumed, thus reducing the problem of food omissions due to memory failure. Weighted food records provide more precise estimates of consumed portions.

New Technologies can be helpful to improve and ease collaboration of respondents, as well as precision of the estimates, although it would be desirable to evaluate the advantages and limitations in order to optimize the implementation.

(*Nutr Hosp* 2015;31(Supl. 3):38-45)

DOI:10.3305/nh.2015.31.sup3.8749

Key words: *Dietary record method. Food intake. Energy and nutrient intakes. Diet assessment. Validity.*

MÉTODOS DE EVALUACIÓN DE LA INGESTA ACTUAL: REGISTRO O DIARIO DIETÉTICO

Resumen

Entre los métodos de evaluación de la ingesta actual los métodos de registro, o diario dietético, destacan por su interés y fiabilidad. Se trata de un método prospectivo en formato abierto que recoge información sobre los alimentos y bebidas consumidos en un periodo de tiempo previamente especificado. Permite estimar la ingesta actual de individuos y de grupos de población, así como identificar grupos con riesgo de presentar ingestas inadecuadas. Se trata de un método de interés para su aplicación en estudios epidemiológicos o en el ámbito clínico.

Cuando se aplica de forma adecuada, y se considera el periodo de estudio suficiente, tiene alta validez y precisión, por lo que es un método de análisis de la ingesta considerado a menudo como referencia en estudios de validación. No obstante, está sujeto a errores y limitaciones, derivadas principalmente de la tendencia del sujeto a declarar consumos de alimentos próximos a los que considera correctos. Otros problemas son la alta demanda de colaboración, posible inducción de modificaciones en la dieta de los sujetos analizados o dificultades para describir los alimentos y/o porciones consumidas. Cuanto mayor es el número de días de observación de la dieta disminuye la calidad de los registros completados. También hay que considerar el elevado coste de procesado de la información. Entre las principales ventajas de este método destaca el registro de los alimentos y bebidas en el momento de su consumo, lo que reduce el problema de omitir alimentos por olvido. El registro por pesada permite estimaciones más precisas de las cantidades consumidas.

Las nuevas tecnologías pueden ser de gran ayuda para mejorar y facilitar el grado de colaboración de las personas estudiadas, así como la precisión de las estimaciones, aunque sería deseable evaluar sus ventajas y limitaciones para optimizar su utilización.

(*Nutr Hosp* 2015;31(Supl. 3):38-45)

DOI:10.3305/nh.2015.31.sup3.8749

Palabras clave: *Registro dietético. Consumo de alimentos. Ingesta de energía y nutrientes. Análisis de la ingesta. Validez.*

Correspondence: Rosa M Ortega.
Departamento de Nutrición, Facultad de Farmacia,
Universidad Complutense de Madrid.
Plaza Ramón y Cajal s/n, 28040-Madrid.
E-mail: rortega@ucm.es

Introduction

Nutrient intake modulates the health and functional capacity, both in the short and in the long term, so the assessment of dietary intake can be of interest for different purposes in a variety of contexts. There are different methods to assess the intake of food and beverages, which can be used to analyse dietary intake from a prospective or a retrospective point of view. The dietary record (DR) highlights among the prospective methods[1-4].

Description and types of DR

A DR is a prospective open-ended assessment method where the subject records all the foods and beverages consumed over a specific period of time. Depending on the aim/hypothesis of the study it is often requested to record detailed information about food preparation methods, ingredients of mixed dishes and recipes, and even the brand name of commercial products, depending on the aim/hypothesis of the study. DR collects data by subjects' self-record at the time the food are eaten, thus minimizes reliance on a subjects' memory. To obtain accurate data, however, respondents must be trained before participating in the survey. Therefore, a high level of motivation is required and relatively large burden is passed onto the respondents[3,4].

Although completely free open-forms could be used, it is very useful to apply a structured format, with additional questions for each eating occasion about name of the meal (breakfast, lunch...), time/hour, location, company, menu, menu ingredients and weight of food consumed, in order to record all details of the meals. The DR forms should be formatted so they provide adequate space for individuals to record all the data. A pocket notebook could be provided in order to record consumption away from home[1].

Close-ended forms have been developed also. These included a specific list of foods so that the interviewee indicates which food has been consumed[5,6]. Additionally, a check list can be developed to assess particular "corefoods" that contribute substantially to intakes of some nutrients, or to track food contaminants. Estimates of portion size can also be asked, either in an open-ended manner or using categories[5,7].

The DR can also be filled in by someone else. This procedure is often used in the case of children, or in the case of people with trouble scoring/recording the food consumed[5]. Theoretically, the food is recorded at the time of each eating occasion, but it is not always necessary to be performed in a paper form. Dictaphones have been used and hold special promise for low literacy groups[4]. Also camera and mobile telephone technology have been used to capture food and meal images, especially in disabled people[8].

Training of interviewees

The interviewee should receive a specific training to be able to describe in a proper way all the foods and the quantities used, including the name/brand of the consumed food, recipes of dishes, method of preparation or cooking, and also the portion sizes. In some studies this training is reinforced with a subsequent contact with the interviewee after the first day of registration, in order to check the registered data and resolve any doubts. At the end of the recorded period, again a trained interviewer should review the DR with the respondent, to clarify any doubts and to probe the possible consumption of forgotten foods[5].

Description of consumed portion sizes

The amount of food consumed should be recorded as precisely as possible. The amounts of each food can be measured with a kitchen weighing scale or using household measures (e.g., bowls, cups, and glasses). Alternatively, portion sizes can be estimated in reference to standard household measures, or using three-dimensional food models, or two-dimensional aids such as photographs[5].

When interviewee uses common household measures to describe the quantities consumed, it is important that coders receive a specific training to transform those amounts described in grams of consumed food. Some software commonly used to process DR (such as DIAL)[7] includes a comprehensive database with information on weight of common household measures or each food (tablespoon, cup, cup, plate...) which facilitates the DR processing (Fig. 1).

In the subsequent revision of DR, and to clarify questions about the amounts described, it may be useful to employ food models representing dishes or foods of different sizes. In this case the interviewee points out which is the closer model to the portion size consumed.

Length of the DR

It is important to establish the number of days to be monitored in the DR and also whether they must be consecutive or not. Ideally the controlled period should be long enough to provide reliable information on usual food consumption (a minimum of 3 days is required), but this has to be balanced against the likelihood of poor compliance if the recording period is too long[1,2].

Traditionally the most common DR monitors the diet for 7 consecutive days. This time period allows for collecting information about the diet minimizing bias related to the day of the week. It also helps collect information about those foods eaten less often.

However, it was found that recording periods of more than 4 consecutive days are usually unsatisfac-

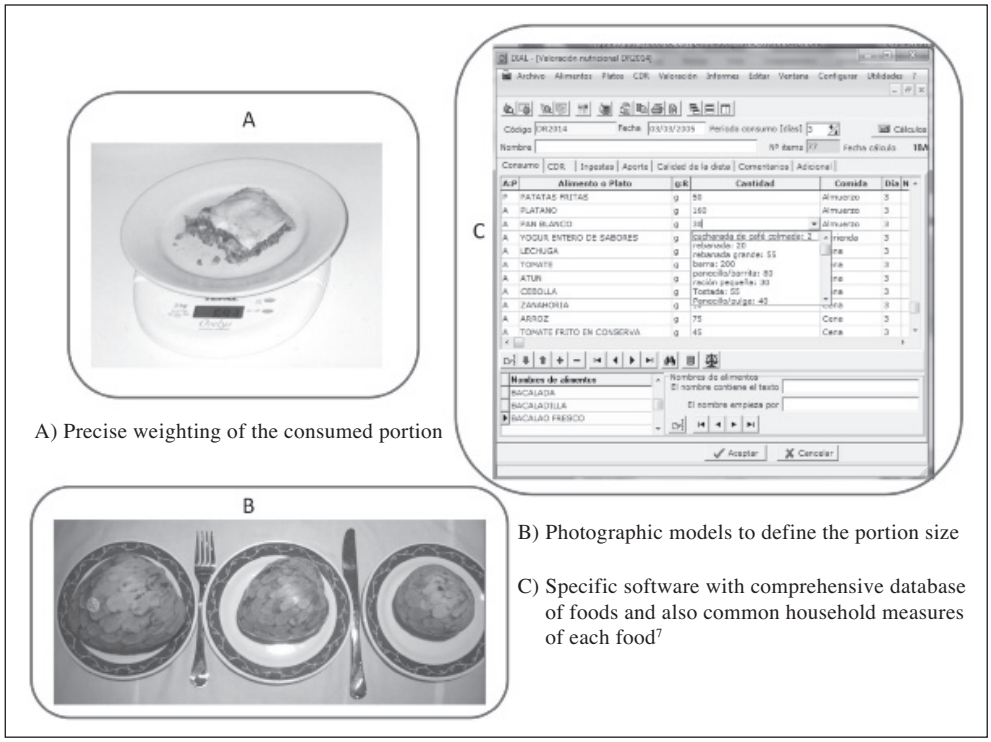


Fig. 1.—Some useful aids in obtaining accurate information and tabulation of DR.

tory, as reported intakes decrease due to respondent fatigue, and individuals who do comply may differ systematically from those who do not. Additionally, it has been noted that many respondents develop the practice of filling out the record retrospectively rather than concurrently[5], so the validity of the collected information decreases in the later days of a 7-day recording period, in contrast to collected information in the earlier days[2,5].

Because of these limitations, shorter DRs are often used[1,2]. The optimal number of days to collect more reliable data depends largely on the nutrient subject of attention or the sample size of the study. As a general rule, the smaller the number of individuals, the greater must be the number of controlled days. When the aim is to have an overview of a group, the main interest is that the sample is large enough to be representative, instead of increasing the number of monitored days. However, it is likely that foods eaten less than once or twice a week may not be captured in 3-4 days DR. In these cases it may be useful to supplement the collected information with a brief Food Frequency Questionnaire (FFQ) or a propensity questionnaire.

On the other hand, because the foods and amounts consumed on consecutive days of reporting may be related (e.g., leftovers and eating more one day and less the next day), it may be advantageous to collect non consecutive single-day records in order to increase representativeness of the individual's diet[5].

Regardless of the length of the DR, it is desirable to control both working and weekend days, in order to get a better picture of the overall diet. In some studies it is also required to collect information in different seasons, bearing in mind that the availability and preparation of food changes with the season. For these reasons, the date of every single day included in the DR should be recorded[1,2,5].

Strengths of DR

The main advantage of DR is its potential to collect accurate quantitative information on individual foods consumed during the registration period[5]. Because of the quality of the dietary data, the DR is considered to be the gold standard of the dietary methods, and is often used as a reference in calibration or validation studies using other less involved and less expensive methods.

The weighed DR provides more precise estimates of intakes for individuals which can be related to health indices, such as nutritional status measured by blood analytes.

As foods are recorded as consumed, it is the less likely to omit / forget food items and moreover, the description thereof is more accurate. Also, as the amount consumed is recorded when eaten, valuable and accurate information about **exact portion size** is provided, and therefore it does not rely on portion size estimation. In this sense, the weighed DR remains an invaluable tool for estimations of actual portion sizes, which are needed for estimated methods.

When the DR uses open-ended questions, **abundant information can be collected** and analyzed in various aspects. For example, if sufficient days are recorded, **day-to-day variation** can be studied. Also

detailed descriptions of the foods consumed and all eating occasions are provided.

It can be easily applied to diverse groups with a **wide range of eating** habits and may be used to estimate the average intake of a certain population[3,5], since provides excellent estimates for energy, nutrients, foods and food groups.

DR is **suitable in metabolic and intervention studies.** In the latter case, the weighed DR is very useful for knowledge of dietary habits and change[5,9]. Recording, by itself, is an effective weight loss technique[5].

Disadvantages of the method

The diet is highly variable from day to day, so that the recorded data can represent the **current diet** but not the **usual diet**. But usual intake can also be estimated if repeated.

Those who have to fill in DR (interviewees or caregivers) must be both motivated and literate (if done on paper), which potentially limits their application in some population groups (people with low literacy, immigrants with low language skills, children, elderly, people with difficulty writing ....). Because the DR require high cooperation limits the type of population that can be applied, and this could compromise the generalizability of the results to the wider population[5] (table I).

The method could be **complex for some individuals**, particularly for those who do not cook regularly and are not familiar with weighing foods (table I).

The knowledge that foods and amounts must be recorded and the demanding task of doing it may **alter the dietary behaviors** the tool is intended to measure. Previous studies have found some respondents may improve their dietary habits unintentionally through self-reflection. However, some respondents may alter their diet intentionally to avoid a burden on responses or even choose to not report actual intake[3].This can affect both the types of food chosen and the quantities consumed[5,10,11]. This effect is a weakness when the aim is to measure typical dietary behaviors[5].

In weighing DR a kitchen scale must be used, and this could bias the study because:

- The subject has to have a scale (participation bias).
- If researcher provides scales, the study may become more expensive (scales must be purchased) and the interviewee has to be specifically trained in the use of the scale and how to record clearly the food consumed (if the weight is just food, or dish, if the weight is complete food or edible part ...).
- The interviewee has to spend more time (in addition to completing the registration he/she must weigh), and always carry with him/her the scale (problem with meals outside the home).
- Can modify further dietary habits and food choices can be more influenced by the fact the subject is more conscious his/her diet will be analyzed.

Unless electronic devices are used to carry out the DR, the coding of an open-ended format requires a considerable effort of data collection, entry and analyses. Each DR requires a careful review by a trained research staff. All food and mixed dishes consumed according to the detailed description of the respondent must be coded and matched with the most appropriate food of the food composition database. Portion size must be converted in its actual weight. These processes tend to be time-consuming, laborious, and highly expensive to implement[3]. In this regard it is of great interest to use software enabling enter information using common spellings of foods, as it helps to save time in the coding of food[5].

Given that it is a method that requires significant personal and economic resources, and the substantial individual burden on the participant, the DR is **not practical for large population studies.**

As DR measures the current intake, and is mainly focused on short-term intake, it cannot be used in studies looking at associations of **past diet** with health outcomes, or when **long-term dietary** exposure is of interest, as when chronic diseases are investigated. In this latter case, to measure average intakes, multiple DRs are needed. Then, the repeated measurement not only requires a lot of resources and time but also the survey repetition can also influence a respondents' diet.

Table I
Characteristics, strengths and limitations of dietary record

Method	*Subjective measure using open-ended, self- administered questionnaires*
Collected data	Actual intake information throughout a specific period
Strengths	Provides detailed intake data; no interviewer required; no recall bias
Limitations	Relatively large respondent burden (literacy and high motivation required, possible under-reporting); expensive and time-consuming; multiple days required to assess usual intake; possible changes to diet if repeated measures
New techniques	Required technology: Software, internet, PDA, mobile phone, application, etc.
Strengths of new techniques	Standardized, real-time data collection possible; likely reduce time and cost; improve feasibility
Limitations of new techniques	Inherent bias related to self-report; requires participant training on how to use the technology

Modified from Shim et al.[3].

Table II
Overall methodological drawbacks of dietary records

Topic	*Issue detected*
Type of foods	Addition /omission of foods influenced by social desirability
Amount of food	Underestimation increases as consumed portion sizes increase Overestimation increases as consumed portion sizes decrease Personal views on specific food items can affect reported portion sizes above or under real intake
Age of the studied population	*Elderly:* Inadequate cognitive function Ignoring food ingredients / difficulties to describe portion sizes Cultural and physical difficulties to write down the food items and portion sizes consumed.
	Children: Ignoring what they consume or the ingredients in food preparations Difficulty to write down the food items consumed
Problems affecting individuals or groups in the studied population	*Obese people, ill people, sport people:* May avoid reporting the consumption of foods being advised not to eat or those considered to help them in their success (sport people)

Sources of error

In DR, and in prospective methods in general, the respondent can voluntarily modify his/her diet because is aware of being studied, so the main source of error is the tendency to declare foods and portion sizes closer to those considered to be socially desirable (table II)[1,2].

Some of the sources of error due to the respondent are:

- Motivation, memory, communication skills.
- Perception (type and amount): over or underestimation.
- Forgetting of certain foods (bread, fats, oils, liquids, snacks, alcohol).
- Personal characteristics (age, sex, obesity).

Other sources of error are linked to the field workers:

- Insufficient training to instruct individuals on undertaking a DR.
- A non-deep check of the DR when collected.
- Mistakes in DR tabulation and food codification.

Other possible sources of error must be considered, such as errors in the food database regarding to the nutritional composition of foods, or the recommended intakes, etc.

Validation of DR data

DRs are often regarded as the "gold standard" against which other dietary methods could be assessed[4]. But, anyway, and considering that the DR has drawbacks as other dietary methods, DR must be validated using a more precise method with a different source of error.

Compared to other methods, like FFQ or 24-hour recall method, that are more practical and cost-effective for application in large epidemiological studies, a 4-day DR provides a stronger estimate of energy and protein intake, as has been shown using doubly labelled water method and 24-hour urinary nitrogen[12]. In the EPIC-Norfolk cohort a 7-day DR showed closer data than FFQs to biomarkers for protein, potassium, and sodium consumptions[13], at least for absolute intakes[14].

Biochemical markers (measured in blood / urine) are helpful to analyze the relationship between a derived DR nutrient intake and the corresponding biochemical index of nutritional status. A positive correlation between the nutrient intake and the serum data helps to validate the DR as reliable. But this correlation is more expected when the nutrient intake is inadequate and the likelihood for reaching optimal blood levels is lower. When the nutrient intake is adequate, a higher intake not always is related to increased blood levels. In this scenario (higher intakes) urine parameters could be more useful if a correlation between the dietary intake and the output of water-soluble nutrients or nitrogen catabolites is expected. Another possibility to test the validity of the DR, is to find significant differences in biochemical parameters between subjects with lower or higher intakes than those recommended[1,2].

Specific biochemical markers have been used as a surrogate to measure the dietary intake of selected nutrients or dietary components in epidemiological studies[3,15-17]. Previous studies have found these markers to be highly correlated with dietary intake levels, free of a social desirability bias, independent of memory, and not based on subjects' ability to describe the type and quantity of food consumed[3,18]. Thus, these biochemical markers may provide more accurate measures than dietary intake estimates do. However, a number of biomarkers have been known to provide integrated

measures reflecting their absorption and metabolism after consumption, and they are also affected by disease or homeostatic regulation, thus their values cannot be translated into the subject's absolute dietary intake. Moreover, the results based on biomarkers cannot provide dietary recommendations to modify a subject's dietary habit. Thus, direct assessment of dietary intake may be more informative than biomarkers are[3,18,19].

Comparing energy intake (EI) to energy expenditure (EE), measured or estimated, in people with stable weight, also helps to identify those subjects more prone to under/overestimation of energy intake. The discrepancy between EI and EE, measured with the formula: (EE-EI) x 100 / EE, provides a percentage of probable underestimation (with positive values) or overestimation (with negative values)[20-22].

Using IOM equations[23] for estimating EE, and EI estimated with DR, some studies found a low discrepancy (-0.64 ± 10.5%)[24]. But this mean figure, that suggests that EI is very close to EE, also highlights that a significant percentage of the studied population underestimated their energy intake[2,20].

There is a general tendency to declare foods and amounts closer to those considered as more correct, and some of the factors that can contribute to this discrepancy may be mentioned:

- **Being overweight or obese**: the underestimation of energy intake increases with increasing weight[20,21].
- **Concern about the body weight/shape**: those people who wish to lose weight, even without excess body weight, show a tendency to underestimate their energy intake to a greater extent than people who do not have this concern about weight, regardless of actual BMI[20,22].

Studies that follow individuals for 30 days to see if their weight was stable[22], show that the underestimation of energy intake was higher in those individuals who reported a desire of losing weight, and this discrepancy increases as BMI does. On the other hand, in those who didn't want to lose weight, a slight overestimation of the intake was observed, which increased as BMI decreases, especially when a weight deficit was observed[22] (Fig. 2).

Having in mind that a high percentage of the population suffer from overweight / obesity[25] or are concerned with the control of body weight (even being normalweight)[26], these data must be taken into account when conducting dietary studies, in order to improve the accuracy of the data.

Another point to consider is that people tend to report food intakes close to those they consider more appropriate or healthy. Sometimes misconceptions and preconceived ideas can make that some foods considered unhealthy (rightly or wrongly) were recorded/declared in lower amounts than true intakes, while higher amounts of top rated foods can be declared/recorded (like fruits, vegetables ....)[27].

New Technologies and DR

In recent years, new technologies have been developed in order to increase feasibility of DR in large epidemiological studies. Their main purposes are to reduce the respondents' burden, improve accuracy and making multiple self-administrations possible. Several reports have discussed their use and implications in clinical and research settings[3,28,29].

Although many of these techniques are still under development, they have made great strides. Admittedly, the development of both software and hardware implies a great investment in the early stages of the research. But once developed, these new technologies can reduce costs and resources. Collecting and handling data are easier, consistency of data improves, and the collection of data and calculation of dietary intakes in real-time allows respondents to focus on dietary assessment[3] (table I).

Some of the applications developed allow the user to use their mobile phone to enter his/her dietary intake.

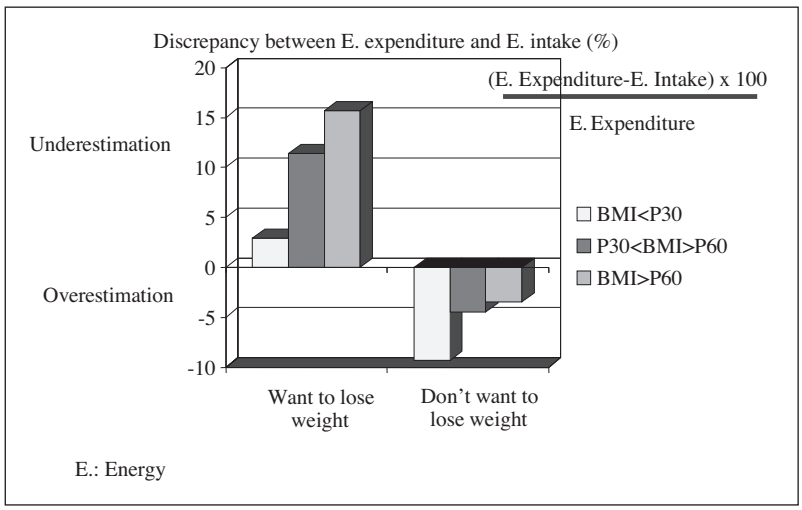


Fig. 2.—Influence of BMI and concern about body weight on discrepancy between Energy intake and Expenditure with DR[22].

The subject can record the diet by matching each food from a predefined list of foods and beverages, and the amount consumed can be recorded choosing pre-defined portion sizes[3,30]. In other studies the subject's camera and mobile phone were use to report everything that was consumed by sending images before and after eating to the research staff[3]. Specific software can be used to estimate the weight of portion sizes. Some internet-based technologies include online tutorials, digital images for food identification and portion-size estimation, and audio files. Thus, those with low literacy can easily complete the survey, and researchers can collect real-time data[3].

While the feasibility of multiple DRs in epidemiological studies has considerably improved with the help of these new technologies, there are still some limitations. First, these methods may be difficult to apply to certain populations who are not familiar with innovative technologies or new devices: Training subjects on how to use these technologies and use a computer including accessing the internet is also required[3]. Second, technical problems in data transfer, storage, battery life, and other concerns must be improved. And third, these new methods do not seem to overcome the methodological problems related to self-report. Subjects still had difficulties in recalling and reporting their diet, underreported in repeated assessments, and altered their food intake when they knew the survey date in advance[28]. For these reasons, open-ended methods with new technologies have not yet been widely implemented as the primary assessment tool in epidemiological studies[3] (table 1).

Conclusions

Dietary intake is difficult to measure, and any single method cannot assess dietary exposure perfectly. But DR is one of the most reliable methods of dietary assessment. However it is important to consider some aspects such as the length of the study (≥ 3 days, ≤7 days), the format of the questionnaire, the motivation of participants, their training in completing the questionnaire, and the need of trained staff. New technologies are very promising and probably in a near future will facilitate the implementation of DR in large epidemiological studies. Some interviewee's factors must be considered as they can influence the accuracy of DR: The BMI, weight/shape concerns, or the subject's perception of certain foods can be useful to detect / fix bugs. Despite being a reliable method, it is always advisable to validate the DR results with biochemical markers or analyze the discrepancy between intake / energy expenditure.

References

1. Ortega RM, Requejo AM, López-Sobaler AM. Questionnaires for dietetic studies and the assessment of nutritional status. In: Nutriguia. Manual of Clinical Nutrition in Primary Care. Ortega RM, Requejo AM. Eds.. Madrid: Complutense ed., pp. 456–67, 2009.
2. 2.-Ortega RM, Requejo AM. Encuestas nutricionales individuales. Criterios de validez. *Nutrición y Obesidad* 2000;3(4): 177-85.
3. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. *Epidemiol Health* 2014;36:e2014009.
4. Thompson FE, Byers T. Dietary assessment resource manual. *J Nutr* 1994;124(11 Suppl): 2245S-317S.
5. Thompson FE, Subar AF. Dietary assessment methodology. In: Nutrition in the Prevention and Treatment of Disease. Coulston AM, Boushey CJ, Ferruzzi MG eds. Amsterdam: Elsevier, Academic Press, pg. 5-46, 2013.
6. Lillegaard IT, Loken EB, Andersen LF. Relative validation of a pre-coded food diary among children, under-reporting varies with reporting day and time of the day. *Eur J Clin Nutr* 2007;61 (1):61-8.
7. Ortega RM, López-Sobaler AM, Andrés P, Requejo AM, Aparicio A, Molinero LM. 2013. DIAL software for assessing diets and food calculations (for Windows, version 3.0.0.5). Department of Nutrition (UCM) & Alceingeniería, S.A. Madrid, Spain. (http://www.alceingenieria.net/nutricion.htm).
8. Ptomey LT, Willis EA, Goetz JR, Lee J, Sullivan DK, Donnelly JE. Digital photography improves estimates of dietary intake in adolescents with intellectual and developmental disabilities. *Disabil Health J* 2014 Aug 29. pii: S1936-6574(14)00139-3.
9. Glanz K, Murphy S, Moylan J, Evensen D, Curb JD, Improving dietary self-monitoring and adherence with hand-held computers: a pilot study. *Am J Health Promot* 2006; 20: 165-70.
10. Kristjansdottir AG, Andersen LF, Haraldsdottir J, de Almeida MD, Thorsdottir I, Validity of a questionnaire to assess fruit and vegetable intake in adults. *Eur J Clin Nutr* 2006; 60:408-15.
11. Aranceta Bartrina J, Pérez Rodrigo C. Diario o registro dietético. Métodos de doble pesada. En: Serra Majem L, Aranceta Bartrina J (eds.). Nutrición y Salud Pública. Métodos, bases científicas y aplicaciones (2.ª edición). Barcelona: Elsevier, pp.158-67. 2006.
12. Prentice RL, Mossavar-Rahmani Y, Huang Y, et al.. Evaluation and comparison of food records, recalls, and frequencies for energy and protein assessment by using recovery biomarkers. *Am J Epidemiol* 2011;174:591-603.
13. Day N, McKeown N, Wong M, et al. Epidemiological assessment of diet: a comparison of a 7-day diary with a food frequency questionnaire using urinary markers of nitrogen, potassium and sodium. *Int J Epidemiol* 2001;30(2):309-17.
14. Willett W. Commentary: dietary diaries versus food frequency questionnaires—a case of undigestible data. *Int J Epidemiol* 2001;30(2):317-9.
15. Ortega RM, López-Sobaler AM, Andrés P, Rodríguez-Rodríguez E, Aparicio A, Perea JM. Folate status in young overweight and obese women: changes associated with weight reduction and increased folate intake. *Int J Nutr Sci Vitaminol (Tokio)* 2009; 55(2):149-55.
16. Ortega RM, López-Sobaler AM, Ballesteros-Arribas JM, Pérez-Farinós N, Rodríguez-Rodríguez E, Aparicio A, Perea JM, Andrés P. Estimation of salt intake by 24-hour urinary sodium excretion in a representative sample of Spanish adults. *Brit J Nutr* 2011; 105:787-94.
17. Rodríguez-Rodríguez E, Navia B, López-Sobaler AM, Ortega RM. Vitamin D in overweight/obese women and its relationship with dietetic and anthropometric variables. *Obesity* 2009;17-(4): 778-82.
18. Potischman N. Biologic and methodologic issues for nutritional biomarkers. *J Nutr* 2003;133 Suppl 3:875S-80S.
19. Wild CP, Andersson C, O'Brien NM, Wilson L, Woods JA. A critical evaluation of the application of biomarkers in epidemiological studies on diet and health. *Br J Nutr* 2001;86 Suppl 1:S37-S53.
20. Ortega RM, Quintas ME, Sánchez-Quiles MB, Andrés P, Requejo AM, Encinas-Sotillos A. Infravaloración de la ingesta energética en un colectivo de jóvenes universitarias de Madrid. *Rev Clin Esp* 1997;197: 545-9.

21. Ortega RM, Redondo MR, Zamora MJ, López-Sobaler AM, Andrés P, Encinas-Sotillos A. Balance energético y perfil calórico en ancianos obesos o con sobrepeso en comparación con los de peso normal. *Med Clin (Barc)* 1995;104: 526.
22. Ortega RM, Requejo AM, Quintas ME, Sánchez-Quiles B, López-Sobaler AM, Andrés P. Estimated energy balance in female university students: differences with respect to body mass index and concern about body weight. *Internat J Obes* 1996; 20: 1127-9.
23. Institute of Medicine, Food and Nutrition Board. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids (Macronutrients). National Academy Press, Washington, DC, 2005.
24. Ortega RM, González-Rodríguez LG, Navia B, Perea JM, Aparicio A, López-Sobaler AM. Ingesta de calcio y vitamina D en una muestra representativa de mujeres españolas; problemática específica en menopausia. *Nutr Hosp* 2013;28(2):306-13.
25. Ortega RM, López-Sobaler AM, Pérez Farinós N. Associated factors of obesity in Spanish representative samples. *Nutr Hosp* 2013; 28(5):56-62.
26. López-Sobaler AM, Ortega RM, Aparicio A, Bermejo LM, Rodríguez-Rodríguez E. La preocupación por el peso corporal. Estudio a nivel nacional sobre errores y hábitos relacionados con el tema, En: Nutrición en población femenina: Desde la infancia a la edad avanzada. Ortega RM ed. Madrid: Ediciones Ergón. pp. 39-49. 2007.
27. Mena MC, Faci M, Ruch AL, Aparicio A, Lozano MC, Ortega RM. Diferencias en los hábitos alimentarios y conocimientos, respecto a las características de una dieta equilibrada, en jóvenes con diferente índice de masa corporal. *Rev Esp Nutr Comunitaria* 2002; 8(1): 19-23.
28. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim SP, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *Int J Epidemiol* 2012;41:1187-203.
29. Stumbo PJ. New technology in dietary assessment: a review of digital methods in improving food record accuracy. *Proc Nutr Soc* 2013; 72:70-6.
30. Lieffers JR, Hanning RM. Dietary assessment and self-monitoring with nutrition applications for mobile devices. *Can J Diet Pract Res* 2012;73:e253-e260.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):46-48
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

What and how much do we eat? 24-hour dietary recall method

Gemma Salvador Castell[1], Lluis Serra-Majem[2,3,4] and Lourdes Ribas-Barba[3,4]

[1]Agència de Salut Pública de Catalunya. Departament de Salut. Generalitat de Catalunya. [2]Instituto de Investigaciones Biomédicas y Sanitarias, Universidad de Las Palmas de Gran Canaria. [3]CiberOBN, Instituto de Salud Carlos III, Madrid. [4]Fundación para la Investigación Nutricional, Parc Científic de Barcelona. España.

Abstract

Diet, along with lifestyle factors, is an important determinant of the health status of an individual and of a community. Dietary assessment at the population level provides us with key information on the frequency and distribution of possible inadequate diets and/or nutritional status. It is also useful as input into the elaboration of food and nutrition policies aiming to improve dietary habits and the health status of a community. This article reviews the characteristics, advantages and limitations of the 24-hour dietary recall method (24hDR), which is one of the most widely used tools in nutrition epidemiology to identify food, energy and nutrient intake in national nutrition surveys, cross-sectional studies, clinical trials and cohort studies as well as in the evaluation of individual dietary intake and Total Diet assessment. To reduce the key factors associated with bias, the importance of previously trained interviewers is highlighted, as well as the role of support materials and the contribution of novel technologies.

(*Nutr Hosp* 2015;31(Supl. 3):46-48)

DOI:10.3305/nh.2015.31.sup3.8750

Key words: *Nutrition assessment. 24-Hour dietary recall. Nutrition surveys. Dietary surveys.*

**¿QUÉ Y CUÁNTO COMEMOS?
MÉTODO DE RECUERDO 24 HORAS**

Resumen

La dieta, junto con los estilos de vida, es un importante factor determinante del estado de salud del individuo y de la comunidad. La valoración de la ingesta dietética a nivel poblacional nos aporta información básica para conocer la frecuencia y la distribución de posibles desequilibrios dietéticos y/o nutricionales, así como para orientar el diseño de políticas nutricionales dirigidas a mejorar los hábitos alimentarios y los niveles de salud de una comunidad. En este artículo se revisan las características, ventajas y limitaciones del método de recordatorio dietético de 24h (RD24h), uno de los métodos mas ampliamente utilizados en epidemiologia nutricional para determinar ingesta de alimentos, energía y nutrientes, en encuestas nutricionales a nivel nacional, en estudios transversales, ensayos clínicos, estudios de cohortes y también en valoraciones individuales y en evaluación de Dieta Total. Se destaca la importancia, para reducir los principales puntos de sesgo, de la formación de los encuestadores, las herramientas de apoyo y las aportaciones de las nuevas tecnologías.

(*Nutr Hosp* 2015;31(Supl. 3):46-48)

DOI:10.3305/nh.2015.31.sup3.8750

Palabras clave: *Valoración nutricional. Recordatorio dietético de 24h. Encuestas nutricionales. Encuestas dietéticas.*

Diet is an important risk factor for a wide range of chronic diseases. The assessment of dietary intake at the population level provides us with important information on the frequency and distribution of inadequate diets and/or nutritional status, as well as guiding the design of population based interventions targeting the improvement of dietary habits at the community level. Obtaining reliable data on food consumption (identifying the intake of energy and nutrients) is a key factor and necessary tool in health promotion and the prediction of disease risk, particularly for cardiovascular diseases[1,2,3].

Correspondence: Gemma Salvador Castell.
Dietista-Nutricionista. Agencia de Salut Pública de Catalunya.
Departamento de Salut. Generalitat de Catalunya.
C/ Roc Boronat, 81-95. 08005 Barcelona, Spain.
E-mail: gemma.salvador@gencat.cat

A wide variety of dietary survey methods exists, with each one presenting a series of advantages and disadvantages that must be taken into consideration based on the study aims, the degree of precision needed and the available resources. Of the numerous methods available, the 24-hour dietary recall (24hDR) is one of the most utilised. In Spain, as well as in many other countries, the majority of nutrition surveys, particularly in the adult population, have employed this method, in combination with others (food frequency questionnaires, diet records, diet history, etc.). The 24hDR has also been systematically utilised in the different editions of the NHANES (National Health and Nutrition Examination Study) in the USA. [4,5,6]

The 24hDR is a subjective, retrospective method that requires a direct face to face or telephone interview, and can also be self-administered using computer programmes (on line retrospective self-reported data). The

method consists of precisely recalling, describing and quantifying the intake of foods and beverages consumed in the 24 hour period prior to, or during the day before the interview, from the first intake in the morning until the last foods or beverages consumed at night (before going to bed or later, in the case of those who get up at midnight and eat and/or drink something). The information should describe the type of food and its characteristics (fresh, precooked, frozen, canned, preserved), the net quantity consumed, method of preparation, commercial brands, sauces, dressings (type of fats and oils used),condiments, liquids, multivitamin supplements and food supplements, as well as the time and place of consumption (at home, away from home), etc.

The information is collected via an open or predetermined questionnaire (paper format or digital format employing specially designed reliable software). The method requires diverse support instruments (examples of dishes, volumes and household measures, drawings, photographic models, three dimensional models, detailed recipe ingredients, etc). The estimated average interview time can vary between 20 to 30 minutes.

The method requires a trained interviewer and the elaboration of a detailed and thorough procedure protocol. A minimum of 2 to 5 24hDRs are needed (in common practice 2-3 are usually collected) to establish usual intake, depending on the study objectives, the nutrients of interest and the sample size, and optimally administered in distinct times of the year so as to capture seasonal variation. In population based studies, interviews are usually conducted in the subject's home and as such, facilitates the quantification of household measures, collect brand names and corroborate the composition of multivitamin/mineral and food supplements[7,8].

The quality of information obtained is largely determined by 5 factors

1. *Interviewee:* age, sex, educational and cultural level, degree of involvement with food and nutrition, recall capacity, etc.
2. *Interviewer:* prior training, specific training for the project, level of commitment, past experience.
3. Quality and adequacy of *interview support tools*.
4. *Coding system and computer software* that allows for the conversion of collected information into data that can be utilised in statistical programmes.
5. *Food and beverage composition table*.

Recommendations and procedures to reduce error and bias

- Conduct interviews over seven days of the week (including weekends).
- Prefer direct face to face interviews (ideally in the subject's home).
- In our setting, it's important to detect seasonal intake (seasonal production and food preparation).
- Essential to have a thorough interviewer training programme and interview protocol. (know how to motivate the subject interviewed to participate, ask questions, assist in recall with influencing responses, identify quantities, foods and ingredients with agility, resolve unexpected events, etc.).
- Have available/elaborate interview support materials: photographs of various serving sizes, volumes, plates, foods, ingredients of recipes prepared food. The use of different sized models improves the reported answers.
- Data collection via specialised software that directly carries out codification improves the quality of information obtained, allows for increasing the number of food codes, reduces possible errors linked to manual coding and also saves time.
- Utilization of novel technologies for data collection and processing.

Advantages of the 24hDR[7,8,9]

- Being a retrospective method, the subject's usual consumption is not altered.
- Serial recalls can estimate the usual intake at the individual as well as the community level.
- It's administration does not require so much time.
- High precision (capacity of the method to produce similar measures or results when the tools is repeatedly administered in one context). Improves with increased numbers of 24hDR administered in the same study subject (2-3 times).
- Elevated response rate.
- Can be administered to low literacy populations (via direct interviews).
- Validity (the extent to which the method or instrument measures what is supposed to be measured and is exempt of systematic errors). It is considered as a valid instrument for the assessment of energy and nutrients. To validate 24hDRs, the use of food records or other methods such as direct observation of actual consumption (weighed food records, doubly labelled water, filming, cameras, etc.) as well as certain biochemical parameters.

Limitations of the 24hDR

- Extensive dependence on the recent memory of the study subject (not recommended for the elderly or subjects less than 12 years of age).
- Depends on interviewer capacity for describing ingredients, food preparation, dishes.

– One single 24hDR does not estimate usual intake. The planning of 2 or more 24hDRs complicates field work.
– Requires well trained interviewers, both for face to face and telephone administered interviews.
– Difficulty in precisely estimating "What, How and How much".
– In general the 24hDR tends to underestimate intake, especially in the elderly and children.
– "Flat slope syndrome" or the tendency to overestimate low intakes and underestimate high intakes
– The quality of data obtained via interviews is frequently limited by the lack of adequate food composition databases.

Digital vs. Paper & Pencil instruments

The majority of the latest generation technologies offer interesting tools for the process of evaluating dietary intake in epidemiological studies[10,11, 12, 13, 14, 15].

The following highlights the advantages of digital instruments:

– Reduces interviewer bias.
– Reduces the time and cost during field work.
– Data collection and codification in real time.
– Automatic calculation of daily intake.
– Highly economic options of capturing food intake: on line (computer, tablets and smart-phone) tools.

New technologies provide us with many possibilities for assessing dietary intake in individuals and groups, although they are not free of certain limitations.

– High cost of programme design in the initial phases.
– High costs related to the acquisition of laptops, tablets...(online programmes and smart-phone applications are the most economic options).
– Methods are difficult to apply to certain population groups that aren't familiar with new technologies and are of a given age.
– Requires access to internet.
– The method still depends on the subject's recall capacity.

Conclusion

Dietary intake is difficult to measure and a single instrument that is optimal for all settings does not exist as each method has its pros and cons or practical difficulties that should be taken into account when selecting the instrument to be administered. Despite the interesting progress and the incorporation of innovative technology into dietary assessment methods, we still remain with some of the same flaws. As such, research groups continue recommending the combination of diverse methods, with the 24hDR being the most thorough, comprehensive and complete instrument that exists to date[7,8,10].

References

1. Michels KB. Nutricional epidemiology-past, present, future. *Int J Epidemiol* 2003; 32:486-88.
2. Baik I, Cho NH, Kim SH, Shin C. Dietary information improves cardiovascular disease risk prediction models. *Eur J Clin Nutr* 2013;67: 25-30.
3. Streppel MT, Sluik D, van Yperen JF, Geelen A, Hofman A, Franco OH, et al. Nutrient-rich foods, cardiovascular diseases and all-cause mortality: the Rotterdam study. *Eur J Clin Nutr* 2014;68:741-747.
4. Serra Majem L, Ribas L, Salvador G, Castell C, Serra J, Jover J, et al. Avaluació de l'estat nutricional de la població catalana (2002-2003). Evolució dels hàbits alimentaris i del consum d'aliments i nutrients a Catalunya (1992-2003). Barcelona: Departament de Salut 2005.
5. Tur Martí JA, Obrador Adrover A. Libro Blanco de la alimentación en las Islas Baleares. Estudio de Nutrición de las Islas Baleares ENIB (1992-2000). *Revista de Ciencia* 2002;27-8.
6. National Health and Nutrition Examinations Survey. Disponible en : www.cdc.gov/nchs/nhanes.htm3.
7. Serra Majem Ll, Ribas Barba L. Recordatorio de 24 horas. En: Serra Majem LL, Aranceta Bartrina J, editores.Nutrición y salud pública: Métodos, bases científicas y aplicaciones.2 ed. Barcelona: Masson; 2006. P.168-177.
8. Martin-Moreno JM, Gorgojo. L. Valoración de la ingesta dietética a nivel poblacional mediante cuestionarios individuales: sombras y luces metodológicas. *Rev Esp Salud Pública* 2007-;81 (5): 507-518.
9. SUVIMAX. Portions alimentaires. Manuel photos pour l'estimation des quantités. Paris, SU.VI.MAX-Candia-Polytecnica; 1994.
10. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiol Health Volume: 36, Article ID: e2014009, 8 pages http://dx.doi.org/10.4178/epih/e2014009
11. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim SP, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *Int J Epidemiol* 2012;41:1187-1203.
12. Shriver BJ, Roman-Shriver CR, Long JD. Technology-based methods of dietary assessment: recent developments and considerations for clinical practice. *Curr Opin Clin Nutr Metab Care* 2010;13:548-551.
13. Schatzkin A, Subar AF, Moore S, Park Y, Potischman N, Thompson FE, et al. Observational epidemiologic studies of nutrition and cancer: the next generation (with better observation). *Cancer Epidemiol Biomarkers Prev* 2009;18:1026-1032.
14. Long JD, Littlefield LA, Estep G, Martin H, Rogers TJ, Boswell C, et al. Evidence review of technology and dietary assessment. *Worldviews Evid Based Nurs* 2010;7:191-204.
15. Hercberg S. Web-based studies: The future in nutritional epidemiology (and overarching epidemiology) for the benefit of public health? *Prev Med* 2012;55:544-545.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):49-56
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Food Frequency Questionnaires

Carmen Pérez Rodrigo[1], Javier Aranceta[2], Gemma Salvador[3] and Gregorio Varela-Moreiras[4,5]

[1]Fundación FIDEC. Bilbao. [2]Departamento de Medicina Preventiva y Salud Pública. Universidad de Navarra. [3]Agència de Salud Pública de Catalunya. Departamento de Salut. Generalitat de Catalunya. [4]Department of Pharmaceutical and Health Sciences, Faculty of Pharmacy, CEU San Pablo University; Madrid. [5]Spanish Nutrition Foundation (FEN), Madrid (SPAIN).

Abstract

Food Frequency Questionnaires are dietary assessment tools widely used in epidemiological studies investigating the relationship between dietary intake and disease or risk factors since the early '90s. The three main components of these questionnaires are the list of foods, frequency of consumption and the portion size consumed. The food list should reflect the food habits of the study population at the time the data is collected. The frequency of consumption may be asked by open ended questions or by presenting frequency categories. Qualitative Food Frequency Questionnaires do not ask about the consumed portions; semi-quantitative include standard portions and quantitative questionnaires ask respondents to estimate the portion size consumed either in household measures or grams. The latter implies a greater participant burden. Some versions include only close-ended questions in a standardized format, while others add an open section with questions about some specific food habits and practices and admit additions to the food list for foods and beverages consumed which are not included. The method can be self-administered, on paper or web-based, or interview administered either face-to-face or by telephone. Due to the standard format, especially closed-ended versions, and method of administration, FFQs are highly cost-effective thus encouraging its widespread use in large scale epidemiological cohort studies and also in other study designs. Coding and processing data collected is also less costly and requires less nutrition expertise compared to other dietary intake assessment methods. However, the main limitations are systematic errors and biases in estimates. Important efforts are being developed to improve the quality of the information. It has been recommended the use of FFQs with other methods thus enabling the adjustments required.

(*Nutr Hosp* 2015;31(Supl. 3):49-56)

DOI:10.3305/nh.2015.31.sup3.8751

Key words: *Food habits. Dietary assessment. Error validity. Population studies.*

Correspondence: Carmen Pérez Rodrigo.
Fundación FIDEC.
Gurtubay s/n. 48010 Bilbao (Spain).
E-mail: carmenperezrodrigo@gmail.com

MÉTODOS DE FRECUENCIA DE CONSUMO ALIMENTARIO

Resumen

Los cuestionarios de frecuencia de consumo son herramientas ampliamente utilizadas en los estudios epidemiológicos que investigan la relación entre ingesta dietética y enfermedad o factores de riesgo desde comienzos de la década de los 90. Los tres componentes principales de estos cuestionarios son la lista de alimentos, la frecuencia de consumo y el tamaño de la ración consumida. La lista de alimentos debe reflejar los hábitos de consumo de la población de estudio en el momento en que se recogen los datos. La frecuencia de consumo puede preguntarse de forma abierta u ofreciendo categorías de frecuencia de consumo. Los cuestionarios cualitativos no preguntan por la ración consumida; los semi-cuantitativos presentan raciones estándar y los cuestionarios cuantitativos solicitan al encuestado que estime el tamaño de la ración consumida en medidas caseras o en gramos. Esta última opción supone un esfuerzo importante para el participante. Existen versiones exclusivamente cerradas en un formato estandarizado y otras que incorporan preguntas abiertas sobre algunos hábitos y prácticas alimentarias específicas y permiten añadir alimentos y bebidas consumidos que no están incluidos en la lista. Pueden ser auto-administrados, en papel o en soporte web, o bien mediante entrevista personal o telefónica. Por su formato estandarizado, especialmente los cerrados, y por la forma de administración, son un método con un alto rendimiento en términos de coste-efectividad que ha favorecido su extendido uso en grandes estudios epidemiológicos de cohortes y también con otros diseños. También el coste de codificación y proceso de la información recogida resulta menos costoso y requiere menos experiencia en temas nutricionales que otros métodos de evaluación de la ingesta. Sin embargo, presenta el inconveniente de incorporar errores sistemáticos y sesgos importantes, por lo que en la actualidad se buscan procedimientos para mejorar la calidad de la información y se recomienda utilizarlos junto a otros métodos que permitan realizar los ajustes necesarios.

(*Nutr Hosp* 2015;31(Supl. 3):49-56)

DOI:10.3305/nh.2015.31.sup3.8751

Palabras clave: *Hábitos alimentarios. Evaluación ingesta dietética. Error validez. Estudios poblacionales.*

Abbreviations

FFQ: Food Frequency Querstionnaire.
HDL: High Density Lipoprotein.
EPIC: European Prospective Investigation into Cancer and Nutrition.
NCI: National Cancer Institute.
DHQ: Diet History Questionnaire.

Introduction

Food Frequency Questionnaires (FFQ) are an advanced form of the diet history method aimed to assess habitual diet by asking how often and how much of selected food items or specific food groups included in a list are consumed over a reference period[1,2].

This method was originally designed to provide descriptive qualitative information about food-consumption patterns and later developed to provide nutrient information by specifying an average portion size. According to the interests of the researchers, FFQs may focus on the intake of specific nutrients, dietary exposures related to a certain disease, or comprehensively assess various nutrients[1-3].

Instruments including about 100 to150 food items take 20-30 minutes to complete and can be completed during an interview or can be self-administered. Thus, this method enables the assessment of long term dietary intake in a relative simple, cost-effective and time-efficient manner[2-4].

FFQs have been widely used in epidemiological studies investigating links between diet and disease. For this purpose it is more important to rank the intake of individuals in comparison to others in the population as high, medium, or low intake or as quantiles of the distribution of intake, than to determine the absolute intake[3,5,6]. In large epidemiological studies, data on diet from FFQs are compared with specific disease outcomes like cancer diagnosis, or risk factors for disease such as total or HDL-cholesterol levels. FFQs may also be used to identify food patterns associated with inadequate intakes of specific nutrients[3].

Components of FFQs

The main components of FFQs are the food list, the frequency of consumption in time units and the portion size consumed of each item.

The food list

The food list should be clear, concise, structured and organized in a systematic way[2,3]. It can be newly designed specifically for the study or can be modified from an existing instrument, but in that case it must be adapted and validated for the study population. FFQs may consist of an extensive or a relatively short list of food items. The foods included should be major sources of a group of nutrients of particular interest for the purpose of the study in which the instrument is to be used or foods which contribute to the variability in intake between individuals in the population. Additionally, should be foods commonly consumed in the study population[2,3,7,8] and reflect the food habits and common practices in that particular group. The length of the food list can range from about 20 to 200 items.

FFQs should be developed specifically for each study group and research purposes because diet may be influenced by ethnicity, culture, an individual's preference, economic status, etc. and the appropriateness of the food list is essential in this method of diet assessment[3,7-10].

FFQs can ask the respondent to report either a combined frequency for a particular food eaten both alone and in mixtures or separate frequencies for each food use[3,4,10]. However, people who is not used to cook or prepare meals may find it difficult to identify the ingredients involved in mixed dishes and it is likely to ignore how often consume certain food items.

Each quantitative FFQ must be associated with a food composition database to allow for the estimation of nutrient intakes for the either assumed or reported portion size of each food item included[3,11,12]. Such a database is created using quantitative dietary intake information from the target population to estimate the typical nutrient density of a particular food group category. A mean or median nutrient composition is estimated based on the individual food codes reported in a population survey. In this case, dietary analyses software, specific to each FFQ, is used to compute nutrient intakes for individual respondents[11,12].

Comprehensive FFQ instruments designed to assess total diet generally list more than 100 food items, many with additional portion size questions, requiring 30 to 60 minutes to complete. This raises concern about length and its effect on response rates. Balance between length and specificity of the food list is required[3,7-10,13]. Optically scanned instruments require the use of closed-ended response categories forcing a loss in specificity.

Frequency of consumption

Frequency of consumption is assessed by a multiple response grid or independent questions asking respondents to estimate how often a particular food or beverage is consumed[2,3]. Frequency categories range from never or less than once per month up to 6 or more times per day and respondents have to choose one of these options. Most FFQs collect data using nine possible responses. Various answer choices have been used to improve data quality and reduce the burden on the subjects[13].

The reference period for which the frequency of consumption is asked can be variable, but usually fo-

cuses over the past six months or the past year, but it is possible to ask about the past week or month depending on specific research situations. Even when respondents are asked about intake over the past year, some studies indicate that the season in which the questionnaire is administered influences reporting over the entire year[3,14].

The format of independent questions can be variable. Sometimes multiple choice questions are used, with an optimal number of 5 to 10 closed, exhaustive and mutually exclusive answer options (Fig. 1). In other cases, partly open answer formats are used, requesting for the frequency of consumption daily, weekly, monthly or yearly (Fig. 2). This allows for more flexibility and can contribute to reduce misclassification error[14,15].

For foods eaten seasonally, subjects are typically asked how frequently and over what duration they ate these seasonal foods. In some cases, the frequency of consumption is averaged for the whole length of the reference period. For frequently consumed foods such as coffee, answers are collected directly as an open-ended question in some FFQs.

Portion sizes commonly eaten

Qualitative FFQs do not ask respondents about portions commonly used. Conversely, quantitative FFQs try to estimate the portion size commonly used for each food item listed and then household measures, food models or other aids may be required for that purpose. Semi-quantitative FFQs include reference portion sizes and respondents are asked how often they consume the specified portion of a particular food or beverage or to assess their usual portion size based on a specified measure.

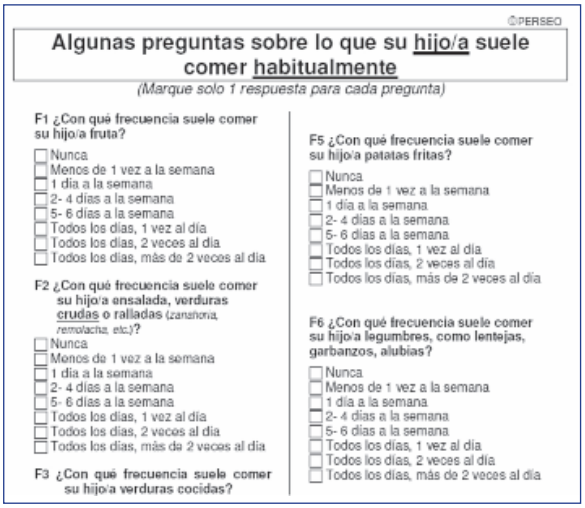
It is controversial whether FFQs should use portion size questions, since reporting portion sizes poses additional respondent burden[3]. Frequency has been reported to be a greater contributor than typical serving size to the variance in intake of most foods, but other authors cite small improvements in the performance of FFQs that ask the respondents to report a usual serving size for each food[13,15]. Some research has been conducted to determine the best ways to ask about portion size on FFQs. Nevertheless the marginal benefit of such information in a particular study may depend on the objectives of the study and population characteristics[13-17].

Some FFQs may include supplementary questions on cooking methods and specific types of fat, bread, milk and condiments or additions to foods such as salt. Brand name information may also be requested[8,13,15]. Other FFQs may have an open-ended section where respondents may record consumption of other foods not included on the food list. This ensures that the total diet of the individual is captured and may also help to identify those whose diet is very unusual, for whom the FFQ may not be appropriate.

Processing of data from food frequency questionnaires require some analytical decisions, such as how to handle missing data, either to assign null values or to assign the median value from those who did provide valid answers. Both approaches have been found equivalent in terms of introducing bias into relative risk estimates[3,18,19].

Uses

FFQs can be self-administered using paper or web-based formats, or interviewer administered, either face-to-face or telephone interview. Many food



©PERSEO

Algunas preguntas sobre lo que su hijo/a suele comer habitualmente

(Marque solo 1 respuesta para cada pregunta)

F1 ¿Con qué frecuencia suele comer su hijo/a fruta?

- ☐ Nunca
- ☐ Menos de 1 vez a la semana
- ☐ 1 día a la semana
- ☐ 2- 4 días a la semana
- ☐ 5- 6 días a la semana
- ☐ Todos los días, 1 vez al día
- ☐ Todos los días, 2 veces al día
- ☐ Todos los días, más de 2 veces al día

F2 ¿Con qué frecuencia suele comer su hijo/a ensalada, verduras crudas o ralladas *(zanahoria, remolacha, etc.)*?

- ☐ Nunca
- ☐ Menos de 1 vez a la semana
- ☐ 1 día a la semana
- ☐ 2- 4 días a la semana
- ☐ 5- 6 días a la semana
- ☐ Todos los días, 1 vez al día
- ☐ Todos los días, 2 veces al día
- ☐ Todos los días, más de 2 veces al día

F3 ¿Con qué frecuencia suele comer su hijo/a verduras cocidas?

F5 ¿Con qué frecuencia suele comer su hijo/a patatas fritas?

- ☐ Nunca
- ☐ Menos de 1 vez a la semana
- ☐ 1 día a la semana
- ☐ 2- 4 días a la semana
- ☐ 5- 6 días a la semana
- ☐ Todos los días, 1 vez al día
- ☐ Todos los días, 2 veces al día
- ☐ Todos los días, más de 2 veces al día

F6 ¿Con qué frecuencia suele comer su hijo/a legumbres, como lentejas, garbanzos, alubias?

- ☐ Nunca
- ☐ Menos de 1 vez a la semana
- ☐ 1 día a la semana
- ☐ 2- 4 días a la semana
- ☐ 5- 6 días a la semana
- ☐ Todos los días, 1 vez al día
- ☐ Todos los días, 2 veces al día
- ☐ Todos los días, más de 2 veces al día

Fig. 1.—Sample of a Qualitative Food Frequency Questionnaire with close-ended frequency range answer options used in PERSEO Project to assess diet of school children. Parents or guardians were invited to fill in the form.

C8 CUESTIONARIO FRECUENCIA DE CONSUMO

C8.1 Algunas preguntas sobre lo que suele comer Usted habitualmente. Piense en los alimentos y bebidas que ha consumido de forma habitual, como promedio, **en los últimos 12 meses**. Para las frutas, verduras y otros productos de consumo estacional, piense en su consumo en ese periodo del año. ¿Qué alimentos suele consumir de cada uno de los grupos que mencionamos a continuación? ¿con qué frecuencia lo consume como promedio? ¿Cómo diría que es la ración más habitual; diría que es grande, mediana o pequeña? ¿y durante el último año, la ha consumido con mayor frecuencia o cantidad, menos o igual que antes?

ALIMENTOS	¿COME?		SI LA RESPUESTA ES "SI COME"			TAMAÑO RACIÓN			Tendencia personal		
	SI	NO	VECES/ DIA	VECES/ SEMANA	VECES/ MES	P	M	G	+	=	
A] CARNES TOTAL	1	2				1	2	3	1	2	3
A.1 Pollo, pavo	1	2				1	2	3	1	2	3
A.2 Vacuno-ternera	1	2				1	2	3	1	2	3
A3. Vacuno buey	1	2				1	2	3	1	2	3
A.4 Cerdo	1	2				1	2	3	1	2	3
A.5 Cordero, cabrito	1	2				1	2	3	1	2	3
A.6 Conejo	1	2				1	2	3	1	2	3
A.7 Caza (corzo, jabalí, faisán...)	1	2				1	2	3	1	2	3
A.8 Vísceras (hígado, callos...)	1	2				1	2	3	1	2	3
A.9 Carne picada	1	2				1	2	3	1	2	3
A.10 Salchichas hamburguesas	1	2				1	2	3	1	2	3
A.11 Morcilla	1	2				1	2	3	1	2	3
A.12 Jamón York	1	2				1	2	3	1	2	3
A.13 Fiambre de pavo	1	2				1	2	3	1	2	3
A.14 Jamón serrano	1	2				1	2	3	1	2	3
A.15 Chorizo, salchichón, mortadela	1	2				1	2	3	1	2	3
A.16 Embutidos bajos en sal	1	2				1	2	3	1	2	3
A.17 Paté, foie gras	1	2				1	2	3	1	2	3
A.18 Otros tipos de productos cárnicos	1	2				1	2	3	1	2	3

Fig. 2.—Example of a semiquantitave Food Frequency and propensity Questionnaire with open-ended options to answer frequency used in ENPE study. Data collected in a face-to-face interview. P: pequeña (small); M: Media (medium); G: grande (large).

frequency instruments are designed to be self-administered and are either optically scanned paper version or web based. Require 30 to 60 minutes to complete depending on the instrument and the respondent and use a standard format, which reduces the time required for processing data.

For these reasons FFQs are one of the most commonly used retrospective methods in nutritional epidemiology, in a wide range of dietary study designs, as a research tool in examining the relationship between dietary intake and disease risk. Large-scale cohort studies[20-22] such as the European Prospective Investigation into Cancer and Nutrition (EPIC) have used the method[23]. In the EPIC study, the FFQ instrument was specifically adapted to each country[24,25]. However, large cohort studies can last for several decades and it is likely that food habits and practices change or new products enter within that period, and the food list may need to be revised and updated to be useful. These changes can make comparisons between observations at different time points in the study more difficult.

Despite FFQs can be designed to assess specific nutrients such as calcium or vitamin D, it is often required to assess the whole diet to obtain estimates of energy intake needed for adjustment and to estimate mis-reporting[3,6,18,19].

FFQs can also be used to identify food patterns associated with inadequate intakes of specific nutrients by using adequate statistical analysis.

Validity

FFQs should be evaluated for their accuracy before being used. Correlation coefficients ranging from 0.5 to 0.7 are considered moderate. Table I shows correlation coefficients ranges observed in a number of validation studies of FFQs since de ‘80s and the reference method used. Since FFQs are often designed to assess the ranking of intakes within a population, they cannot be relied on to produce reliable estimates of absolute intake. Over-estimation is common, particularly for

Table I
Selected validation studies of FFQs: population, items, procedure and reference method

Authors	*Population*	*Number of items*	*FFQ*	*Reference method*	*Number of days repetition*	*Correlations range*
Bohlscheid-Thomas, 1997	49 men, 55 women	104	Self	24-HR	12× in 1 y	
Boucher, 2006	166 women	126	Self	24-HR	2×	
Flagg, 2000	216 men, 223 women	114	Self	24-HR	4× in 1 y	
Jain, 2003	151 men, 159 women	166	Self	24-HR	3× in 1 y	
Johansson, 2002	96 men, 99 women	84	Interview	24-HR	10× in 1 y	
Katsouyanni, 1997	42 men, 38 women	190	Self	24-HR	12× in 1 y	
Kroke, 1999	75 men, 59 women	146	Self	DLW; 24-HR	14 d; 12× in 1 y	
Ocke, 1997	63 men, 58 women	178	Self	24-HR	12× in 1 y	0,42 energy - 0,69 alcohol
Pisani, 1997	47 men, 150 women	47	Self	24-HR	8–14× in 1 y	
Subar, 2001 (Block FFQ)	247 men, 267 women	106	Self	24-HR	4× in 1 y	
Subar, 2001 (DHQ)	501 men, 560 women	124	Self	24-HR	4× in 1 y	
Subar, 2001 (Willett FFQ)	254 men, 293 women	126	Self	24-HR	4× in 1 y	
Subar, 2003	261 men, 223 women	124	Self	DLW; 24-HR	14 d; 2× in 3 m	
van Liere, 1997	123 women	238	Self	24-HR	12× in 1 y	
Feunekes, 1993	95 men, 96 women	104	Interview	DH*	1 × 1 m	0,77 energy
Jain et al, 1982	50 women	69	Self	DH*	DH	0,50 cholesterol - 0,64 energy
Andersen, 2003	17 women	180	Self	DLW*	10 d	

Table I ***(cont.)***
Selected validation studies of FFQs: population, items, procedure and reference method

Authors	*Population*	*Number of items*	*FFQ*	*Reference method*	*Number of days repetition*	*Correlations range*
Andersen, 1999	125 men	180	Self	FR*	14 d in 5 w	
Barasi et al 1983	103 women	27	Self	FR	4 d	
Bingham, 1997	156 women	130	Self	FR	4 × 4 d in 1 y	
Block, 1990	102 women	60	Self	FR	2 × 7 d	
Block, 1992	85 men and women	98	Interview	FR	4 × 3 d in 1 y	
Brunner, 2001	457 men, 403 women	127	Self	FR	7 d	
Callmer, 1993	57 men, 50 women	250	Self	FR	6 × 3 d in 1 y	
Engle, 1990	16 men, 34 women	120	Self	FR	7 d	
Fidanza, 1995	11 men, 35 women	93	Self	FR	7 d	
Goldbohm, 1994	59 men, 50 women	150	Self	FR	3 × 3 d in 1 y	
Hartwell, 2001	16 men, 9 women	162	Self	FR	2 × 4 d	
Larkin, 1989	228 men and women	116	Interview	FR	16 d in 1 y	
Longnecker, 1993	64 men, 74 women	116	Self	FR	3 × 2 d or 2 × 2 d	0,77 energy 0,50 cholesterol - 0,64 energy
Mannisto, 1996	152 women	110	Self	FR	2 × 7 d in 3 m	
Martin-Moreno, 1993	147 women	118	Self	FR	4 × 4 d in 1 y	
McKeown, 2001	58 men, 88 women	130	Self	FR	2 × 7 d	
Munger, 1992	44 women	126	Self	FR	3 d	
Patterson, 1999	113 women	122	Self	FR	4 × 4 d	
Pietinen et al 1988	190 men	276	Self	FR	12 × 2 d in 6 m	
Pietinen et al 1988	190 men	44	Self	FR	12 × 2 d in 6 m	
Riboli, 1997	57 men, 50 women	350	Self	FR	6 × 3 d in 1 y	
Rimm, 1992	127 men and women	131	Self	FR	2 × 7 d in 6 m	
Schroder, 2001	44 men and women	157	Self	FR	3 d	
Stuff et al, 1983	40 pregnant women	105		FR	7 d	
Tjonneland, 1991	59 men, 85 women	92	Self	FR	2 × 7 d	
Willett, 1985	173 women	61	Self	FR	4 × 7 d in 1 y	
Willett, 1988	150 women	116	Self	FR	4 × 7 d, 3–4 y before	
Yarnell, 1983	119 men	54	Self	FR	7 d	

24HR: 24 Hour recall; FR: food record; DLW; Doubly labelled water; d: day; y: year. Modified from: Molag ML et al. 2007[13].

foods eaten less often or for foods perceived as 'healthy' such as fruit and vegetables. There is some evidence that over-estimation increase with the length of the food list[3,26-28].

Validation studies of various FFQs using biomarkers have found large underestimates of self-reported energy intake and some underestimation of protein intake. Correlations of FFQs and the biomarkers ranged from 0.1 to 0.5 for energy and from 0.2 to 0.7 for protein[26,28]. These results suggest that the measurement error associated with FFQs is larger than was previously estimated.

Various statistical methods employing measurement error models and energy adjustment are used to assess the validity of FFQs but also to adjust estimates of relative risks for disease outcomes[6,19]. Analyses comparing relative risk estimation from FFQs to dietary records in prospective cohort studies indicate that observed relationships using an FFQ are severely attenuated, thereby obscuring associations that might exist[29]. Controversy about error in FFQs has raised a debate considering alternative methods of collecting dietary data in large-scale prospective studies. In particular, the association between dietary fat consumption

and breast cancer is controversial and limitations of FFQs have been questioned[30-32].

For any study, the advantages and disadvantages of using FFQs compared to other dietary assessment methods should be carefully considered. It has been suggested that using a combination of methods, such as FFQ with dietary records or 24 hour recalls, or FFQ with biomarker levels provide more accurate estimates of dietary intakes than individual methods[4,33].

Several researchers have explored the use of cognitive interviewing techniques to increase the validity of self-reported data. Respondents are encouraged to verbalize their thought processes as they retrieve information from long-term memory to answer questions on the FFQ and then identify difficulties in formulating answers to specific questions, such as intake of seasonal foods or estimating portion sizes[34,35].

Qualitative study methods inform that several factors can influence individuals' perception of portion size, including; the type of food being considered, the role of a given food item in the meal (i.e. as a main or a side dish) and personal preference for the food. Cognitive research has also indicated that the level of grouping of foods can affect the recall of food intake and that respondents find it easier to respond to items when disaggregated, but this needs to be balanced with the disadvantages of longer food lists and the likelihood of over-estimation of intake and additional respondent burden[34,35].

Advantages and limitations of the method

Table II summarizes main pros and cons of Food Frequency Questionnaires. FFQs can be self-administered using paper or web-based formats thus reducing data collection costs. Paper forms are often designed to be optically scanned so that data can be entered and analyzed in a comparatively short period of time, often in an automated process, allowing dietary data on a large number of people to be collected relatively inexpensively. There is also less need for nutritional expertise in data entry.

Additional advantages of FFQs include low respondent burden compared to other methods. Frequency questionnaires assess habitual consumption over an extended period of time. More complete data may be collected if the FFQ is interviewer administered, but respondent bias may be less if self-administered. FFQs can be designed to focus on a particular group of foods or to assess the whole diet, including portion size estimates that can be used to obtain absolute nutrient intakes.

When an open section is included respondents can record consumption of foods which are not included on the food list. Sometimes include separate sections asking about consumption of seasonal foods, cooking procedures or additions to foods such as sauces and condiments.

The major limitation of the food frequency method is that it contains a substantial amount of measurement

Table II
Advantages and limitations of Food Frequency Methodology

Advantages	*Limitations*
Can be self-administered	Marked frequency of consumption and portion size may not represent usual intake of respondent Requires certain literacy and cognitive skills Often incomplete data is collected
Can be optically scanned	Effort and time consuming instrument design
Modest respondent burden	Depends on the respondents ability to describe diet
Relatively low cost for large scale studies	Relatively low cost for large scale studies
May be a better representation of usual dietary patterns than only a few days of observation	Particularly complex for children and elderly people
Instrument design can be based on population data	Memory of diet in the past may be biased by present diet
Does not influence dietary behaviour	Sometimes limited precision in estimates and quantifying food portion sizes
Classify individuals in food consumption categories	
Does not require deeply trained interviewers	
Easy to code and viable for automated processing if closed-ended	
Web-based administered improve the quality of collected data. Can add help aids, additional models and information.	Requires computer and internet access Requires web navigation skills Persist systematic errors inherent to the method Response bias Security risk for study data

error. Many details of dietary intake are not measured, and the quantification of intake is not as accurate as with recalls or records. Inaccuracies result from an incomplete listing of all possible foods and from errors in frequency and usual serving size estimations. A comprehensive list of all foods eaten cannot be included and reported intake is limited to the foods contained in the food list. Accurate reporting relies on respondent memory. Bias may be introduced with respondents reporting eating according to social desirability, thus resulting in over-estimation of certain foods and under-estimation of other items. A relatively high degree of literacy and numeracy skills are required if self-administered. Interviewers can help overcome this problem[3,4].

The serving size of foods consumed is difficult for respondents to evaluate in all assessment instruments, but attempting to estimate usual serving size in FFQs may be even more complex because a respondent is asked to estimate an average for foods that may have highly variable portion sizes depending on eating occasions. The use of small, medium and large to describe portion size may not have a commonly accepted meaning[34,35].

FFQs developed in one country or for a specific subpopulation are unlikely to be appropriate for use in another, since dietary habits differ. The same problem arises due to ethnical and cultural differences in a population.

Pre-prepared meals such as ready meals or take-away foods may not be easy for respondents to classify if the food list is based on more basic food categories, but grouping of foods into individual items may make answering some questions problematic. Validity can vary widely between foods and nutrients from the same FFQ

Recommendations and suggested improvements

Innovative FFQs are web-based. However, measurement errors in such instruments are most likely similar to those in conventional paper-based Food Frequency Questionnaires, suggesting that the underlying methodology is unchanged by the technology. New instruments such as the web-based version of the National Cancer Institute's (NCI) 124-item diet history questionnaire (Web-DHQ) include digital photographs to estimate portion sizes. Moderate-to-a-very good correlation has been assessed indicating reproducibility was observed between the NCI's Web-DHQ and its original paper version (Paper-DHQ)[15].

The strengths of these innovative alternatives include data consistency and completeness through technical requisites, particularly in larger, geographically dispersed or multi-centric study populations. . Innovative technological alternatives of the FFQs may have greater potential to overcome some of the completion difficulties that have been reported in the cognitive research about conventional paper-based FFQs. Implementing digital pictures, for example, may improve the food identification. Also, certain technical functionalities can facilitate the skipping to more tailored questions at individual level or provide explanations on how to answer questions appropriately[3,4,15].

It has been suggested that in addition to focusing attention on trying to measure nutrients, also formulate hypotheses in terms of dietary behaviors including questions about usual dietary practices. Such questions may be more easily and accurately recalled than the frequencies and portion sizes of a long list of foods[34,35].

When FFQs are interviewer administered, interviewers should be properly trained to conduct the interview and to provide adequate information to participants either if the interviews are conducted face-to-face or by telephone. Appropriate ways of asking the questions and recording the answers need to be considered, particularly for telephone interviews that require full attention through the whole duration of the questionnaire. When the respondents are children, elder or handicapped people, parents, guardians or carers have to be present.

Standardised operating procedures are required for data checking, cleaning and analysis.

Some large epidemiological studies have implemented short-term dietary assessment methods, either as reference calibration method in a sub-sample or as main dietary assessment method for the entire population, given the debate about the accuracy of FFQs in ranking the individuals according to their usual dietary intake because methodological limitations. There is cumulated evidence that repeated open-ended quantitative 24-hour dietary recalls or food records may outperform the FFQ in assessing accurately individual usual intake. The complementation of the repeated short-term quantitative measures with the non-quantitative information on usual consumption (e.g. from non-quantitative FFQs, defined as Food Propensity Questionnaires or FPQs) and/or biomarkers and integrated with statistical modelling, may yield more accurate individual usual dietary intake estimates[15]. This may particularly provide less biased estimates for the intake of infrequently consumed foods that are often missed in the short-term dietary measures.

References

1. Serra Majem Ll, Aranceta Bartrina J (eds). Nutrición y salud pública: Métodos, bases científicas y aplicaciones. 2 ed. *Barcelona: Elsevier- Masson* 2006.
2. Martin-Moreno JM, Gorgojo L.Valoración de la ingesta dietética a nivel poblacional mediante cuestionarios individuales: sombras y luces metodológicas. *Rev Esp Salud Pública* 2007; 81: 507-518.
3. Thompson FE, Subar AF. Dietary Assessment Methodology. In: Coulston A, Boushey C (eds). Nutrition in the Prevention and Treatment of Disease, 2nd ed. *Academic Press* 2008: pp 3-38.

4. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. *Epidemiol Health* 2014; 36: e2014009.
5. Willett WC, Hu FB. The food frequency questionnaire. *Cancer Epidemiol Biomarkers Prev* 2007;16:182-183.
6. Willett WC. Nutritional Epidemiology. 2ª ed. *Nueva York: Oxford University Press* 1998.
7. Block G, Hartman AM, Dresser CM, Carroll MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. *Am J Epidemiol* 1986;124:453-469.
8. Cade JE, Burley VJ, Warm DL, Thompson RL, Margetts BM Food-frequency questionnaires: a review of their design, validation and utilization. *Nutr Res Rev* 2004; 17:5-22.
9. Martin-Moreno JM, Boyle P, Gorgojo L, Maisonneuve P, Fernandez-Rodriguez JC, Salvini S, Willett WC. Development and validation of a food frequency questionnaire in Spain. *Int J Epidemiol* 1993; 22:512-9.
10. Shai I, Shahar DR, Vardi H, Fraser D. Selection of food items for inclusion in a newly developed food-frequency questionnaire. *Public Health Nutr* 2004; 7:745-9.
11. Welch AA, Luben R, Khaw KT, Bingham SA. The CAFE computer program for nutritional analysis of the EPIC-Norfolk food frequency questionnaire and identification of extreme nutrient values. *J Hum Nutr Diet* 2005;18:99–116.
12. Mulligan AA, Luben RN, Bhaniani A, Parry-Smith DJ, O'Connor L, Khawaja AP, Forouhi NG et al. A new tool for converting food frequency questionnaire data into nutrient and food group values: FETA research methods and availability. *BMJ Open* 2014;4:e004503.
13. Molag ML, de Vries JH, Ocke MC, Dagnelie PC, van den Brandt PA, Jansen MC, et al. Design characteristics of food frequency questionnaires in relation to their validity. *Am J Epidemiol* 2007 15;166(12):1468-78 Epub 2007 Sep 18.
14. Marks GC, Hughes MC, van der Pols JC. Relative validity of food intake estimates using a food frequency questionnaire is associated with sex, age, and other personal characteristics. *J Nutr* 2006; 136:459-65.
15. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim SP, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *International Journal of Epidemiology* 2012;41:1187–1203.
16. Forster H, Fallaize R, Gallagher C, O'Donovan CB, Woolhead C, Walsh MC, et al. Online Dietary Intake Estimation: The Food4Me Food Frequency Questionnaire. *J Med Internet Res* 2014; 16(6): e150.
17. Quandt SA, Vitolins MZ, Smith SL, Tooze JA, Bell RA, Davis CC, et al. Comparative validation of standard, picture-sort and meal-based food-frequency questionnaires adapted for an elderly population of low socio-economic status. *Public Health Nutr* 2007; 10:524-32.
18. Kushi LH: Gaps in epidemiology research methods: design considerations for studies that use food-frequency questionnaires. *Am J Clin Nutr* 1994, 59(Suppl 1):180S-184S.
19. Liu K: Statistical issues related to semiquantitative food-frequency questionnaires. *Am J Clin Nutr* 1994, 59 (Suppl 1):262S-265S.
20. Subar AF, Thompson FE, Kipnis V, Midthune D, Hurwitz P, McNutt S, et al. Comparative validation of the Block, Willett, and National Cancer Institute food frequency questionnaires: the Eating at America's Table Study. *Am J Epidemiol* 2001;154: 1089–1099.
21. Estruch R, Martinez-Gonzalez MA, Corella D, Salas-Salvado J, Ruiz-Gutierrez V, Covas MI, et al. Effects of a Mediterranean-style diet on cardiovascular risk factors: a randomized trial. *Ann Intern Med* 2006; 145:1-11.
22. Martínez-González MA. The SUN cohort study (Seguimiento University of Navarra). *Public Health Nutr* 2006; 9:127-31.
23. Bingham SA. Dietary assessments in the European prospective study of diet and cancer (EPIC). *Eur J Cancer Prev* 1997; 6: 118–124.
24. Bingham SA, Welch AA, McTaggart A, Mulligan AA, Runswick SA, Luben R et al. Nutritional Methods in the European Prospective Investigation of Cancer in Norfolk. *Public Health Nutr* 2001; 4(3), 847-858.
25. Ocke MC, Bueno-de-Mesquita HB, Goddijn HE, Jansen A, Pols MA, van Staveren WA, Kromhout D. The Dutch EPIC food frequency questionnaire. I. Description of the questionnaire, and relative validity and reproducibility for food groups. *Int J Epidemiol* 1997; 26(suppl 1): S37–S48.
26. Bingham SA, Gill C, Welch A, Cassidy A, Runswick SA, Oakes S et al. Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. *Int J Epidemiol* 1997;26(suppl 1):S137–51.
27. Block G, Wakimoto P, Jensen C, Mandel S, Green RR. Validation of a food frequency questionnaire for Hispanics. *Prev Chronic Dis* 2006;3: A77.
28. Subar AF, Kipnis V, Troiano RP, Midthune D, Schoeller DA, Bingham S et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. *Am J Epidemiol* 2003;158:1-13.
29. Day NE, Wong MY, Bingham S, Khaw KT, Luben R, Michels KB, et al. Correlated measurement error--implications for nutritional epidemiology. *Int J Epidemiol* 2004; 33:1373–81.
30. Bingham SA, Day N. Commentary: fat and breast cancer: time to re-evaluate both methods and results? *Int J Epidemiol* 2006; 35:1022-4.
31. Kristal AR, Peters U, Potter JD. Is It Time to Abandon the Food Frequency Questionnaire? *Cancer Epidemiol Biomarkers Prev* 2005;14(12):2826 – 8.
32. Willet WC, Hu FB. Not the time to abandon the Food Frequency Questionnaire: Point. *Cancer Epidemiol Biomarkers Prev* 2006; 15:1757-8.
33. Bingham SA, Gill C,Welch A, Day K, Cassidy A, Khaw KT, et al. Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br J Nutr* 1994; 72:619-43.
34. Chambers E, Godwin SL, Vecchio FA. Cognitive strategies for reporting portion sizes using dietary recall procedures. *J Am Diet Assoc* 2000; 100, 891-7.
35. Thompson FE, Subar AF, Brown CC, Smith AF, Sharbaugh CO et al Cognitive research enhances accuracy of food frequency questionnaire reports: results of an experimental validation study. *J Am Diet Assoc* 2002; 102:212-25.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):57-61
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Diet history: Method and applications

Luis Juan Morán Fagúndez[1], Alejandra Rivera Torres[1], María Eugenia González Sánchez[1], Mari Lourdes de Torres Aured[2], Carmen Pérez Rodrigo[3] and José Antonio Irles Rocamora[4]

[1]Sociedad Andaluza de Nutrición Clínica y Dietética (SANCYD). [2]Unidad de Dietética y Nutrición. Hospital Universitario Miguel Servet. Zaragoza. [3]Fundación FIDEC, Bilbao. [4]Unidad de Gestión Clínica de Endocrinología y Nutrición Hospital Universitario Virgen de Valme. Sevilla.

Abstract

The diet history is a traditional method of analysis of food intake. In its traditional structure consists of three components that provide an overall information of the usual food consumption pattern of the individual and also detailed information on certain foods. The information is collected in an interview and requires highly experienced qualified interviewers. The quality of information depends largely on the skills of the interviewer. It is mostly used in clinical practice. It has also been used in studies of diet and health relationship to investigate the usual diet in the past. The high cost and long duration of the interview limit their usefulness in large epidemiological studies

(*Nutr Hosp* 2015;31(Supl. 3):57-61)

DOI:10.3305/nh.2015.31.sup3.8752

Key Words: *Food. Food Habits. Diet Records. History.*

HISTORIA DIETÉTICA: METODOLOGÍA Y APLICACIONES

Resumen

La historia dietética es método tradicional de análisis de la ingesta alimentaria. En su estructura tradicional consta de tres componentes que proporcionan una información global del patrón de ingesta habitual del individuo y también información detallada sobre algunos alimentos. La información se recoge en una entrevista y requiere encuestadores cualificados con gran experiencia. La calidad de la información depende en gran medida de la habilidad del encuestador. Se utiliza sobre todo en la práctica clínica. También se ha utilizado en estudios sobre la relación dieta y salud para investigar la dieta habitual en el pasado. El alto coste y la larga duración de la entrevista limitan su utilidad en grandes estudios epidemiológicos.

(*Nutr Hosp* 2015;31(Supl. 3):57-61)

DOI:10.3305/nh.2015.31.sup3.8752

Palabras clave: *Alimentos. Hábitos alimentarios. Registro dietético. Dietética. Historia.*

Several methods have been described with the aim to assess food intake of an individual or a group, where information is collected during a face-to-face interview, by self-reports in traditional paper and pencil forms or supported by the new technologies in electronic forms, web-based or other electronic devices, collected by direct observations, etc. The first food consumption studies conducted using rigorous methodology were published in the decade of the 1930s[1].

The Diet History methodology is a detailed retrospective method of diet assessment used more frequently in the clinical practice than in research studies. Diet History is used to describe food and/or usual nutrient intake during a relatively long period, for example, 1 month, 6 months or 1 year.

The Diet History method was developed by Burke during the years 1938 to 1947 in a clinical environment[2]. Hence the name "Diet History" in analogy to the classic "Clinical History".

Correspondence: Luis Juan Morán Fagúndez.
Sociedad Andaluza de Nutrición Clínica y Dietética (SANCYD).
Pagés del Corro nº 80, 3º 41010. Sevilla.
E-mail: luisjmoran@ono.com

The original technique was structured in 3 parts:

- Interview about the usual food intake pattern of the surveyed individual, estimating the amount consumed by means of household measures.
- A questionnaire consisting of a detailed food list to assess the overall pattern of food intake and to cross-check the information collected in the first part.
- A 3-day food record with estimated portion sizes of the foods and beverages consumed[3].

As described by Burke, the central element of the Diet History is the detailed interview on the usual intake of the subject. The food diary for 3 days and the food frequency questionnaire are used as a cross-checking technique for verifying information.

This method has been used in multiple well known studies, since its use in the initial phases of the Framingham study in USA[4], up to the fieldwork conducted in Spain within the European Pilot Study on Diet and Cancer (EPIC)[5]. Nevertheless, the method has several

limitations that should be considered and have prevented a generalized use in epidemiological studies. Some authors, checking such pilot studies as the previously mentioned Framingham, suggest that generally, the diet history method tends to overestimate intake[6].

The Diet History method

Basically the diet history is an interview with the studied person carried out by an interviewer who needs to be highly qualified in nutrition and dietetics and properly trained to conduct the interview. Participants are asked to try to remember their own food intake for a certain period of time[7].

In its original format the interview asked about the usual meal pattern, food preparation methods as well as frequency of food consumption. This original model has been modified over the years and nowadays there is not a homogeneous standard for the utilization of this tool.

The diet history method assesses quantitatively the global food intake of an individual, habits in relation to food consumption, distribution and usual composition of meals throughout the day, etc ...[8].

The complete method usually consists of the following parts[9]:

- An interview to estimate the habitual consumption of a wide variety of foods in the different eating occasions in a day that often begins by a 24 hours recall, bearing in mind possible seasonal or week variations.
- A food frequency questionnaire to verify information.
- A 3 day dietary record.

Most of the research studies that have used this method to collect diet information have limited the tool to the first part. The photographs or food models are very helpful to estimate the size of the portions eaten.

Nevertheless, currently there is no standard protocol to apply this method which is accepted unanimously, and very different approaches to this method are reported in published research[10].

Adequate training of the interviewers is a very important aspect to guarantee the quality of the information and to reduce differences between interviewers in the quality of the data collected[11,12]. It is recommended that experienced nutritionists familiar with the method are responsible for conducting the interviews, so that they do not interfere in the information and are able to direct and guide the interview up to its conclusion[13].

The complexity of the interview requires experience with the method and training in dietetics and nutrition to be able to carry it out properly. The interviewer can give prompts to help recall, but must not make suggestions that interfere or induce answers. At an early stage, before the start of fieldwork, all the interviewers involved in data collection should follow a strict training protocol to control and reduce systematic error. The quality of the obtained information and therefore the validity of the method depends basically on the ability and skills of the trained interviewers. The person responsible for conducting the interviews need to be familiar with the protocol, the questionnaire to use and require good communications skills, so they are able to create a nice atmosphere for the interview. They must keep the pace of the interview and ask control questions to make sure of the answers that on the other hand, must be as concrete and specific as possible.

The person carrying out the interview will try to gather information not only on the regular consumption of food and drinks, but also on all the related information that is considered to be important in connection with the food habits of the person interviewed (food allergies, dietetic preferences, seasonal variations, etc.).

Information is compiled in an interview that can take from 1 to 2 hours. For that reason it is important to provide standard forms to collect the information, including day-to- day variations and irregular patterns or exceptional food consumptions.

However, such a long procedure can turn out to be tedious for the person being interviewed. Some authors have contributed with innovations to the method that try to reduce the duration of the interview and to systematize the format to gather information, in a way that the presence of the interviewer is not specifically required[14].

The Diet History method requires an effort to recognize the usual pattern of food consumption of the individual, which requires a high capacity for abstraction. So it is not a method applicable to children under 14 yr . or the elderly aged over 80 yr., since the method rather than being based on their ability to recall punctual aspects, it tries to help them recognize their general habits of food intake.

Methodology

As previously outlined, the Diet History can be divided into three parts:

- The record of food consumed during 2 or 3 days or a recall of the food consumed over the previous 24 hours to learn the food intake pattern.
- Frequency of food consumption.
- Specific questions relevant for the survey carried out.

The 24 hours recall is a retrospective method in which the interviewed person is requested to remember all the food and drinks consumed in the previous 24 hours period, or during the previous day. The interviewer uses photographs or household measures in order to help the interviewed to quantify the amounts

used of all food items and/or ingredients of the plates and drinks consumed.

Usually a chronological order is followed throughout the day. Therefore it is advisable to structure the interview into different time slots during the day, such as breakfast, mid-morning snack, lunch, afternoon snack, dinner and other occasions [15].

If the procedure of choice is the food diary or dietary record, unlike the previous one, it consists of asking the interviewed person to note down every day (during a variable period of 3 to 7 days), all food and drinks consumed during each of the surveyed days. This method requires to provide detailed instructions to the interviewed person previously. The double weighing method (weighing before and after the meal) is a variation of the food diary or dietary record.

The food frequency questionnaire consists of a list of foods, or groups of food, for which frequency of consumption is requested (daily, weekly or monthly), on each one of the items.

The information obtained is basically qualitative, though if the proportion or average portion consumed is added next to each foodstuff, a semi-quantitative assessment can be obtained. This questionnaire can be self-administered[16].

The food frequency questionnaire it is not intended to assess the food consumed in a certain day, but to assess broadly the usual pattern. For this purpose the procedure asks about the food usually consumed, the way it is prepared, how frequently it is consumed as part of the diet (daily, weekly or monthly) and in what quantity. It must be clearly stated that the questionnaire refers to the habits of food consumption of the interviewed person specifically. Sometimes the respondents are the persons in charge of the family meals and it is possible that they refer to the family habits in their answers and not to their own. Figure 1 shows an example of a questionnaire about breakfast habits.

It is useful to estimate the quantities in household measures, units, portions or servings as well as to describe the recipes.

Photographs of foods and dishes, different types of food models or replicas showing different serving and portion sizes are useful aids to estimate the amount of food consumed or the size of the reported portion. Sometimes a suggested list of food is used for each of the main meals and eating occasions throughout the day, different ways of preparation etc. to facilitate the recall process of the interviewed person. This list also serves as a checking mechanism and quality control of the data collected.

The interviewed person is asked whether or not usually consumes each one of the foods included in the list and a usual consumption is considered for foods consumed at least once a month[17], prepared in any way. If the answer is "YES" for an item in the food

Desayuno ¿Cuántas veces desayuna a la semana? ( )							¿Es igual los fines de semana? SI ( ) NO ( )			
ALIMENTOS	TIPO	CONSUME		FRECUENCIA			CANTIDAD	Nº UNIDADES	Nº MODELO	MARCAS OBSERVACIONES	Gramos /día
		SI	NO	D	S	M	Tamaño de medida, porción o ración		Si existen modelos de referencia		
Leche											
Yogur											
Zumos											
Infusiones											
¿Añade algo a lo anterior?											
Café											
Cacao											
Azúcar											
Miel											
Edulcorante											
Otros											
Pan											
Bollería											
Galletas											
Cereales											
Frutas											
Otros											
¿Unta algo en el pan o en la bollería? Siempre ( ) A veces ( ) Nunca ( )											
Aceite											
Mantequilla											
Margarina											
Mermelada											
Otros											
¿Añade algo a lo anterior?											
Jamón cocido											
Jamón serrano											
Fiambre de pavo											
Queso											
Huevos											
Otros											

Fig. 1.—Model simple of a diet history questionnaire about food usually consumed for breakfast .

Table II
Uses, advantages and limitations of the Diet History method

Uses	*Advantages*	*Limitations*
Main use in clinical practice	Can be used with low literacy people	Quality of the data collected depends to a great extent on the skills of the interviewer
Provides information about the usual food consumption pattern	Details about the different foods consumed in each meal or eating occasion	An expert interviewer is required and demands a high collaboration from the interview
Estimate prevalence of diet inadequacy	Includes foods consumed less frequently or irregularly	The method is difficult for people with highly variable food habits, such as people working in shifts
Useful in epidemiological studies about the relationship between diet and health, both retrospective and prospective studies	Asks about the usual food intake of an individual	It can be difficult to assess portion sizes even when food photographs or food models are used as aids
Usual mean intake of nutrients over a period of time	Collects information about the whole diet	Due to the need for specific training of interviewers, coding, etc. it can be a costly method
	Allows to get a more representative pattern than other methods of diet assessment in the past	Comparability of the data is not epidemiologically guaranteed as no standard protocol to complete a diet history
	Can be design to assess the whole dieto or just certain nutrients	Imprecise from a quantitative view
	There are some versions with limited added cost	Use not recommended with children under 14 yr or adults aged 80+ yr
	Does not influence food behaviour of the interviewee	Difficult to precise the period to recall
		The long interview, may be tiring for the respondent
		Tendency to overreporting of intake
		The recall of diet in the past may be influenced by current dietary habits

Modified from: Aranceta Bartrina J, Serra Majem Ll. Historia dietética. En: Serra Majem Ll, Aranceta Bartrina J (eds). Nutrición y salud pública. Métodos, bases científicas y aplicaciones (2ª edición). Barcelona: Elsevier, 2006: 184-191[8]

list, we try to assess how often it is usually consumed, avoiding ambiguous or doubtful answers. It must be the interviewed person who defines the frequency of consumption and in no way the interviewer should assume or decide it.

Some authors have suggested the possibility of using pre-coded questionnaires and a close-ended list of foods as an alternative to the open interview. When these standardized protocols are the procedure of choice it is not required highly skilled qualified interviewers to collect the information.

Table II presents a summary of advantages and limitations of the Diet History method.

Applications

This method is adequate when detailed information on usual food intake or food intake during a specific period of life at individual level is required[18].

Nowadays the main application of the diet history method is in clinical practice. Given the historical relevance of the method, many attempts have been made to shorten and simplify the procedures in this method and therefore it could be useful and applicable in epidemiological studies[19,20]. Many case control studies have used a modified version of the diet history methodology[21].

The diet history is a costly method and often it is not applicable in large scale population studies. The quality of the information depends mostly on the skills and experience of the person conducting the interview. Generally, the method collects qualitative data on habits of food consumption, rather than quantitative absolute values of intake, except for the case some adjustments are introduced in the protocol so that it is possible to collect quantitative reliable information[22].

The method focuses on the evaluation of the usual regular pattern, so exceptional or situations are underestimated. Diet history is problematic for application

in groups with very irregular habits of food consumption. It can be of limited use when collecting data on people that snacking during the whole day and do not have proper meals in an organized way.

The ability to recall food intake often refers to the recent past and may not be exactly the same as the reference period of interest for the study. By means of the diet history it is possible to assess the habits of use of particular foods of interest; nevertheless, it is not possible to estimate day-to-day variation in consumption.

Obtaining information about diet in the distant past by means of retrospective diet history is a useful method in studies on the relationship between diet and cancer or diet and chronic diseases in spite of the systematic bias involved and can provide useful information about the current food consumption habits[23].

References

1. Medlin Ch. Individual dietary intake methodology: A 50 year review of progress. *J Am Diet Assoc* 1988;88:1250-1257.
2. Burke BS. The dietary history as a research tool. *Am Diet Assoc* 1947, 23:1041-1046.
3. Abramson JH. Slome C, Kosovsky C. Food Frequency Interview as an Epidemiological Tool. *Am J Public Health Nations Health* 1963 July; 53[7]: 1093–1101.
4. Mann GV, Pearson G, Gordon T, Dawber TR, Lyell L, Shurtleff D. Diet and cardiovascular disease in the Framingham study I. Measurement of dietary intake. *Am J Clin Nutr* 1962; 11:200-10.
5. EPIC Group of Spain. Relative Validity and Reproducibility of a Diet History Questionnaire in Spain. I. Foods. *Int J Epidemiol* 1997; 26 (Supl 1):91-9.
6. Kohemeier L. The Diet History Method. *London: Smith-Gordon* 1991.
7. Martin-Moreno JM, Gorgojo L.Valoración de la ingesta dietética a nivel poblacional mediante cuestionarios individuales: sombras y luces metodológicas. *Rev Esp Salud Pública* 2007; 81: 507-518
8. Aranceta Bartrina J, Serra Majem Ll. Historia dietética. En: Serra Majem Ll, Aranceta Bartrina J (eds). Nutrición y salud pública. Métodos, bases científicas y aplicaciones (2ª edición). *Barcelona: Elsevier* 2006: 184-191
9. Nelson M, Bingham S. Assessment of food consumption and nutrient intake. In: Margetts BM, Nelson M (eds). Design concepts in nutritional epidemiology (Second edition). *Oxford: Oxford University Press* 1997: 123-169
10. Tapsell LC, Pettengell K, Denmeade SL. Assessment of a narrative approach to the diet history. *Public Health Nutr* 1999; 2:61-7.
11. Nelson M, Bingham S. Assessment of food consumption and nutrient intake. In: Margetts BM, Nelson M (eds). Design concepts in nutritional epidemiology (Second edition). *Oxford: Oxford University Press* 1997: 123-169
12. Jain M. Diet history: questionnaire and interview techniques used in some retrospective studies on cancer. *J Am Diet Assoc* 1989; 89:1647-1652.
13. Bingham S, Nelson M, Paul A, Haraldsdottir J, Bjorge Loken E, van Staveren W. Methods for data collection at an individual level. In: Cameron ME, Van Staveren W. Manual on methodology for foof consumption studies. *Oxford: Oxford University Press* 1988: 53-106.
14. Block G, Hartman AM. Dietary Assessment methods. In: Moon The, Micozzi MS. Nutrition and cancer prevention. Investigating the role of micronutrients. *New York: Marcel Dekker* 1989:159-180.
15. Carbajal A. Manual de Nutrición y Dietética. Departamento de Nutrición. Facultad de Farmacia. *Universidad Complutense de Madrid* Sept 2013.
16. Salvador G, Palma I, Puchal A, Vilà MC, Miserachs M, llan M. Entrevista dietética. Herramientas útiles para la recogida de datos. *Rev Med Univ Navarra* 2006; 50[4]: 46-55
17. Jain M, Howe GR, Harrison L, Miller AB. A study of repeatability of dietary data over a seven year period. *Am J Epidemiol* 1989; 129: 422-429.
18. MRC_Medical Research Council UK. Dietary assessment - Diet history. Available at: [http://dapa-toolkit.mrc.ac.uk/dietary-assessment/methods/diet-history/index.html] (Accessed 12 January 2015)
19. Beal VA. The nutritional history in longitudinal research. *J Am Diet Assoc* 1967; 51: 426-432.
20. Jain M, Howe GR, Johnson KC, Miller AB. Evaluation of a diet history questionnaire for epidemiology studies. *Am J Epidemiol* 1980; 111: 212-219.
21. Morgan RW, Jain M, Miller AB, Choi NW, Matthews V, Munan L, et al. A comparison of dietary methods in epidemiologic studies. *Am J Epidemiol* 1978; 107: 488-498.
22. Burema J, Van Staveren WA. Validation of the dietary history method. In: The Diet History Method. Kohemeier L (ed.). *London, Smith-Gordon* 1991; 73-86.
23. Dwyer J, Gardner J, Halvorsen K, Krall Z, Cohen A, Valadian I. Memory of food intake in the distant past. *Am J Epidemiol* 1989; 130: 1033-1046.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):62-69
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Assessment of Beverage intake and Hydration status

Mariela Nissensohn[1,2], Marisa López-Ufano[3], Itandehui Castro-Quezada[1] and Lluis Serra-Majem[1,2]

[1]Nutrition Research Group, Research Institute of Biomedical and Health Sciences (IUIBS), University of Las Palmas de Gran Canaria. [2]Ciber Obn Physiopathology of Obesity and Nutrition. Institute of Health "Carlos III", Madrid. [3]Madrid European University (UEM) and Servicio Madrileño de Salud (SERMAS). Spain.

Abstract

Water is the main constituent of the human body. It is involved in practically all its functions. It is particularly important for thermoregulation and in the physical and cognitive performance. Water balance reflects water intake and loss. Intake of water is done mainly through consumption of drinking water and beverages (70 to 80%) plus water containing foods (20 to 30%). Water loss is mainly due to excretion of water in urine, faeces and sweat.

The interest in the type and quantity of beverage consumption is not new, and numerous approaches have been used to assess beverage intake, but the validity of these approaches has not been well established. There is no standardized questionnaire developed as a research tool for the evaluation of water intake in the general population. Sometimes, the information comes from different sources or from different methodological characteristics which raises problems of the comparability. In the European Union, current epidemiological studies that focus exclusively on beverage intake are scarce.

Biomarkers of intake are able to objectively assess dietary intake/status without the bias of self-reported dietary intake errors and also overcome the problem of intra-individual diet variability. Furthermore, some methods of measuring dietary intake used biomarkers to validate the data it collects. Biological markers may offer advantages and be able to improve the estimates of dietary intake assessment, which impact into the statistical power of the study. There is a surprising paucity of studies that systematically examine the correlation of beverages intake and hydration biomarker in different populations.

A pilot investigation was developed to evaluate the comparative validity and reliability of newly developed interactive multimedia (IMM) versions compared to validated paper-administered (PP) versions of the Hedrick et al. beverage questionnaire. The study showed that the IMM appears to be a valid and reliable measure to assess habitual beverage intake. Similar study was developed in China, but in this case, the use of Smartphone technology was employed for beverage assessment.

***Conclusion:* The methodology for measuring beverage intake in population studies remains controversial. There are few validated and reproducible studies, so there is**

Correspondence: Nissensohn Mariela,
Department of Clinical Sciences,
University of Las Palmas de Gran Canaria,
Las Palmas de Gran Canaria, Spain.
E-mail: mnissensohn@acciones.ulpgc.es

VALORACIÓN DE LA INGESTA DE BEBIDAS Y EL ESTADO DE HIDRATACIÓN

Resumen

El agua es el principal constituyente del cuerpo humano. Está implicado en prácticamente la totalidad de sus funciones. Es especialmente importante en la termorregulación y en el rendimiento físico y cognitivo. El balance de agua refleja la ingesta y la pérdida de agua. La ingesta se realiza principalmente a través del consumo de agua potable y de bebidas (70 a 80%) más el agua que contienen los alimentos (20 a 30%). La pérdida de agua se realiza gracias a su excreción a través de la orina, las heces y el sudor.

El interés por el tipo y la cantidad de bebidas consumidas no es nuevo, y numerosos enfoques se han utilizado para evaluarla, pero la validez de estos enfoques no se han establecido correctamente. Aún no existe, en población general, un cuestionario estandarizado desarrollado como herramienta de investigación para la evaluación de la ingesta de agua. El uso de información de diferentes fuentes y diferentes características metodológicas plantea problemas de comparabilidad entre estudios. En Europa los estudios epidemiológicos actuales que se centran exclusivamente en el consumo de bebidas son escasos.

Los biomarcadores de ingesta permiten evaluar objetivamente la ingesta dietética sin el sesgo producido por los errores del auto-reporte. Además permiten superar el problema de la variabilidad intra-individual. Algunos métodos para medir ingesta alimentaria utilizan biomarcadores para validar los datos que recoge. Los marcadores biológicos ofrecen ventajas y son capaces de mejorar las estimaciones de la evaluación de ingesta dietética. Sin embargo, existen muy pocos estudios que examinen sistemáticamente la correlación entre la ingesta de bebidas y los biomarcadores de hidratación en diferentes poblaciones.

Utilizando el cuestionario de bebidas de Hedrick y col. se realizó un estudio piloto para evaluar la validez y fiabilidad de un modelo multimedia interactivo (IMM) y para compararlo con una versión en papel-auto administrado (PP). El estudio mostró que el IMM parece ser un modelo válido y fiable para evaluar la ingesta de bebidas habitual. Un estudio similar se realizó en China, pero en este caso, se empleó para evaluar ingesta de bebidas la tecnología Smartphone.

***Conclusión:* La metodología para valorar el consumo de bebidas en estudios poblacionales sigue siendo un tema controvertido. Existen pocos estudios validados y reproducibles, por lo que todavía no se dispone de un mé-**

still lacking an ideal method (ie, short, easy to administer, inexpensive and accurate) in this regard. Clearly, this is an area of scientific interest that is still in development and seems to be very promising for improving health research.

(*Nutr Hosp* 2015;31(Supl. 3):62-69)

DOI:10.3305/nh.2015.31.sup3.8753

Key words: *Water. Beverages intake. Hydration biomarkers. Beverage assessment.*

todo ideal (corto, fácil de administrar, económico y preciso). Esta es un área de interés científico que aún está en desarrollo y que parece ser muy prometedora para mejorar las investigaciones en el área de la salud.

(*Nutr Hosp* 2015;31(Supl. 3):62-69)

DOI:10.3305/nh.2015.31.sup3.8753

Palabras clave: *Agua. Consumo de bebidas. Biomarcadores de hidratación. Evaluación.*

Introduction

Water is the main constituent of the human body. About 63% of body weight in adult males and 50 to 55% in females, because they have a higher proportion of body fat than males, and up to 75% in a newborn infant[1]. Two-thirds of total body fluid is intracellular, and the remaining third is extracellular fluid, which is divided into plasma and interstitial fluid. There is also a third space, known as "transcellular fluid", which is contained in body cavities, such as cerebral spinal fluid and synovial, peritoneal and pleural fluids. Although these fluid compartments are classified as separate areas, water and electrolytes continuously circulate between them.

Water is involved in practically all functions of the human body. It is particularly important for thermoregulation and in the physical and cognitive performance. Drinking at least five glasses of water or more per day was associated with lower rates of death from coronary heart disease in middle-aged and elderly subjects. Good hydration can reduce the risk of developing kidney stones because the urine diluted helps preventing stone formation. Furthermore, water is considered as an essential part of the dietary management of diabetes because limit the development of diabetic ketoacidosis during insulin deficiency in type 1 diabetes, helping to maintain healthy blood sugar levels. Adequate fluid intake has been associated with gastrointestinal benefits: lower rate of constipation and lower use of laxatives fees. Some authors have reported a reduced risk of bladder cancer in men, urinary tract infections, dental disease, and benefits in bronchopulmonary disorders.

Fluid balance is a term used to describe the balance of the input and output of fluids in the body to allow metabolic processes to function correctly[2]. Water balance reflects water intake and loss. Water intake is done mainly through consumption of drinking water and beverages (70 to 80%) plus water containing foods (20 to 30%). Food water content is usually below 40% in bakery products, between 40% and 70% in hot meals, 48% in fruit and vegetables and about 90% in both human and cows' milk[1]. Diets rich in vegetables and fruit provide significant amounts of the total water intake, whereas, for example, fast food products as a rule have low liquid content[3]. Water loss is mainly due to excretion of water in urine, faeces and sweat. The contribution of sweat in water loss is higher in physically active person and in hot climates. Therefore, this component is highly variable depending on the lifestyle of the individual and on the environmental conditions[4].

Assessment beverages intake

At the present time, beverages seem to influence the diet and nutrient intakes more than in previous generations, likely due to increased accessibility, changing food trends, and marketing by food venders. The importance of beverages as foods and their effects on nutrient intake have recently been the focus of intense scrutiny. However, the interest in the type and quantity of beverage consumption is not new, and numerous approaches have been used to assess beverage intake, but the validity of these approaches has not been well established[5].

Until now, in the dietary surveys, beverage consumption was recorded as part of the food frequency questionnaires (FFQ) or 24 h recalls. However, these tools were designed especially for recording food intake, no beverages. Moreover, often, in many studies, assessment of water consumption is dismissed or rarely mentioned, since it does not contribute calories or nutrient. Furthermore, beverage intake has focused on sugary drinks (in most of the children and adolescents surveys) and alcoholic beverages (in most of adults' surveys). Sometimes the information comes from different sources or from different methodological characteristics, which raises problems of the comparability. In general, the studies focused the moment of consumption, i.e. meals and snacks, but many people consume water between meals without necessarily consuming other calories, and this amount does not generally show up on records. This result in a low estimate of the amount of water consumed. The timing of the studies is needed and also the seasonally because the weather variations along the year could affect the volume of beverage and water consumption.

There is no standardized questionnaire developed as a research tool for the evaluation of water intake in general population. Sometimes, the use of information from different sources and different methodological characteristics raises issues of comparability that are difficult to address. Furthermore, dietary intake of

water is a highly variable event, which experiences significant differences by the day of the week, by the body size, by the physical activity and by the climatic exposure[6] on a basic underlying pattern of consumption.

In the European Union, current epidemiological studies that focus exclusively on beverage intake are scarce. This hinders research on this topic, which is needed to underpin nutrition policies for these populations. On 2013 we developed a study[7] who described which was the most frequent method applied to assess water (or liquid) intake in European populations. This study reported a current comprehensive overview of European hydration data using gray literature as source of information. Twelve epidemiological studies conducted between years 2003 and 2011 were included. We assigned three major groups of liquid intake in order to organize the beverage intake information extracted. The groups were: 1) total water, 2) non-alcoholic beverages and 3) alcoholic beverages. In some cases, information of total water was collected as mineral water or tap water. Non-alcoholic beverages data were divided into four subgroups (fruit and vegetable juices, coffee, tea and other hot drinks, milk and milk drinks, and carbonated, soft, isotonic drinks and others). With the average intake of water, soft drinks and alcohol intake, we calculated total fluid intake, reported in g/d. However, none of the studies collected information from all categories of beverages evaluated. The beverage information was collected by different types of assessment: 7-d dietary record, 3-d dietary record, 24-h recall, 4-d semi-weighted food record and a Beverage Dietary History applied only in Germany. The Beverage Dietary History was developed to assess beverage intake exclusively. We consider that this reliable beverage intake questionnaire may be desirable for practitioners as well as for researchers assessing habitual beverage intake, although some refining may be needed. The results of this review show that the studies on beverage intake in European countries are diverse with regard to design: they differ in dietary assessment; composition databases, sampling procedures and age range, and this may confound comparisons between countries. Those differences are derived from the methodology used. The choice of an appropriate method is essential in order to have a precise and reliable recollection of information. It is really necessary to focus on developing a method that provides more accuracy and reliability to record all liquids drank at different times, before, during and after meals, specifying each case the amount consumed the type of beverages and the seasonal variability.

What is the real implication of not having enough records that obtain accurate water or beverage consumption? If we note that the recommendations of water consumption or ''adequate intake'' are based on these kind of surveys, it is easy to understand that they are not always adapted well enough to populations and even less to different physiological states[7].

The European Food Safety Authority (EFSA) in addition to affirming that there is lack of data, proposed a clear need to develop a better methodology to produce intake recommendations evidence-based fluids.

Hydration biomarkers

Recently, several questionnaires have been developed to evaluate water intake or the contribution of solid and fluid foods to water intake. These are usually based on reporting the recalled frequency of intake of fluid and solid foods and of drinking water. A common limitation of research in this area is a reliance on self-reported measures of habitual intake. Thus, the need for novel methods to assess intake objectively beverage intake and hydration status, such as beverage's biomarkers, has been recognized[8]. Those biomarkers are able to objectively dietary intake/ status without the bias of self-reported dietary intake errors[8], and also overcome the problem of intra-individual diet variability. Furthermore, some methods of measuring dietary intake use biomarkers to validate the collected data. Biological markers may offer advantages and be able to improve the estimates of dietary intake assessment, due to the independence of their random errors in relation to the errors inherent to the intake questionnaires (memory of the interviewee, underestimate beverage intake reported), which impact into the statistical power of the study. When a method of dietary intake uses one or more biomarkers to validate the data it collects, the validation study is also called relative validation/calibration study. In this case, one dietary method is compared to another beverage intake assess method. The correlation coefficients obtained from the validation studies can reflect the capability of the method to rank individuals according to beverage intake.

However, biomarkers do not replace the traditional methods of food intake. They should be used as additional measures. Moreover, most of the biomarker analyses are expensive, with some degree of invasiveness and quite often it is not possible to perform them as part of a large epidemiological study[9].

Various markers have been proposed to assess the state of hydration (plasma osmolality, urine specific gravity (Usg), urine osmolality, total volume of urine for 24 hours, etc) (Table I), which can be used in different laboratory conditions, clinical practice or sports. However, to current date, there is a lack of an universally accepted biomarker that reflects[10] the increase of hydration status in response to an increase in beverage intake. Therefore, there are no markers defined as "gold standard"[11].

Furthermore, there is a surprising paucity of studies that systematically examine the correlation of beverages intake and hydration biomarkers in different populations. Only two recently questionnaires have been designed to capture the usual beverage intake and were validated against Usg as a biomarker:

1. **Beverage Intake Questionnaire (BEVQ)** from Hedrick et al.[12] developed in the United States. The BEVQ was created to estimate mean daily intake of water, sugar sweet beverages and total beverages across 19 beverage categories plus one open-ended section for "other" beverages not listed. This tool is a quantitative food frequency questionnaire; it allows assessing the frequency of food items and amounts consumed. It was developed to be useful for researchers and clinicians interested in assessing habitual beverage consumption patterns, particularly in large-scale investigations where lengthier, resource-intensive dietary intake assessment techniques are not feasible. Among dietetic practitioners, this tool could be utilized as rapid method to assess beverage consumption as part of nutrition assessment in the primary care process, surveillance and evaluation. In the BEVQ, beverage categories were grouped by energy and macronutrient content using published food composition tables[13] and nutritional analysis software. Common United States beverage portion sizes (e.g., 12 fl oz can of soft drinks, 20 fl oz bottles of juice/water/soft drinks), and common United States cup sizes (e.g., juice glasses [4–6 fl oz] and cups [8 fl oz]) were utilized to correctly assess the amounts consumed. Due to the desire to develop a brief, single-page BEVQ, the most commonly consumed beverage units were included. To score the BEVQ, frequency ("How often") was converted to the unit of times per day, then multiplied by the amount consumed ("How much each time") to provide average daily beverage consumption in fl oz. Energy and grams (per fl oz) for each beverage category were determined using food composition tables[13]. Total energy and grams of each beverage were determined by multiplying the number of fl oz per day by the energy and grams per fl oz of each category.

Table I
Characteristics of Hydration Biomarkers

Hydration Assessment Technique	*Body Fluids Involved*
Stable isotope dilution	all (ECF and ICF)
Neutron activation analysis	all
Bioelectrical impedance spectroscopy (BIS)	uncertain
Body mass change (a)	all
Plasma osmolality (b)	ECF
% plasma volume change	blood
Urine osmolality	excreted urine
Urine specific gravity	excreted urine
Urine conductivity	excreted urine
Urine colour	excreted urine
24-hour urine volume	excreted urine
Salivary flow rate, osmolality, total protein	whole, mixed saliva
Rating of thirst	hypothalamus

Abbreviations:
ECF: extracellular fluid; ICF: intracellular fluid.
(a) using a floor scale.
(b) freezing point depression method.
From Armstrong LE. Assessing hydration status: the elusive gold standard. *J Am Coll Nutr* 2007; 26 (5 Supl): 575S-584S.

2. **Water balance questionnaire (WBQ)** from Malisova et al.[4] in Greece. The WBQ included a series of questions regarding a) the profile of the individual; b) consumption of solid and fluid food (FFQ which included 58 food items); c) drinking water or beverage intake; d) physical activity; e) sweating; f) urine and faecal excretions and g) trends on fluid and water intake, and it was filled in a 3-day diary. A series of questions regarding age, gender, years of education, profession and health status, emphasizing medication and disease that may affect hydration such as kidney disease, urinary tract infection or diabetes, were included to assess the profile of the interviewee. The assessment included information about the lifestyle of the individual, eating and drinking habits, activity levels, as well as weather conditions, may affect water balance. The reference portion of the FFQ was settled next to the food or the liquid, and the frequency of consumption was recorded as 'never', 'once a month', '1–3 times per month', '1–2 times per week', '3–6 times per week', 'once per day' to 'more than twice a day'. Habits on drinking water or beverages were recorded in detail seeking quantitative information on glasses, bottles or cups consumed per day. The level of physical activity was estimated through the International Physical Activity Questionnaire[14] while duration of physical activity was recorded for three activity levels (intense, moderate and mild) or for sedentary conditions. This questionnaire allows an evaluation of water balance from the estimation of water intake and loss through properly designed questions. Water intake refers to water from solid and fluid foods and drinking water[1]; thus, it depends on the eating and drinking habits of the individual. Water loss refers mainly to water excreted in urine, faeces and sweat. For the evaluation of water loss, self-estimation with the aid of a point scale scoring was used. This innovative approach was based on the recent concept that point scales are important tools in evaluating an individual's health characteristics when those are difficult to or cannot be measured directly[15]. They are also considered as reliable tools and therefore during the past years, they have become a routine part of evaluating interventions and health care planning. The application of a point

scale in the estimation of water loss in urine, faeces and sweat involved the difficulty of quantifying self-reporting increments, i.e. to correspond the scoring of the point scale to water volume. This was achieved by accepting that the range of scores provided in the point scale corresponded to the range of physiological water losses in urine, faeces or sweat. Sweating was recorded using a 10-point scale twice, for activity or sedentary conditions. Urination and defecation were recorded on the basis of frequency.

At the final section of the WBQ, attitudes and trends about consumption of fluids as well as knowledge of the participant on recommended water intake for males and females were recorded[4]. The WBQ was shown to be a practical research tool for estimating water balance because it allowed screening a relatively large sample and gather detailed information on water balance. Nevertheless, interpretations on screening for water loss must be treated with particular caution because the WBQ has been validated for water balance and for water intake but not for water loss[4]. It must be noted that, with this research tool, it was not possible to draw conclusions on the hydration status of the population. This limitation arises because the threshold limits on water balance from the WBQ for euhydration, hyperhydration and dehydration have not been established. Consequently, if such threshold limits are recognised, then the WBQ would be a sufficiently powerful questionnaire that could provide useful information in relation to the hydration of the population[16].

In Hedrick´s study[12], the correlation measured by BEVQ against Usg as a biomarker was negatively correlated in two measures: the first one ($r=-0.202$, $p< 0.05$ was found, when people drank 2,017 ± 94 ml and $r = -0.238$, $p< 0.05$ in the second measure when people drank 1,965 ± 96 ml).

Malisova´s study[4] reported no statistically significant correlations between beverage intake estimated from the WBQ against Usg ranging of -0.107, $p = 0.403$. However, they found moderated correlations with the others biomarkers measured (Urine volume, Urine Color, Urine Osmolality). Moreover, results reveled high validity of the WBQ among females (n = 25; correlation with urine osmolality $r = 0.43$, $p = 0.004$; with urine volume $r = 0.3$, $p = 0.04$ and with urine colour $r = -0.35$, $p = 0.033$) but not among males (n = 15; all $ps > 0.05$).

The FFQ used in the BEVQ of the Hedrick's study[12] appears to be a better measuring method for assessing beverage intake than the 3-day dietary questionnaire used in Malisova's study[4] when compared to biomarkers. However, this conclusion is based just in the global correlations found from FFQ and Usg of two papers. There not gold method or gold biomarker. Thus, at present time the WBQ of the Malisova's study[4] seems to a more complete method to evaluate the hydration balance.

Situation in Spain

Over recent months, we have adapted the questionnaire proposed by Hedrick et al.[12], to Spanish population and it is being tested in a group of 120 people participating in the study PREDIMED PLUS (www.predimedplus.com), men and women aged 56 or more, from the cities of Reus and Las Palmas (Annex I). The objective of this questionnaire is to evaluate the consumption of water and drinks in the Spanish population and to validate it against biomarkers of hydration, to obtain reliable data on beverage consumption, in order to determine the consumption patterns of different populations. To achieve this, we will analyze urine osmolality, Usg and total volume of urine for 24 hours. The data obtained through the questionnaire will be correlated with biochemical data analysis using Pearson or Spearman correlations, and then patterns of consumption will be established.

New tools development

Due in part to the increased use and accessibility of computers in multiple settings[17] (i.e. homes, libraries, churches, recreational community centers, grocery stores, and schools)[18], the use of Web and computer-based assessment in large research trials has increased over the past 10 years[19,20]. The National Institute of Health has recognized the need for novel/innovative assessment methods using technological advances in physical activity and dietary assessment. Recently, computerized diet and physical activity assessments have emerged. But, until now, there is no consensus to whether a paper-based assessment is superior to a computerized one[21]; however, computer-based tools can provide an alternative means to collect and analyze data and may be appealing to practitioners and researchers because of their proposed benefits. Computer-administered assessments may overcome difficulties sometimes associated with paper-based surveys as they allow for interactivity-two-way communication between computer and participant through photographs, videos, and displayed text with or without audio[18]. Other advantages of computerized questionnaire administration include-complete responses (ie, prompting individuals to answer all questions), written and narrated text, visual cues of portion sizes, immediate and rapid data entry and scoring, decreased scoring errors, increased attentiveness from participants, instantaneous feedback, and a greater ability to access understudied populations[20]. Additionally, multi-part questions of computerized assessments can be programmed to reduce administration time by providing only relevant data and information for the participant[18]. In low health literacy populations, computerized questionnaires may be advantageous since text can be narrated and visual aids can be used, which may reduce response errors and the necessity of advanced reading skills[18]. Another potential advantage of computer-ba-

ESTUDIO PREDIMED PLUS
CUESTIONARIO
DE INGESTA DE BEBIDAS

Nodo	Paciente	Visita	Fecha Actual

Instrucciones:
Por favor indique su respuesta haciendo referencia al mes pasado.
Por cada tipo de bebida consumida, marque con un número la cantidad de veces al día o a la semana, y con una "X" el momento en que la bebió.
Por ejemplo, si usted bebió 2 vasos de vino por semana, marque en "veces", en la columna"a la semana" el número 2. Si se trata de una bebida que consume todos los días, por ejemplo agua, indique cuantas veces "al día", por ejemplo: 6 veces al día.

2. No cuente los líquidos utilizados en la cocina o en otras preparaciones, como por ejemplo al preparar una salsa o un postre casero.
3. Si consume el café con leche, márquelo en la categoría de bebidas "café con leche" y no en las categorías de leche.
4. Si realiza actividad física, recuerde incluir los líquidos ingeridos durante la práctica.

TIPO DE BEBIDA		FRECUENCIA DE CONSUMO										
		VECES			MOMENTO							
		NUNCA O CASI NUNCA	A LA SEMANA	AL DÍA	ANTES DEL DESAYUNO	CON EL DESAYUNO	ENTRE DES. Y COMIDA	CON LA COMIDA	ENTRE COMIDA Y CENA	CON LA CENA	DESPUÉS DE LA CENA	DURANTE LA NOCHE
Agua de grifo	1 botellín o 1 vaso: 200 cc											
Agua embotellada (con gas/ sin gas)	1 botellín o 1 vaso: 200 cc											
Zumos naturales de frutas	1 vaso: 200 cc											
Zumos envasados de frutas	1 vaso: 200 cc											
Zumos vegetales naturales (gazpacho, de tomate,…)	1 vaso: 200 cc											
Zumos vegetales envasados (gazpacho, de tomate,…)	1 vaso: 200 cc											
Leche entera	1 vaso o taza: 200 cc											
Leche semidesnatada	1 vaso o taza: 200cc											
Leche desnatada	1 vaso o taza: 200 cc											
Lácteos bebibles	1 botellín: 100 cc											
	1 botellín o 1 vaso: 200 cc											
Batidos lácteos	1 vaso: 200 cc											
Bebidas vegetales (bebida de soja, almendras, almendrina…)	1 vaso: 200 cc											
Sopas y caldos	1 taza o plato: 200 cc											
Sorbetes, gelatinas	1 unidad: 120 cc											
Refrescos	1 botellín o 1 vaso: 200 cc											
	1 lata: 330 cc											
Refrescos Light /Zero	1 lata: 330 cc											
	1 botellín o 1 vaso: 200 cc											
Café sólo o cortado con azúcar	1 taza: 30-50 cc											
Café sólo o cortado sin azúcar, con/sin edulcorante artificial	1 taza: 30-50 cc											
Café con leche o americano y azúcar	1 taza: 125 cc											
Café con leche o americano sin azúcar, con/sin edulcorante artificial	1 taza: 125 cc											
Té con azúcar	1 taza: 200 cc											
Té sin azúcar, con/sin edulcorante artificial	1 taza: 200 cc											
Otras infusiones con azúcar	1 taza: 200 cc											
Otras infusiones sin azúcar	1 taza: 200 cc											
Cerveza, Sidra	1 botellín o 1 vaso: 200 cc											
	1 lata: 330 cc											
Cerveza sin alcohol o Light	1 lata: 330 cc											
	1 botellín o 1 vaso: 200 cc											
Vino (tinto, rosado o blanco), cava	1 vaso: 120 cc											
Bebidas alcohólicas de alta graduación (whisky, ron, vodka, ginebra)	1 copa 50 cc											
Bebidas alcohólicas combinadas (cubata, gintonic, piña colada, daikiri, otras)	1 vaso: 200 cc											
Bebidas energéticas (Red Bull, Burn,…)	1 vaso: 200 cc											
Bebidas para deportistas/isotónicas	1 vaso: 200 cc											
	1 lata: 330 cc											
Batidos sustitutivos de comidas/ híper proteicos	1 vaso: 200 cc											
Otros (especifique):												

sed assessments is that response-bias and intimidation may be reduced with computer-administered surveys, although additional research addressing this possibility is needed[18,22,23]. However, when using identical computerized versions of paper assessments comparability cannot be assumed because interface characteristics like font size, line length, scrolling ability, and amount of information visible on the screen can all influence user performance[24].

Prior research has demonstrated the reliability and validity of the self-administered paper-based questionnaire that assesses habitual beverage intake (BEVQ-15)[25]. To the best of our knowledge, no computer-based beverage intake questionnaire exists. The recently developed Automated Self-Administered 24-hour Recall[26] is computer-based and contains questions about beverage intake; however, results on its validity and usability has yet to be published[27]. Lately a pilot investigation was developed to evaluate the comparative validity and reliability of newly developed interactive multimedia (IMM) versions compared to validated paper-administered (PP) versions of the BEVQ-15[25]. The conclusion of the study shows that the IMM BEVQ-15 appears to be a valid and reliable measure to assess habitual beverage intake, although software familiarization may increase response accuracy. Future larger-scale investigations are warranted to confirm these possibilities.

Similar study was developed by Smith et al.[28] in China, but in this case, the use of Smartphone technology was employed for beverage assessment. Smartphone offered a promising new way to record beverage consumption, as participants can easily capture images of beverages prior drinking[29]. In particular, video records provide an enhanced ability to see all food items in a shot, and also can encompass voice annotation, allowing the participants to describe the foods or beverages consumed. These videos and vocal records can then be used during 24-hour recalls to prompt memory and aid portion size estimation, improving the accuracy of the 24-hour recall[30]. In addition, the study employed the Ecologic Momentary Assessment (EMA), a periodically assessment that prompts participants to record beverages they have recently consumed[31], further reducing the likelihood of omission.

The objectives of this study were: 1) to compare beverage consumption data collected using a 3-day Smartphone-assisted 24-hour recall (SA-24R) vs. beverage data collected using the written record-assisted 24-hour recall (WA-24R) and 2) to validate, in a small subset, the extent to which each recall method adequately estimates total beverage intake based on correlation with total urine volume measured in 24-hour urine samples.

For this study, also the BEVQ of Hedrick study[25] was used. The beverage categories were adapted from a validated beverage questionnaire screener in consultation with a panel of experts about beverages that are commonly consumed in China. In this study, the SA-24R and WA-24R showed moderate correlation between reported fluid intake and total urine output. Correlations between the two methods showed moderate agreement across beverage categories, with an average Spearman rank correlation of 0.42. Despite these moderate correlations, mean beverage intake was significantly lower by 222 g/day in the SA-24R compared to the WA-24R. In this case, the use of a SA-24R does not appear to improve the quantification of beverage intake compared to a WA-24R recall in Chinese population.

Further recearch is required to understand the optimal method for collecting information on beverage intake in the dynamic food environment.

Conclusion

The methodology for measuring beverage intake in population studies remains controversial for most of the researchers. There are few validated and reproducible studies, so there is still lacking an ideal method (i.e., that is short, easy to administer, inexpensive and accurate) in this regard. Sidossi[32] argues that the ideal methodology does not exist so far and that existing validated methods (24 hours recall and food frequency questionnaires) accompanied by a computer program on food composition are acceptable and reliable for the beverage intake assessment[32]. Clearly, this is an area of scientific interest that is still in development and seems to be very promising for improving health research.

Acknowledgements

Mariela Nissensohn and Lluis Serra-Majem contributed to the design of the manuscript. Lluis Serra-Majem and Marisa López-Ufano prepared the main outline of the manuscript. Mariela Nissensohn selected the data and writed the manuscript. All authors contributed to the preparation of the final manuscript.

Conflict of Interest Section

Neither Marisa López-Ufano nor Itandehui Castro-Quezada report conflicts of interest to disclose. Mariela Nissensohn recieved a grant from the European Hydration Institute through the Canarian Foundation Science and Tecnology Park of the University of Las Palmas de Gran Canaria. Lluis Serra-Majem serves at the Scientific Committee of the European Hydration Institute.

References

1. European Food Safety Authority, EFSA Panel on Dietetic Products, Nutrition, and Allergies. Parma, Italy 2010. Scientific opinion on dietary reference values for water. *EFSA* J 8:1459, 48 pp.

2. Welch K Fluid balance. *Learning Disability Practice* 2010; 13: 6, 33-38.
3. Przyrembel H. *Energiedichte der Nahrung: Welche Rolle spielen Kohlenhydrate? Aktuelle Erna¨hrungsmedizin* 2006; 31:28–36.
4. Malisova O, Bountziouka V, Panagiotakos DB, Zampelas A, Kapsokefalou M. The water balance questionnaire: design, reliability and validity of a questionnaire to evaluate water balance in the general population. *Int J Food Sci Nutr* 2012; 63 (2):138-44.
5. Marshall TA, Eichenberger Gilmore JM, Broffitt B, Levy SM, Stumbo PJ. Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *J Am Diet Assoc* 2003; 103: 714-20.
6. Fulgoni VL. Limitations of data on fluid intake. *J Am Coll Nutr* 2007; 26(5 Suppl):588S-591S.
7. Nissensohn M, Castro-Quezada I, Serra-Majem L. Beverage and water intake of healthy adults in some European countries. *Int J Food Sci Nutr* 2013; 64(7):801-5.
8. Hardin DS. Validating dietary intake with biochemical markers. *J Am Diet Assoc* 2009; 109: 1698-9.
9. Kabagambe EK, Baylin A, Allan DA, Siles X, Spiegelman D, Campos H. Application of the method of triads to evaluate the performance of food frequency questionnaires and biomarkers as indicators of long-term dietary intake. *Am J Epidemiol* 2001; 154:1126-35.
10. Armstrong LE, Maresh CM, Castellani JW, Bergeron MF, Kenefick RW, LaGasse KE, Riebe D. Urinary indices of hydration status. *Int J Sport Nutrition* 1994; 4: 265-79.
11. Nissensohn M, Ruano C, Serra-Majem L.Validation of beverage intake methods vs. hydration biomarkers; a short review. *Nutr Hosp* 2013; 1;28(6):1815-9.
12. Hedrick VE, Comber DL, Estabrooks PA, Savla J, Davy BM. The beverage intake questionnaire: determining initial validity and reliability. *J Am Diet Assoc* 2010; 110 (8): 1227-32.
13. Pennington, J; Bowes, ADP.; Church, HN. Bowes & Church's Food Values of Portions Commonly Used. 17th ed. *Lippincott Williams & Wilkins* 1998.
14. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. Med. *Sci. Sports Exerc* 2003; 35, 1381–1395.
15. Panagiotakos D. Health measurement scales: methodological issues. *Open Cardiovasc. Med J* 2009; 23(3):160–165.
16. Malisova O, Bountziouka V, Panagiotakos DB, Zampelas A, Kapsokefalou M. Evaluation of seasonality on total water intake, water loss and water balance in the general population in Greece. *J Hum Nutr Diet* 2013; 26 Suppl 1:90-6.
17. Riebl SK, Paone AC, Hedrick VE, Zoellner JM, Estabrooks PA, Davy BM. The comparative validity of interactive multimedia questionnaires to paper-administered questionnaires for beverage intake and physical activity: pilot study. *JMIR Res Protoc* 2013 22;2(2):e40
18. Jantz C, Anderson J, Gould SM. Using computer-based assessments to evaluate interactive multimedia nutrition education among low-income predominantly Hispanic participants. *J Nutr Educ Behav* 2002; 34(5):252-260.
19. Ekman A, Dickman PW, Klint A, Weiderpass E, Litton JE. Feasibility of using web-based questionnaires in large population-based epidemiological studies. *Eur J Epidemiol* 2006; 21(2):103-111.
20. Ekman A, Litton JE. New times, new needs; e-epidemiology. *Eur J Epidemiol* 2007; 22(5):285-292.
21. Noyes JM, Garland KJ. Computer- vs. paper-based tasks: are they equivalent? *Ergonomics* 2008; 51(9):1352-1375.
22. Ekman A, Klint A, Dickman PW, Adami HO, Litton JE. Optimizing the design of web-based questionnaires-experience from a population-based study among 50,000 women. *Eur J Epidemiol* 2007; 22(5):293-300.
23. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim SP, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *Int J Epidemiol* 2012; 41(4):1187-1203
24. Clariana R, Wallace P. Paper-based versus computer-based assessment: key factors associated with the test mode effect. *Br J Educ Technol* 2002;33(5):593-602.
25. Hedrick VE, Savla J, Comber DL, Flack KD, Estabrooks PA, Nsiah-Kumi PA, Ortmeier S, Davy BM. Development of a brief questionnaire to assess habitual beverage intake (BEVQ-15): sugar-sweetened beverages and total beverage energy intake. *J Acad Nutr Diet* 2012; 112 (6): 840-9.
26. National Cancer Institute. *Applied Research: Cancer Control and Population Sciences* 2013. ASA24 Automated Self-administered 24-hour Recall URL: http://appliedresearch.cancer.gov/tools/instruments/asa24/ [accessed 2013-10-05].
27. Subar AF, Kirkpatrick SI, Mittl B, Zimmerman TP, Thompson FE, Bingley C, et al. The Automated Self-Administered 24-hour dietary recall (ASA24): a resource for researchers, clinicians, and educators from the National Cancer Institute. *J Acad Nutr Diet* 2012; 112(8):1134-1137.
28. Smith LP, Hua J, Seto E, Du S, Zang J, Zou S, Popkin BM, Mendez MA. Development and validity of a 3-day smartphone assisted 24-hour recall to assess beverage consumption in a Chinese population: a randomized cross-over study. *Asia Pac J Clin Nutr* 2014; 23(4):678-90.
29. Winter J, Boushey C. Workshop 1: use of technology in dietary assessment. *Eur J Clin Nutr* 2009; S75–S77.
30. Lazarte CE, Encinas ME, Alegre C, Granfeldt Y. Validation of digital photographs, as a tool in 24-h recall, for the improvement of dietary assessment among rural populations in developing countries. *Nutrition Journal* 2012; 1:61.
31. Stone AA, Shiffman S. Ecological momentary assessment (EMA) in behavorial medicine. *Ann Behav Med* 1994; 3:199–202.
32. Sidossis LS. Assessment of energy expenditure and energy intake in children: is it possible? *Curr Op Clin Nutr Metab Care* 2003; 6(5):499.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):70-75
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Consumption estimation of non alcoholic beverages, sodium, food supplements and oil

María Luisa López Díaz-Ufano

Madrid European University (UEM) and Servicio Madrileño de Salud (SERMAS).

Abstract:

The interest in the type and quantity of non alcoholic beverage, sodium, food supplements and oil consumption is not new, and numerous approaches have been used to assess beverage intake, but the validity of these approaches has not been well established.

The need to intake liquids varies depending on the diet, the physical activity carried out, the environmental temperature, the humidity, etc. The variety of beverages in the diet can contribute to increasing the micro nutrient intake: vitamins, antioxidants, minerals.

Risks associated to high sodium consumption are: an increase in high blood pressure, vascular endothelial deterioration, bone demineralisation, kidney disease, stomach cancer. Progress in health, investigation, education, etc. are leading to an increase in food supplement consumption. Olive oil represents one of the basic pillars of the Mediterranean diet and its normal presence in nutrition guarantees an adequate content of some important nutrients; not only oleic acid and linoleic acid but also tocopherols, phytoesterols and phenolic compounds.

Biomarkers of intake are able to objectively assess dietary intake/status without the bias of self-reported dietary intake errors and also overcome the problem of intra-individual diet variability. Furthermore, some methods of of measuring dietary intake used biomarkers to validate the data it collects. Biological markers may offer advantages and be able to improve the estimates of dietary intake assessment, which impact into the statistical power of the study. There is a surprising paucity of studies that systematically examine the correlation of beverages intake and hydration biomarker in different populations.

***Conclusion:* There is no standardized questionnaire developed as a research tool for the evaluation of non alcoholic beverages, sodium, food supplements and oil intake in the general population. Sometimes, the information comes from different sources or from different methodological characteristics which raises problems of the comparability. In the European Union, current epidemiological studies are scarce.**

(*Nutr Hosp* 2015;31(Supl. 3):70-75)

DOI:10.3305/nh.2015.31.sup3.8754

Key words: *Sodium, Food supplements. Oil. Biomarkers, beverage assessment.*

Correspondence: María Luisa López Díaz-Ufano.
Servicio Madrileño de Salud (SERMAS).
Madrid, Spain.
E-mail: marisalopezdiaz@telefonica.net

ESTIMACIÓN DEL CONSUMO DE BEBIDAS NO ALCOHÓLICAS, SODIO, SUPLEMENTOS Y ACEITE

Resumen:

El interés por el tipo y la cantidad de bebidas no alcohólicas, sodio, suplementos y aceite consumidos no es nuevo, y numerosos enfoques se han utilizado para evaluarla, pero la validez de estos enfoques no se ha establecido correctamente.

Las necesidades de líquidos varían dependiendo de la dieta, de la actividad física realizada, de la temperatura ambiental, de la humedad, etc. La variedad de bebidas en la dieta puede contribuir a incrementar la ingesta de micronutrientes: vitaminas, antioxidantes, minerales.

Los riesgos asociados al elevado consumo de sodio son: aumento de hipertensión arterial, deterior endotelial vascular, desmineralización ósea, enfermedad renal, cáncer de estómago. Los avances en salud, investigación, educación, etc. llevan a un creciente consumo de suplementos alimenticios. El aceite de oliva representa uno de los pilares básicos de la Dieta Mediterránea y su presencia habitual en la alimentación garantiza un adecuado aporte de algunos nutrientes importantes, no sólo ácido oleico y linoleico, si no también tocoferoles, fitoesteroles y compuestos fenólicos.

Los biomarcadores de ingesta permiten evaluar objetivamente la ingesta dietética sin el sesgo producido por los errores del auto-reporte. Además permiten superar el problema de la variabilidad intra-individual. Algunos métodos para medir ingesta alimentaria utilizan biomarcadores para validar los datos que recoge. Los marcadores biológicos ofrecen ventajas y son capaces de mejorar las estimaciones de la evaluación de ingesta dietética. Sin embargo, existen muy pocos estudios que examinen sistemáticamente la correlación entre la ingesta de bebidas y los biomarcadores de hidratación en diferentes poblaciones.

***Conclusión:* Aún no existe, en población general, un cuestionario estandarizado desarrollado como herramienta de investigación para la evaluación de la ingesta de bebidas no alcohólicas, sodio, suplementos y aceite. El uso de información de diferentes fuentes y diferentes características metodológicas plantea problemas de comparabilidad entre estudios. En Europa los estudios epidemiológicos actuales son escasos.**

(*Nutr Hosp* 2015;31(Supl. 3):70-75)

DOI:10.3305/nh.2015.31.sup3.8754

Palabras clave: *Sodio. Suplementos. Aceite. Biomarcadores. Consumo de bebidas.*

Introduction

In order to know about individual or group food consumption there are several tools available, that estimate consumption along a determine period of time. There is no ideal method to value food take in a precise way. The assessment methods that are used estimate intake with different levels of accuracy.

Individual methods to value food consumption permit you to relate the diet with other variables of the person, as for example their age, sex, economic situation, style of life, biochemical nutritional status, health state, etc.

It's important to know the features of the most used questionnaires, their implementation possibilities and their limits[1].

Table I summarizes the key features, applications and limitations of different food consumption assessment methods.

Choosing a food consumption assessment method will depend principally on the desired objectives.

In the year 1993[2] experts on food and nutrition studies, gathered by the General Direction of Public Health of the Health and Consumption Ministry, reached a consensus about recommending, for assessment studies on individual consumption in Spanish population, the use of the 24hrs method for 2 or 3 non consecutive days. And this method may be complemented with a food consumption questionnaire.

Table I
Features, applications and limitations of commonly used food consumption assessment methods

	Features and applications	*Limitations*
Food record	• It estimates real intake quantitatively. • When the number of days are increased, the estimation approximates to normal intake. • Useful in epidemiological studies and nutritional counseling. • The precision of the questionnaires increases. • from the estimation register to the food weight register and lastly the double weight register with complementary chemical analysis.	• It requires proper cooperation from the participant. He/she must know how to read and write. • The participant's cooperation, the cost of the method and modifying the consumption pattern that is produced increase from the estimation register to the food weight register and lastly the double weight register with complementary chemical analysis.
24 hr recall	• It estimates real intake quantitatively. When the number of days are increased, the estimation approximates to normal intake. • Useful in epidemiological studies and nutritional counseling. • It does not modify consumption patterns. • It may be used with illiterate subjects.	• Memory failure. Difficult to use with children and elderly. • Difficulty when trying to quantify the size of the serving consumed.
Diet history	• It estimates real intake quantitatively. • Useful in epidemiological studies and nutritional counseling. • It does not modify consumption patterns. • It may be used with illiterate subjects.	• Long and expensive. • Polling experts are required.
Food Frequency Questionnaires	• It estimates qualitatively normal intake according to food groups. It can quantify normal consumption servings. • Useful in epidemiological studies to be able to classify subjects by consumption categories and useful in nutritional counseling. • Quick and easy. • It does not modify consumption patterns. • It does not require polling experts. • Low applying costs.	• Less precise than quantitative methods. • Difficult use on children, elderly and subjects with low intelligence levels. • It requires memory. • It is qualitative or semi-quantitative. • Questionnaire requires validating before use. • High cost.
Fast methods	• They identify consumption habits. • Useful to detect risky consumption, diet support. • Very easy to apply. • Low cost.	• Less precise than previous methods.
Biochemical methods to value food intake.	• It provides direct, objective information about nutrient availability.	• It does not provide information about the global diet. • Not all nutrients have a proper biochemical indicator.

Non-alcoholic beverages consumption estimate

The need to intake liquids varies depending on the diet, the physical activity carried out, the environmental temperature, the humidity, etc.

It is essential to replace water and salt loss in order to maintain an adequate hydration level and a good health state. Food provides between[3] 20%-25% of the total water intake, whereas beverages represent the other 75%-80%.

The variety of beverages in the diet can contribute to increasing the micro nutrient intake: vitamins, antioxidants, minerals, etc.

When it comes to assessing beverage consumption one has to take into consideration the type of beverage: We have non-bottled water (with different types of treatments to obtain the quality necessary for human consumption and this will depend on different geographical regions); bottled water (that is classified in mineral water, stream water and prepared waters); juices (natural or not, vegetables); milk (whole-milk, semi-skimmed, skimmed, fortified); dairy milk shakes; soft drinks (light / zero); coffee (with or without milk, with or without sugar, with sweetener); tea (with or without sugar, with sweetener, with milk; other teas (with or without sugar); beer (with or without alcohol); cider, soups, energy drinks (Table II).

To estimate intake one may use the following type of registers:

Once the quantity of consumption register is done (24hrs method for 2 or 3 consecutive days, completed with the food consumption register) we must consult the specific labeling of each of them to know the micro nutrient content and therefore be able to calculate the intake of these.

If we seek to assess the individual's hydration level we may do this through[4]:

- Dilution techniques.
- Bio-electrical impedance.
- Plasma indicators.
- Urine indicators.
- Body weight changes.
- Water loss.
- Clinic.

Table II
Sample food frequency questionnaire to assess consumption of beverages

BEVERAGES	*Never or rarely*	*At month*	*At week*			*At day*		
		1-3	*1*	*2-4*	*5-6*	*1*	*2-3*	*4-6*
Tap water Bottled water (w. or w/o gas) Mineral water Stream water *1 glass=200cc*								
Natural juice (orange or others) Canned or bottled juice Natural vegetable juice Canned or bottled vegetable juice *1 can = 330cc*								
Whole milk Semi-skimmed milk Skimmed milk Soya drink *1 glass = 200cc*								
Soft drinks Soft drinks light/zero *1 can =330cc*								
Black coffee w or w/o a little milk with sugar Black coffee w or w/o a little milk w/o sugar *1 cup = 30cc* Coffee with milk and sugar Coffee with milk w/o sugar *1 cup=200cc*								
Tea with sugar Tea w/o sugar Other teas *1 cup=200cc*								
Soups *1 bowl=250cc*								
Must *1 glass=200cc*								
Alcohol free beer *1 bottle=200cc* Beer *1 can=330cc*								
Cider *1 glass=200cc*								

1. *Dilution techniques*. They use bio-markers. They permit you to measure directly the hydration state. They are very exact. Problems: The indicator must be distributed evenly, it's necessary to know the discharge or metabolic breakdown of the indicating substance, the bio-marker must be easy to measure, non-toxic and must not alter the body's water distribution. The technical requirements and high costs make them be rarely-used techniques.
2. *Bio-electrical impedance*. There are different bio-electrical impedance analysis (AIB): AIB mono-frequency, AIB multi-frequency and bio-electrical impedance spectroscopy (EIB). The factors that can affect the impedance reliability are: configuration and position of the electrodes; electrical frequency; body position; internal and external temperature, perspiration; previous exercise; hormone changes; hematocrit; body fat distribution and metal objects (prostheses, pacemaker, etc).
3. *Plasma indicators:* Plasma Osmolarity: 280 moms/liter; Plasma volume; Sodium; Others: Hematocrit, Potassium, Adrenaline, Noradrenaline, Cortisol, Aldosterone, Blood urea nitrogen (BUN), Relation between BUN/Creatinine, Testosterone.
4. *Urine indicators*. Urine Osmolality (particles/kg of water), Osmolarity (particles / liter of solution), Urine volume: *dehydration when one eliminates* < 30 ml/h and volume over 300-600 ml/h indicates that there is an excessive intake of liquids.
5. *Body weight changes*. It's a reliable, valid, precise, fast and cheap marker. Well used in sport. If the loss is 5% body weight the clinical signs depend on interstitial liquid loss (sunken eyes, dry mucous membranes, sunken fontanelle); if the loss is between 5-10 % body weight, the clinical signs depend on interstitial deficit added to intravascular liquid deficit (lethargy, tachycardia, low blood pressure, urine output decrease), and last of all if the loss is between 10-15% body weight, the clinical signs will be caused by hydra depletion of the interstitial and intravascular space (low blood pressure, oliguria, rapid pulse, etc).
6. *Water loss*. To assess an individual's hydration one has to take into consideration the daily minimum water loss and its production (Table III).

Table III
Estimation of daily minimum water loss and its production[5]

Source	*Loss (cc)*	*Production (cc)*
Respiratory loss	-250 / -350	
Urine loss	-500 / -1000	
Faeces loss	-100 / -200	
Unconscious loss	-450 / -1900	
Metabolic production		+ 250 / + 350
Total	-1300 / -3450	+ 250 / + 350
Net loss	-1050 / -3100	

7. *Clinic*. Symptoms: Dry mouth, dizziness, vertigo, no tear drop production, sunken eyes, sunken fontanelle (babies), lethargy.
   Signs: Low blood pressure, orthostatic hipopresion, tachycardia, thready pulse, signs of skin folds, delayed capillary refill, shock.

Sodium consumption estimation

The physiological needs of sodium consumption vary depending on the age, sex, weight, physiological state (growth, pregnancy, breastfeeding), physical activity level, etc. These physiological needs are also influenced by environmental conditions (hot climates), certain types of jobs (bakers, stokers) and pathological situations (diarrhea, vomiting).

Risks associated to high sodium consumption are: an increase in high blood pressure, vascular endothelial deterioration, bone demineralisation, kidney disease, stomach cancer.

The WHO[6] recommends healthy population an average consumption of 5 gr of salt per day. *Salt = sodium (grams) x 2.5 - multiply 2,5 by the content of grams of sodium that the food label indicates*. Nevertheless, making out the sodium intake is not easy, as it is difficult to know how much salt one uses when cooking and there are any foods that are not well labeled.

To be able to estimate how much sodium has been consumed one must ask if the subject never uses salt, or if he always uses salt, and if salt is used, which type (iodized or not).

Sodium excretion measurement through urine (24hr urine) is the objective biochemical parameter to be able to know how much sodium has been consumed, as all sodium consumption is eliminated through urine. For adults, the normal sodium levels in urine are 20mEq/l/day[7].

Food supplement consumption estimation

Progress in health, investigation, education, etc. are leading to an increase in food supplement consumption.

Vitamins are organic substances of diverse chemical structure that the body is not able to synthesize, reason why it needs exogenous intake in small quantities, generally from the diet, with the exception of vitamin D which is endogenously synthesized under the influence of ultraviolet light. Vitamins are essential when it comes to maintaining many metabolic functions. To not have enough in the diet provokes deficiencies or hypovitaminosis. Though different in their structure and function, they are classified, according to their solubility, in water-soluble and lipid-soluble.

Minerals have numerous functions in the human organism, represent 4% of body weight. The amount of a mineral in the body element is no functional importance index, the copper zinc or iodine present in very

Table IV
Example of a food frequency questionnaire to assess the consumption of supplements

SUPPLEMENTS	*Never or rarely*	*At month*	*At week*			*At day*		
		1-3	*1*	*2-4*	*5-6*	*1*	*2-3*	*4-6*
Brand of the vitamin or mineral supplement or the diet product.								

small amounts perform vital functions. Most mineral are found in any balanced diet.

Its deficiency states are often linked to the industrialization of food, its preparation, unbalanced diets, increased needs, drug interactions and/or intestinal malabsorption.

To be able to estimate their consumption questionnaires of the type showed on table IV may be used.

Once the quantity of consumption register is done (24hrs method for 2 or 3 consecutive days, completed with the food consumption register) we must consult the specific labeling of each of them to know the micro nutrient content and therefore be able to calculate the intake of these.

For consumption estimation[8], biochemical parameters are more precise, specific and sensitive indicators than consumption assessment methods (questionnaires). The most frequently used samples are blood and urine, though on some occasions other samples are used: tear drops, hair, saliva, nails, skin tissue, etc. Samples of hair and nails have especially been used to assess the nutritional situation in minerals and trace elements.

In general, vitamin intake assessment could be done analyzing the serum levels. Though the ideal situation is to be able to use a functional parameter, as for example assessing the enzyme activity of some metabolic process in which the vitamin intervenes.

Vitamin A: Its deficiency could be determined through clinical signs (Xerophthalmia and night blindness). As a biochemical parameter, the levels of retinol in plasma or of its transportation protein (RBT) can be determined.

Vitamin D: To be able to know its nutritional situation the levels of 25-hydroxycholecalciferol in plasma are measured.

Vitamin E: We have the following biochemical parameters to know its levels:

- Plasma level of tocopherol: it is recommended to express the levels as mg of tocopherol per gr of total lipid serum.
- Level of tocopherol in erythrocytes or platelets.
- Red blood cell hemolysis level: Cell hemolysis over 20 % indicates vitamin deficiency.

Vitamin K: The classic criteria of nutritional state assessment is done determining the prothrombin time (PT).

Vitamin C: Its levels of serum can be determined easily. Levels below 0.1mg/dl are considered deficient. It has no relation with the appearance of clinical signs of scurvy. Assigning vitamin C levels in leukocytes is somewhat more difficult but has a more direct correlation with its levels in skin tissue. Values below 20mg/dl indicate deficiency. After 120 days of deficient feeding, the storage elements might start to run out.

Vitamin B complex: There are different specific parameters for each of them, that we will use depending on what is being investigated. There are also hematologic alterations as for example neutrophil hyper-segmentation, and in the last stage of the deficiency megalobastic anemia is produced.

To value minerals there are direct methods of assessment measuring their levels in plasma or blood cells. The nutritional situation can also be assessed indirectly taking into consideration the enzyme activity of which it takes part.

Iron: There is no unique parameter to diagnose sensitively and specifically iron deficiency, they are used combined. Ferritin serum (early indicator of iron depletion, it measures its deposits, its levels are deficient when they are below 12ng/ml in adults) must be assessed: also transferrin (serum levels, iron fixing properties, saturation percentage) and erythrocyte protoporphyrin (hemoglobin precursor). Sideremy is subjected to numerous fluctuations, it even varies very much in the same individual along the day.

Zinc: Its plasma levels, the levels of zinc in red blood cells and the erythrocyte metallothioneins can be determined.

Copper: To be able to evaluate the deficiency of this mineral the following elements are established: level of copper in plasma, erythrocyte and / or leukocytes, protein levels that unite to copper (serum ceruloplasmin or erythrocyte metallothionein) and the activity of the copper dependent enzymes (cytochrome oxidase, super-oxide dismutase).

Selenium: The serum levels reflect recent mineral intake. These levels have been used on hair and nails as indicators of long term intake. With serum le-

Table V
Example of a food frequency questionnaire to assess oil consumption

OIL	*Never or rarely*	*At month*	*At week*			*At day*		
		1-3	*1*	*2-4*	*5-6*	*1*	*2-3*	*4-6*
Corn oil *1 spoon full =15cc o 12g*								
Sunflower oil								
Soya oil								
Virgin olive oil								
Extra-virgin olive oil								
Compressed first olive oil								

vels in hair one must be very cautious because many shampoos contain this element. The peroxidase glutathione activity is affected when there are selenium deficiencies.

Vitamin and mineral urine excretion increases as does its intake and decreases if it is deficient. On many occasions it is the principal method to assess the nutritional state. In general the urine levels are expressed by mg of excreted creatinine. Lipid-soluble vitamins can not be determined in urine as they are not soluble in water except vitamin K whose metabolite, the gamma-carboxyglutamic acid, is eliminated through urine.

Excess tests also permit us assess the vitamin and mineral nutritional situation. The quantity eliminated is proportional to the excess of the nutrient in the organism. To detect vitamin B6 deficiency an excess of tryptophan test is carried out; for folate deficiency the histidine excess test and for vitamin B12 deficiency the valine and histidine excess test.

Oil consumption estimation

Oils can be subdivided into saturated (coconut, palm), monounsaturated (olive) and polyunsaturated (corn, soya, sunflower). This is a simplified classification as in each subgroup there are important differences that effect their properties.

Olive oil represents one of the basic pillars of the Mediterranean diet and its normal presence in nutrition guarantees an adequate content of some important nutrients; not only oleic acid and linoleic acid but also tocopherols, phytoesterols and phenolic compounds. The content of fatty acids, olive oil tocopherols, differs significantly depending on the variety of olive. Phytoesterol content can vary depending on the ripening of the olive when collecting. On the other hand, the content of poly-phenols will depend on the olive oil's refining, being extra olive oil especially rich in these. The European Food Safety Authority (EFSA)[9] recommends a minimum consumption of 20 gr per day to benefit from the effects of poly-phenols that extra virgin olive oil contains.

Not only must one have in mind the variety of oils, but also the type of preservation (temperature, light, oxygen presence, type of packaging) and the use given (raw, fried).

The recommended quantity of daily olive oil consumption has problems in practice as there is no unanimity in the guides (spoon fulls, cubic centimeters, milliliters, grams).

Oil consumption can be assessed with a questionnaire similar to that showed on table V.

Once the quantity of consumption register is done (24hrs method for 2 or 3 consecutive days, completed with the food consumption register) we must consult the specific labeling of each of them to know the micro nutrient content and therefore be able to calculate the intake of these.

Determining essential fatty acids in plasma (oleic acid, linoleic acid and arachidonic acid) and vitamin E can indicate the amount of oil consumed.

References

1. Aranceta J, Pérez C. *Diario o registro dietético*. *Nutrición y salud pública*. 2ª Ed. Serra Majem Ll, Aranceta Bartrina J Editores. Barcelona 2006:158-67.
2. Banegas JR, Villar F, Aranceta J, Serra Ll, Vázquez C, Sastre et al. *Rev San Hig Pub* 1991. Vol 68. Nº2.
3. Mataix J. *Nutrición y Alimentación Humana*. Ed Ergon. 2009. Vol 2 68-70.
4. EFSA. Panel on Dietetic Products, and Allergies (NDA); Scientific Opinion on Dietary reference values for water. *EFSA Journal* 2010; 8(3):1459-84.
5. Committee on the Scientific of Dietary Reference Intake: *Dietary reference intakes for water, potassium, sodium, Chloride and Sulfate*. Washigton. 2005.
6. Reducción del consumo de sal en la población. Informe OMS. Paris 2006.
7. Métodos para determinar las principales fuentes de sal en la alimentación. Informe expertos OPS/OMS. Ferr-Luzzi A. Keynote paper: Individual food intake survey methods. http://www.fao.org/docrep/005/y4249e.htm. 2010.
8. Ortega RM, Requejo AN. Guías en Alimentación. *Manual de Nutrición Clínica en Atención Primaria*. Ed Complutense. Madrid. 2006.
9. *EFSA Journal* 2011; 9(4):2033.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):76-83
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Dietary assessment in children and adolescents: issues and recommendations

Carmen Pérez-Rodrigo[1,2], Belén Artiach Escauriaza[2], Javier Aranceta Bartrina[3,4,5] and Isabel Polanco Allúe[6]

[1]Fundación FIDEC. Bilbao (Spain). [2]Spanish Society of Community Nutrition (SENC). [3]Departamento de Medicina Preventiva y Salud Pública. Universidad de Navarra. [4]Fundación para la Investigación Nutricional, Parc Científic de Barcelona. [5]CiberOBN, Instituto de Salud Carlos III, Madrid. [6]Facultad de Medicina, UAM. Servicio de Gastroenterología y Nutrición, Hospital Infantil Universitario La Paz, Madrid, España.

Abstract

The assessment of dietary intake in children and adolescents is of great interest for different purposes. The characteristics of each developmental stage and associated cognitive abilities are two factors that influence the ability of children to provide valid and reliable information on food consumption. The ability to remember, limitations of vocabulary or the ability to identify different foods are some of the relevant aspects. In addition, often parents or caregivers provide surrogate information and their degree of knowledge depends on the time they spend with the child and on whether they share meals. As children grow they become more independent and increasingly spend more time away from their parents. Children also have limitations to recognize food models and photographs and associate them with different amounts of food consumed. On the other hand, often children and adolescents perceive long interviews or self-administered questionnaires they as long and boring. The use of new technologies is contributing to the development of new tools adapting dietary assessment the methods to the cognitive abilities of children, introducing gaming environments and narrative structures that attract their interest and improve the quality of information they report..

(*Nutr Hosp* 2015;31(Supl. 3):76-83)

DOI:10.3305/nh.2015.31.sup3.8755

Key words: *Children adolescents. Food habits. Dietary assessment. New technology.*

EVALUACIÓN DE LA INGESTA EN NIÑOS Y ADOLESCENTES: PROBLEMAS Y RECOMENDACIONES

Resumen

El análisis de la ingesta alimentaria en niños y adolescentes es de gran interés con diferentes fines. Las características propias de cada etapa del desarrollo evolutivo y las capacidades cognitivas en cada edad son dos factores que influyen sobre la capacidad de los niños para proporcionar información válida y fiable sobre el consumo de alimentos. La capacidad de recordar, limitaciones de vocabulario o la capacidad para identificar distintos alimentos son algunos de los aspectos relevantes. Además a menudo son los padres o cuidadores quienes facilitan la información y su grado de conocimiento depende del tiempo que pasen con el niño y si comparten las comidas. A medida que crecen los niños son más independientes y cada vez pasan más tiempo sin sus padres. Los niños también tienen limitaciones a la hora de reconocer modelos de alimentos y asociarlos con diferentes cantidades. Por otro lado, las entrevistas largas o los cuestionarios auto-administrados les resultan largos y aburridos. El uso de las nuevas tecnologías están favoreciendo el desarrollo de nuevas herramientas que permiten adaptar los métodos de análisis de la ingesta a la capacidad cognitiva de los niños, introduciendo componentes lúdicos y narrativos que atraigan su interés y mejoren la calidad de la información..

(*Nutr Hosp* 2015;31(Supl. 3):76-83)

DOI:10.3305/nh.2015.31.sup3.8755

Palabras clave: *Niños adolescentes. Hábitos alimentarios. Análisis de la ingesta. Nuevas tecnologías.*

Correspondence: Carmen Pérez Rodrigo.
Fundación FIDEC. Gurtubay s/n.48010 Bilbao (Spain)
E-mail: carmenperezrodrigo@gmail.com

Abbreviations

BMI :Body Mass Index.
EGFCD: Expert Group on Food Consumption Data.
EU: European Union.
EFSA: European Food Safety Authority.
EPIC: European Prospective Investigation into Cancer and Nutrition.
EU Menu: What's on the Menu in Europe.
FFQs: Food Frequency Questionnaires.
IDEFICS: Identification and Prevention of Dietary- and Lifestyle-induced Health Effects in Children and Infants.
PANCAKE: Pilot study for the Assessment of Nutrient intake and food Consumption Among Kids in Europe.
RFPM: Remote Food Photography Method.

Introduction

Accurate assessment of food and beverage consumption in children and adolescents is central to monitor trends. Often it is also required for epidemiological and clinical research on the associations between diet and health. It is essential as well to identify predictors and outcomes of children's diets, identify targets for intervention, understanding behaviour change processes, plan policies and to develop and evaluate interventions.

Dietary assessment is always a challenge and previous research suggests that collecting reliable and accurate dietary data from children and adolescents can be difficult. The 24-hour recall, dietary records, dietary histories, Food Frequency Questionnaires (FFQs), brief instruments, observations of children's diets and mixed instruments such as a dietary record-assisted 24-hour recall have all been used to assess children's intakes.

Developmental, cognitive, social and behavioural characteristics of respondents have an influence, but also the observer needs special requirements and attributes. Hence, in addition to the systematic error and bias inherent to each method of dietary assessment, peculiarities in the population group make their reporting of food intake prone to additional error. However,

Table I
Issues to consider in the assessment of dietary intakes of children and adolescents

Cognitive Ability	Lower literacy skills
	Limited attention span
	Limited concept of time
	Limited memory – subconscious memory lapses across all or selected dietary items such as snacks
	Limited knowledge of food, food preparation, measurement
	Lack of familiarity with components of mixed dishes and added ingredients
	Portion size estimation
	Frequency of consumption estimation
Surrogate reporting	Parents
	Caregivers
	Combination
Social desirability	Under reporting – Over reporting
	Weight status of the child
	Weight status of the parents
Dietary Habits	Variable food habits - more structured in childhood than in adolescence
	More in-home eating (childhood)
	More out-of-home eating (adolescence)
	Parental influence important in childhood
	Peer influence important in adolescence
Other considerations	Body image concerns and dieting behaviours
	Lack of co-operation and motivation (adolescence)
	A conscious/subconscious need for social approval

research on the magnitude and direction of bias is limited. Validation studies using biomarkers of energy intake such as doubly labelled water have provided an insight[1]. Research on cognitive processes involved in dietary recall and estimation of portion size has informed interesting developments and projects based on the new technologies that can reduce bias and improve the accuracy of reports on children's diets[2].

Children dietary assessment often rely on respondents self-reported intakes, either by children them self, by parents, by caregivers or a combination. The accuracy of these self-reports may be compromised because of cognitive factors, such as children's memory of food intake and retrieval of information, their ability to estimate the size of portions consumed, ability to identify foods, knowledge of food names, etc. [1].Social desirability such as reporting in line with perceived norms also influences self-reports[3], as well as study factors, such as taking part in an intervention study focusing on healthy dietary habits. Reporting about diet itself may also modify eating habits. Table I displays a number of issues that should be considered when deciding the suitable dietary assessment method to use in children.

Cognitive abilities and reporting dietary intake

Dietary assessment techniques often require the respondent to remember many details about their food intake at different points in the past, including the names of the foods and beverages consumed, type, preparation, time of consumption, place, eating occasion, weekday, but also they have to remember and estimate the amount of food consumed, and when doing so, they are asked to relate their memory to pictures, models or household measures. These are complex tasks that require attention for the whole duration of the interview and certain literacy and writing skills. Researchers have identified these abilities as an adequately developed concept of time, a good memory and attention span, and knowledge of the names of foods[4], but the level of development of such abilities depends on the developmental stage and varies between children.

Research on this regard suggests that children between 0-7 years probably need a proxy reporter or observer. Between ages 8-10 years some children may need assistance. It is not clear how well can report 11-13 year-olds, and many of those aged 14 years + can probably provide self-reports. Thus parents or caregivers are often used as proxy reporters of their children's dietary intake, particularly needed for details about the types and quantities of food consumed, because of children's more limited food vocabularies[1,5]. The age at which a child becomes an accurate self-reporter of his own dietary intake has been estimated to be approximately 12 years, although this varies by dietary assessment method, with a transition period between ages 8 -12 years, but there is no recommendations on who is the most appropriate reporter of dietary intake for children in this age range[6]. From the age of about 7–8 years there is a fairly rapid increase in the ability of children to participate in unassisted recall, but only for food eaten in the immediate past and for no longer than the previous 24 hours. Even in that case it is likely that older children can remember better weekday food intake than more irregular eating patterns, weekend days or events[1,7].

Self-reporting on dietary intake involve understanding what information is being asked for, and searching for and evaluating the retrieved information before providing a response. Errors can emerge because the respondent is unable to complete the task but also because the observer provided inappropriate cues. Errors associated with children's recall of food intake includes both, under-reporting (missing foods), over-reporting (phantom foods/intrusions) and limited memory –subconscious memory lapses across all or selected dietary items such as snacks and incorrect identification of foods because of a limited knowledge about foods[8]. Baxter et al. found that reporting accuracy in children was related to their age/sex Body Mass Index (BMI) percentile, with greater underreporting among the obese. Moore et al reported that episodic memory, classroom behaviour, attitudes, socioeconomic status, and total items consumed were associated with bias in questionnaire self reports[9]. In addition, distractions may interfere as well. Certain foods such as main course items may be recalled more easily than less common foods or side dishes and additions to foods[8]. Children often have limited knowledge of food, food preparation and are not familiar with components of mixed dishes and added ingredients.

A validation study investigating the effects of retention interval - the elapsed time between to-be-reported meals and the interview- on children's accuracy for reporting school-meal intake during 24-hour dietary recalls in fourth grade students, analyzed food-item-level for omission rates (percentage of observed but unreported items), intrusion rates (percentage of reported but unobserved items), and total inaccuracy (combined reporting errors for items and amounts). Researchers found that children's accuracy for reporting school-meal intake was better for prior- 24-hour recalls than previous-day recalls, best for prior- 24-hour recalls obtained in the afternoon and evening, and worst for previous-day recalls obtained in the afternoon and evening[10].

Children are able to answer many questions that are directly relevant to them, but to date little is known about the cognitive constraints on children's ability to retrieve dietary information. Baranowski et al. suggested a model that categorizes the processes involved into attention, perception, organization, retention, retrieval and response formulation. Further development of the model includes the following retrieval strategies during children dietary self-report[11]: visual imagery (appearance of the food); usual practice (familiarity

with eating the food); behaviour chaining (association with preferred food or favourite activity during a meal or day); and preference (favourite food).

It is not clear whether children under 10 years could accurately answer a FFQ covering a period longer than 1 day, since this requires abilities such as conceptualize frequency. This involves averaging and abstraction skills children of that age are not able to cope with[1,12]. In addition, FFQs require capacity to concentrate and attention throughout the whole questionnaire. It has been suggested that to complete an FFQ, children need to be >12 years old. However, it is uncertain when a child is between eight and 12 years old as to who, parent or child, should be asked to report child intake, considering factors such as increasing child independence, cognitive abilities and increased consumption of food and drinks outside the home outside of parental control[13]. Overall, the consensus seems to be that the characteristics of different age groups call for the use of different assessment approaches[14].

Adapting FFQs for children need to consider a number of issues. Regarding the food list, children are more likely to interpret questions literally, impairing their ability to report accurately about composite foods. Time intervals are another issue. Concept of the past can make estimating frequency of food use during a specific time period more problematic. Time periods may need to be fixed by meaningful start and end points and may need to be shorter, as children typically have more changeable food patterns. Children tend to respond affirmatively to authoritatively phrased questions, or if unsure of the question, do not have an opinion or are disinterested, thereby reducing accuracy of information provided. Words that are consistent with a child's understanding of a given situation need to be used. Probes may need to be more specific. The structure of the questionnaire requires some careful attention. Easier questions on topics of interest must be asked first, followed by more difficult or more threatening questions[15, 16].

Surrogate reporting of children's dietary intake

Although parents of preschool children may provide accurate reports of their children's food consumption, reports appear to be no more valid than children's self-reports once children reach school age. However, young children may spend part of the day with child minders or away from home in care centres.

School age children become more independent. They often have lunch and snacks at school, to some extent decide on their own choices on what they eat or even shop limited items by themselves. In addition, they often do not share meals with their parents, who may not be responsible either for preparing the food, but delegate the task on someone else who may be required to provide additional information on what children eat[17].

Results from studies comparing the results of direct observations of children's food intake with 24hour recall by parents, suggest that parents can be reliable reporters of their children's food intake in the home setting, but less reliable reporters of their children's food intake out of home[17].

Some children aged 10 years and older would perceive assistance from parents or teachers as an intrusion, and would like to complete the dietary assessment by themselves[1].

Questions have also been raised about the bias that parents may provide to their child's report of intake[1,18]. A Finnish study showed that parents were more likely to report health behaviours in line with recommended and desired behaviours than children do[19]. However, a recall where the mother and/or father assists and cooperate with the child may yield better estimates than the child or parent alone[20]. The parents can assist by prompting children, adding food details and assist with practical issues connected to reporting.

Burrows et al compared and validated 8-11 years children versus parents reporting of children's energy intake using food frequency questionnaires versus food records. They concluded that children were the most accurate reporters when compared to their parents, with fathers more accurate than mothers. They also found that estimates of energy intake based on 4-day weighted food records were approximately equal to the child report FFQ[13].

For preschool-aged children, information is obtained from surrogates, usually the primary caretaker. A "consensus" recall method, in which the child and parents report as a group on a 24-hour recall, has been shown to give more accurate information than a recall from either parent or child alone[21]. Tips for interviewers to maximize data accuracy have been suggested.

In the Identification and Prevention of Dietary- and Lifestyle-induced Health Effects in Children and Infants study (IDEFICs), two proxy-reported 24-hour recalls from 4-10 year old children were found to be a valid instrument to assess energy intake on group level but not on the individual level[22].

Portion size

Early studies suggested that young children cannot estimate portion size accurately, even when prompted with visual aids[1]. However, older children and adolescents also experience difficulty in reporting portion size. Overall, in the majority of studies that have used quantification tools such as household measures and graduated food models, little attention has been paid to how well such aids work with children[1]. Estimating the amount of food consumed is a complex cognitive task difficult for many children[11, 23]. It requires that children can recognize and describe food quantities in terms of proportions or whole units. It also assumes that children can think abstractly about food and understand

the meaning of generic food models of different volumes and dimensions, or food photographs. Children younger than 10-11 years old are very unlikely to be able to efficiently perform these abstraction tasks. The accuracy of children's estimates of portion size using age-appropriate photographs, sensitive to the cognitive abilities of children, has shown not to be different from that of adults in a study by Foster et al.[24].

Foster et al. demonstrated that children are able to use portion size assessment tools to estimate portion size as young as 4–6 years old, although precision and accuracy of estimates improved with age using different tools[24]. Conservation is the ability to recognise that a size or quantity remains the same when the appearance of the object changes. The ability to conserve develops at about 7 years of age. Additionally, children need to be able to report foods actually consumed, rather than that served, which requires reporting leftovers, thus portion sizes suitable for estimation of leftovers may be required as well. Foster et al tested different measurement aids with children and found photographs and an interactive tool to perform better than food models. Baranowski et al found that multiple smaller food images in progressively larger amounts on the same screen enabled children to more quickly report food portion size than larger single-portion pictures presented one at a time. The presence or absence of visual cues such as a tablecloth and cutlery in images did not influence accuracy of portion size[25].

Dietary habits of children and adolescents

Food habits of children are more structured than in adolescence. Children more often eat at home while adolescents often do it out-of-home. Parental influence is important in childhood, while peer influence in important in adolescence.

In adolescence eating habits are rapidly changing and unstructured eating is common (snacks, meal skipping), with high levels of restrained eating.

Additional considerations regarding adolescence include body image concerns and dieting behaviours[26].

Social desirability

Children may under-report or over-report some dietary habits because they may perceive their own practices, or what they report as own practice, are either socially undesirable or desirable, respectively. Socially desirable responses are more frequent in younger than in older children[27]. Interviewer administrated 24 hour recall, where children and/or parents are sitting in front of an interviewer, have shown to provide social desirability biases[28,29]. This may not occur to the same extend when reporting in private.

The association between dieting and weight consciousness with misreporting is the most frequent and consistent. Parental obesity status and/or the extent to which parents perceive that information about their child's diet is a reflection of their child's weight may also compromise reporting accuracy[1]. It has been suggested that a small part of the inaccuracy of children's self-reports is deliberate and might be due to social desirability[4].

Co-operation of respondent

Engaging children and adolescents in reporting their food intake is particularly challenging, but motivation is essential to gain collaboration which will help overcome some of the difficulties discussed. Assessment tools should facilitate cooperation of children and parents. Some useful characteristics for that purpose are being intuitive, easy and fast to complete, flexible in choices, nonintrusive, engaging, age appropriate and fun. Providing feed-back, and some kind of recognition such as gift or incentive may also be important. Co-operation and motivation is more difficult in adolescence. Although they are more able to report, adolescents may be less interested in giving accurate reports[18].

Other factors

Being part of an intervention study focused on body weight and healthy eating habits, having clinical measurements or blood samples taken as indicators of diet, health or lifestyle diseases may unconsciously change influence dietary behaviour. Reporting food intake may in itself cause reactivity and a change in habits. This is especially a risk with Food diaries and food records. Reporting foods as they are eaten can affect both the types of foods and the amounts consumed, thus leading to under eating in the reporting period[14]. Furthermore, completing food records is time consuming, and can be perceived as boring. Using self-administered tools as well as long monotonous face-to-face interviews can result boring and cause fatigue in children that affect dietary information retrieval[12]. This may lead to misreporting or alternative eating habits substituting foods which are easier to report[3].

Advantages and limitations of different dietary assessment methods in children

Single or repeated 24-hour recalls and food records of varying duration have been widely used in children and adolescents. For school-age children and adolescents, there is no consensus of which dietary assessment method is most accurate. The choice of which instrument to use may depend on the study objectives and study design factors, all of which will influence the appropriateness and feasibility of different approaches[14].

Developmental cognitive issues, problems with memory and information retrieval in children as well as those related to estimation of portion sizes have been discussed above. These issues are particularly relevant for 24 hour recalls and FFQs. In children, previous studies with double-labeled water used as a standard have shown that the food frequency questionnaire overestimates total calorie intake by ;50%,83 whereas repeated 24-hour recalls84 and weighed diet records 85 provide reasonably accurate group mean values for intake, although the values are not accurate on an individual basis[30]. Generally, correlations between food frequency type instruments and more precise reference instruments have been lower in child and adolescent populations than in adult populations. A web-based food behavioural questionnaire underestimated the intake of middle-school children compared to a multiple-pass 24-hour recall[31].

It has been suggested that food records using digital pictures may be a valid and feasible method for assessing food intake of preschool children[32]. Results of a pilot test showed an average 0,96 correlation between estimated weights and actual weights and the digital diet estimates were 5% lower than the actual weights. The Remote Food Photography Method (RFPM), which relies on smartphones to estimate food intake in near real-time in free-living conditions. When using the RFPM, participants capture images of food selection and leftovers using a smartphone and these images are wirelessly transmitted in near real-time to a server for analysis[33].

Systems based on digital photography to be used in school cafeterias have been developed and tested as well. This observation method consists of standardized photography of the food selected before the meal and the plate waste following the meal. Using reference portions of measured quantities of the foods, expert judgment is used to estimate the amount of each food consumed[34, 35].

Another approach that has been used with school-age children is a combination instrument, the record assisted 24-hour recall. In this case children record only the names of foods and beverages consumed throughout a 24-hour period. This information serves as a cue for the later 24-hour recall interview.

The European Food Consumption Validation Project provisionally recommended a similar approach -a food recording booklet for foods eaten away from home- for schoolchildren 7-14 years old. Nevertheless, studies examining the validity of this approach have had mixed results

An European Union (EU)-wide standardized food consumption data collection system (EU Menu) was initiated in 2010. The system uses a methodology that enables comparability of data and provides information that is detailed enough for risk assessments that are representative of all countries and regions in the EU. In addition, the data will useful nutrition purposes and public health policy makers. The collection of food consumption data is planned to be carried out as a rolling programme from 2012 to 2017[36].

The Expert Group on Food Consumption Data (EGFCD) recommended in 2009 the dietary record including two non-consecutive days the method to be used in to infants, toddlers and other children (from 36 months to 10 years of age). The EGFCD considered that this method facilitates a combination of parents and (various) caretakers in recording the foods and beverages consumed, depending on the location of the child. The group considered that non-respondent bias is probably less of a problem in this population group since response rates in studies among children are generally higher compared to other population groups[37].

The Pilot study for the Assessment of Nutrient intake and food Consumption Among Kids in Europe (PANCAKE) project provided tools and protocols for a future harmonised pan-European food consumption survey in infants, toddlers and children, with specific recommendations for further improvement and on the preferred dietary assessment method. The authors recommended to use the two non-consecutive one-day food diaries followed by an EPIC-Soft completion interview with the parent/caretaker as main dietary assessment method. They also advise the use of validated PANCAKE picture books for quantification of portion sizes of consumed foods and recommend to collect additional information with a questionnaire on background characteristics, a food propensity questionnaire, and measurement of height and weight[38].

New approaches and technologies to improve accuracy in diet reporting

Formative research on the use of innovative technologies, such as computers, the Internet, personal digital assistants and mobile phones, to obtain information on food consumption is important for the development of these technologies[39-41]. The many possibilities technologies offer have been used in diverse ways to enhance accuracy, minimize self-report errors and otherwise make it easier to report diet[42]. A number of innovative technology based methods to address the needs for dietary assessment in children have been developed. New technology-based methods, such as disposable cameras, mobile phones with cameras, and smart phones, are being developed for collecting records.

Using web-based technology for dietary assessment offers standardization of the sequence of the questions, can include audiovisual stimuli, provide immediate results, increased flexibility, and easy and fast updating facilities[9,18,43]. The use of technology to collect dietary intake data is especially engaging to children, adolescents and younger adults who are familiar with the technology in their daily lives. Perceptions of “enjoyable” and “easy to use” are rated highly in many com-

puterized diet programmes. Many adolescents prefer these methods to traditional methods[14].

To be successful, however, any self- completed diet assessment instrument requires some minimum attention, memory, and categorization skills. A useful skill for successfully self-completing a 24-hour diet recall is the ability to identify foods consumed by "browsing" among hierarchically organized food groups or by "searching" (typing in food names). Observers reported that many children relied on pictures of foods (category collages) rather than text to make their selections in the cover-flow method[25].

A web-based dietary assessment software system that assess the dietary intake among 8-10 year old children should include motivation factors, and try to motivate the children by the soft-wares functionality, content, aesthetics and setting[25].

Boredom and fatigue affect dietary information retrieval especially when using self-administered instruments with children[12]. Theories from media psychology and communication research provide innovative perspectives to address children's motivation and accuracy in dietary assessment. A challenge for entertainment media is to provide an environment that motivates children to accurately complete the dietary assessment task[44] Innovative strategies for enhancing children's motivation for dietary assessment and for enhancing accuracy of reporting have been suggested. One of the strategies suggested to motivate children to complete a dietary assessment is the use of animated, customisable agents which could guide and interact with children during the process. Embed the assessment process into a video game is another motivating strategy. Control and interactivity are two distinct features of videogames. The challenge is to design such interactivity to minimise adverse reaction to the reporting of dietary intake, for instance by providing non-evaluative feedback periodically during dietary report[44]. A third useful strategy is to add narratives to encourage self-reporting behaviour. Stories could provide intriguing incentives for children who feel encouraged to finish the story. Virtual recreation of intake environment, training sessions interspersed to improve portion estimation and implicit attitudinal measures incorporated in the process as a control or to increase validity have been suggested among the strategies to improve accuracy. Many motivation and accuracy strategies could be combined. For example, a video game with an involving storyline could include multiple accuracy training sessions via a virtual environment. However, more research is needed to operationalise and validate these theoretically useful strategies.

References

1. Livingstone MBE, Robson PJ, Wallace JMW. Issues in dietary intake assessment of children and adolescents. *Br J Nutr* 2004; 92 (Suppl. 2): S213–S222
2. Adamson AJ, Baranowski T. Developing technological solutions for dietary assessment in children and young people. Journal of Human Nutrition and Dietetics J. *Hum Nutr Diet* 2014; 27(Suppl. 1), 1–3.
3. Macdiarmid J, Blundell J. Assessing dietary intake: Who, what and why of under-reporting. *Nutr.Res.Rev* 1998; 11: 231-253.
4. National Cancer Institute. National Children's Study Dietary Assessment Literature Review. http://riskfactor.cancer.gov/tools/children/review/pdf/ (Accessed January 2015).
5. Sobo EJ, Rock CL. "You ate all that!?": caretaker-child interaction during children's assisted dietary recall interviews. *Med Anthropol Q* 2001;15: 222-244.
6. Burrows TL, Martin RJ, Collins CE. A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labeled Water. *J Am Diet Assoc* 2010;110:1501-1510
7. Haraldsdöttir J, Hermansen B. Repeated 24-h recalls with young schoolchildren. A feasible alternative to diet history from parents? *Eur J Clin Nutr* 1995; 49: 729–739.
8. Baxter SD. Cognitive processes in children's dietary recalls: insight from methodological studies. *Eur J Clin.Nutr* 2009; 63 Suppl 1: S19-S32.
9. Moore GF, Tapper K, Moore L, Murphy S. Cognitive, Behavioral, and Social Factors Are Associated with Bias in Dietary Questionnaire Self-Reports by Schoolchildren Aged 9 to 11 Years. *J Am Diet Assoc* 2008;108:1865-1873.
10. Baxter SD, Guinn CH, Royer JA, Hardin JW, Smith AF. Shortening the Retention Interval of 24-Hour Dietary Recalls Increases Fourth-Grade Children's Accuracy for Reporting Energy and Macronutrient Intake at School Meals. *J Am Diet Assoc* 2010;110:1178-1188
11. Baranowski T, Domel SB. A cognitive model of children's reporting of food intake. *Am J Clin Nutr* 1994;59, Suppl.: 212S–217S
12. Domel SB, Baranowski T, Davis H, Leonard SB, Riley P, Baranowski J .Fruit and vegetable food frequencies by fourth and fifth grade students: validity and reliability. *J Am Coll Nutr* 1994;13, 33–39.
13. Burrows TL, Truby H, Morgan PJ, Callister R, Davies PSW, Collins CE. A comparison and validation of child versus parent reporting of children's energy intake using food frequency questionnaires versus food records: Who's an accurate reporter? *Clin Nutr* 2013; 32: 613e618
14. Thompson FE, Subar AF. Dietary assessment methodology. In: Coulston AM, Boushey CJ, Ferruzzi MG, eds. Nutrition in the prevention and treatment of disease. 3rd ed. *New York: Academic Press* 2012:5–46.
15. Subar AF, Thompson FE, Kipnis V, Midthune D, Hurwitz P, McNutt S, et al. Comparative validation of the Block, Willett, and National Cancer Institute food frequency questionnaires : the Eating at America's Table Study. *Am J Epidemiol* 2001 Dec 15;154[12]:1089-99.
16. McPherson RS, Hoelscher DM, Alexander M, Scanlon KS, Serdula MK. Dietary Assessment Methods among School-aged children: Validity and Reliability. *Prev Med* 2000;31:S11-S33.
17. Baranowski T, Sprague D, Baranowski JH, Harrison JA. Accuracy of maternal dietary recall for preschool children. *J Am Diet Assoc* 1991;91, 669–674.,
18. Biltoft-Jensen A. Web-based Dietary Assessment for 8-11 Year Old School- children PhD Thesis. DTU National Food Institute. *National Food Institute Technical University of Denmark Division of Nutrition. Søborg, DK* 2012
19. Ross E, Ray C, Stoor C. Measuring children's health behaviours, comparing answers from 10-11 years old children and their parents. *7th International Conference on Diet and Activity Methods* 2009: pp. 305-306. National Cancer Institute, Washington, DC
20. Eck LH, Klesges RC, Hanson CL. Recall of a child's intake from one meal: are parents accurate? *J Am.Diet.Assoc* 1989, 89, 784-789.
21. Sobo EJ, Rock CL. "You ate all that!?": caretaker-child interaction during children's assisted dietary recall interviews, Med. Anthropol. *Q* 2001; 15: 222-244)

22. Börnhorst C, Bel-Serrat S, Pigeot I, Huybrechts I, Ottavaere C, Sioen I. et al.Validity of 24-h recalls in (pre-)school aged children: Comparison of proxy-reported energy intakes with measured energy expenditure. *Clin Nutr* 2014; 33: 79e84
23. Matheson DM, Hanson KA, McDonald TE, Robinson TN. Validity of children's food portion estimates: a comparison of 2 measurement aids. *Arch Pediatr Adolesc Med* 2002; 156, 867–871.
24. Foster E, Adamson AJ, Anderson AS, Barton KL, Wrieden WL. Estimation of portion size in children's dietary assessment: lessons learnt. *Eur J Clin Nutr* 2009;, 63, S45-S49
25. Baranowski T, Islam N, Baranowski J, Martin S, Beltran A, Dadabhoy H et al. Comparison of a Web-Based versus Traditional Diet Recall among Children. *J Acad Nutr Diet* 2012;112:527-532)
26. Marshall S, Watson J, Burrows T, Guest M, Collins CE. The development and evaluation of the Australian child and adolescent recommended food score: a cross-sectional study. *Nutr J* 2012 Nov 19;11:96. doi: 10.1186/1475-2891-11-96.
27. Baxter SD, Smith AF, Litaker MS, Baglio ML, Guinn CH, Shaffer NM. Children's Social Desirability and Dietary Reports. *J Nutr Educ.Behav* 2004; 36: 84-89.
28. Guinn CH, Baxter SD, Hardin JW, Royer JA, Smith AF. Intrusions in children's dietary recalls: the roles of BMI, sex, race, interview protocol, and social desirability. *Obesity (Silver Spring)* 2008; 16: 2169-2174.
29. Sherwood N. Diet assessment in children and adolescents. In: Elissa J, Steele RG (eds). Handbook of childhood and adolescent obesity. *Springer* 2008: pp. 73-89.
30. Goran MI. Measurement Issues Related to Studies of Childhood Obesity: Assessment of Body Composition, Body Fat Distribution, Physical Activity, and Food Intake. *Pediatrics* 1998;101:505–518
31. Hanning RM, Royall D, Toews JE,. Blashill L, Wegener J, Driezen P. Web-based Food Behaviour Questionnaire: validation with grades six to eight students, Can. J. Diet. Pract. *Res* 2009; 70: 172-178
32. Nicklas TA, O'Neil CE, Stuff J, Goodell LS, Liu Y, Martin CK. Validity and Feasibility of a Digital Diet Estimation Method for Use with Preschool Children: A Pilot Study. *J Nutr Educ Behav* 2012;44:618-623.
33. Magarey A, Watson J , Golley RK , Burrows T , Sutherland R, McNaughton SA et al. Assessing dietary intake in children and adolescents: Considerations and recommendations for obesity research. *Int J Pediatr Obes* 2011; 6[1]: 2-11 (doi: 10.3109/17477161003728469)
34. Martin CK, Newton RL Jr, Anton SD, Allen HR, Alfonso A, Han H, et al., Measurement of children's food intake with digital photography and the effects of second servings upon food intake. Eat. *Behav* 2007; 8: 148-156.
35. Biltoft-Jensen A, Trolle E, Christensen T, Islam N, , Andersen LF, Egenfeldt-Nielsen S, Tetens I. WebDASC: a web-based dietary assessment software for 8–11-year-old Danish children. *J Hum Nutr Diet* 2014 Jan;27 Suppl 1:43-53. doi: 10.1111/j.1365-277X.2012.01257.x. Epub 2012 May 18.
36. European Food Safety Authority; on request of EFSA. EFSA Report on Data Collection: Future Directions. EFSA Journal 2010; 8[5]:1533. [35 pp.]. doi:10.2903/j.efsa.2010.1533. Available online: www.efsa.europa.eu
37. European Food Safety Authority; General principles for the collection of national food consumption data in the view of a pan-European dietary survey. *EFSA Journal* 2009; 7[12]:1435. doi:10.2903/j.efsa.2009.1435. Available online: www.efsa.europa.eu
38. Ocké M, de Boer E, Brants H, van der Laan J, Niekerk M, van Rossum C et al. PANCAKE – Pilot study for the Assessment of Nutrient intake and food Consumption Among Kids in Europe. *Supporting Publications* 2012:EN-339 [120 pp.]. Available online: www.efsa.europa.eu/publications
39. Ngo J, Engelen A, Molag M, Roesle J, Garcia-Segovia P, Serra-Majem L. A review of the use of information and communication technologies for dietary assessment. *Br. J. Nutr* 2009; 101, S102–S112;
40. García-Segovia P, González-Carrascosa R, Martínez-Monzó J, Ngo J, Serra-Majem L. New technologies applied to food frequency questionnaires: a current perspective. *Nutr. Hosp* 2011; 26, 803–806
41. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim SP, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *Int J Epidemiol* 2012;41:1187–1203
42. Long JD, Littlefield LA, Estep G, Martin H, Rogers TJ., Boswell C, Shriver BJ, Roman-Shriver CR. Evidence review of technology and dietary assessment. Worldviews Evid. *Based Nurs* 2010; 7, 191–204.
43. Vereecken CA, Covents M, Sichert-Hellert W, Alvira JM,Phillipp MK, Beghin L, et al. Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. *Int J Obes (Lond)* 2008; 32 Suppl 5, S26-S34.
44. Lu A, Baranowski J, Islam N, Baranowski T. How to engage children in self-administered dietary assessment programs. J. Hum. *Nutr. Diet* 2014; 27(Suppl. 1), 5–9.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):84-90
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Special considerations for nutritional studies in elderly

Pilar Riobó Serván[1], Roberto Sierra Poyatos[1], Judith Soldo Rodríguez[1], Carmen Gómez-Candela[2], Pedro Pablo García Luna[3] and Lluis Serra-Majem[4]

[1]Endocrinology and Nutrition Department. Hospital Fundación Jiménez Díaz- idc salud. Madrid. [2]Nutrition Department, Hospital La Paz. University Autonoma of Madrid. [3]Endocrinology and Nutrition Department. Hospital Virgen del Rocío. Sevilla. [4]Health Public DepartmentResearch Institute of Biomedical and Health Sciences, Universidad de Las Palmas De Gran Canaria. Spain.

Abstract

The elderly population is increasing and it is well documented that may present some health problems related to nutritional intake. Both mental and physical impairments in the elderly may need specific adaptations to dietary assessment methods. But all self-report approaches include systematic and random errors, and under-reporting of dietary energy intake is common. Biomarkers of protein intake, as 24 hours urinary Nitrogen, may not be useful in elderly patients because of incontinence problems. Some micronutrients, like vitamin B12, have special importance in the elderly population. Also, measurement of fluid intake is also critical because elderly population is prone to dehydration. A detailed malnutrition status assessment should be included in the geriatric dietary history, and assessment. Body mass index (BMI) is not useful in the elderly, and it is important to evaluate functional status. Gait speed, handgrip strength using hand dynamometry can be used. Body Shape Index (ABSI) appears to be an accurate measure of adiposity, and is associated with total mortality. Further research is needed to clarify the best and simple methods to accurately estimate food and beverage fluid intake in the elderly population, and to evaluate nutritional and hidration status.

(*Nutr Hosp* 2015;31(Supl. 3):84-90)

DOI:10.3305/nh.2015.31.sup3.8756

Key words: *Elderly population. Underreporting. Nutritional status. Obesity. Food frequency questionnaire. Biomarkers. Energy intake.*

CONSIDERACIONES Y RECOMENDACIONES EN EL CASO DE ESTUDIOS NUTRICIONALES REALIZADOS EN ADULTOS MAYORES

Resumen

La población de edad avanzada está aumentando y puede presentar problemas de salud relacionados con la ingesta alimentaria. Los ancianos presentan alteraciones mentales, físicas y funcionales que precisan de adaptaciones específicas en los métodos de evaluación dietética. Todas las aproximaciones auto-referidas presentan errores sistemáticos, y es frecuente que se refiera una menor ingesta energética. Los biomarcadores de ingesta proteica, como el Nitrógeno urinario de 24 horas, pueden no ser útiles debido a la incontinencia. Algunos micronutrientes, como la vitamina B12, tienen una importancia especial en la población de edad avanzada. Igualmente, la medición de la ingesta de líquidos es importante, ya que pueden sufrir deshidratación. En la evaluación geriátrica debería incluirse una evaluación de la malnutrición. El índice de masa corporal (IMC) no es muy útil en el anciano, y es mejor evaluar la situación funcional. Pueden medirse la velocidad de la marcha, y la fuerza de prensión, medida con dinamómetro. El Índice de Forma Corporal parece ser una medición fiable de la adiposidad y se asocia con la mortalidad. Son necesarios más estudios para aclarar cuál es el mejor método para estimar de forma fiable la ingesta de comida y bebida en la población anciana y para evaluar el estado nutricional.

(*Nutr Hosp* 2015;31(Supl. 3):84-90)

DOI:10.3305/nh.2015.31.sup3.8756

Palabras clave: *Tercera edad. Infraestimación. Estado nutricional. Obesidad. Cuestionario de frecuencia de consumo. Biomarcadores. Ingesta energética.*

Abbreviations

BMI: Body mass index.
ABSI: Body Shape Index.
IMC: Índice de masa corporal.
FFQs: Food frequency questionnaires.
24HDR: 24 hour dietary recall.
4DFR: 4 day food record.
WHI: Women's Health Iniciative.
EI: Energy intake.
EE: Energy expenditure.
DLW: Doubly labeled water.
SWA: Sense Wear Pro3 Armband.
PFD: Coded food diary.
ICC: Intraclass correlation coefficient.

Correspondance: Pilar Riobó.
Endocrinology and Nutrition Department.
Hospital Fundación Jiménez Díaz- idc salud. Madrid, Spain.
E-mail: priobo@telefonica.net

DH: Dietary history.
EDR: Estimated dietary record.
BM: Biomarkers.
WBQ: Water balance questionnaire.
SGA: Subjective Global Assessment.
MUST: Malnutrition Universal Screening Tool.
NRS: Nutritional Risk Screening.
MNA: Mini Nutritional Assessment.
MNA-SF: Mini Nutritional Assessment Short Form.
GNRI: Geriatric Nutritional Risk Index.
NHANES: National Health and Nutrition Examination Survey.
HALS: Health and Lifestyle Survey.

Introduction

It is predicted that elderly population will reach more than 25% by year 2050[1], and this will may make us to face present different health problems due to increasing trend of nutritional related diseasesrelated to nutritional intake. A direct relationship between dietary habits and health outcomes[2] and mortality[3] have been reported. Even more, changes that occur during aging may, directly or indirectly, influence food and beverage intake. For example, smell and taste diminish, and digestive disorders can easily appear. Poor intakes are associated with increased risk of poor health, including functional decline. So, it is really important to accurately assess the nutritional situation of the elderly population.

Dietary intake

Several methods are available to assess dietary intake. Food frequency questionnaires (FFQs) have been used extensively used in nutritional epidemiology for assessing past and usual intake.They can be self-administered and are relatively inexpensive.The FFQ usually administered to elderly people have a range ofincluded food items included, reaching to more than 200. Other approaches are the 24 hour dietary recall (24HDR) and the 3 to 74 day food record (4DFR). The concern with short-term recalls and diet records is that they are expensive and unrepresentative of usual intake if only a few days are assessed. And all self-report approaches include systematic and random errors that can distort the described associations between diet and disease. It is well known that a general finding in dietary studies is under-reporting of energy intake, and it has been found in both adult and in elderly populations. Under-reporting in women is associated with fear of negative evaluation, weight loss history, percentage of energy from fat, or variability in number of meals per day[4]. Under-reporters usually tend to be less physically active, and they are more likely to dieting. For example, in the OPEN Study[5], a larger underreporting of dietary energy intake by overweight women was shown. In the Women's Health Iniciative (WHI), under-reporting by postmenopausic women was associated with fear of negative evaluation, weight loss history, less active, more likely to be on diet and eating less fat, restrained eating or the conscious effort to restrict calorie intake, high disinhibition or the loss of self-control in eating behaviour or anxiety and distress. In the WHI-NBS, a modest additional underreporting of energy intake was found among racial and ethnic minorities compared with white participants. In a study with 70–79 years old persons, by Sharhar et al.[6] among high-functioning community-dwelling elderly, it was shown that underreporters had significantly higher body weight than the rest of the participants.

Another important problem is that elderly population is an heterogeneous group, ranging from healthy, physically active and independently living people, to centenarians, fully dependent on care. Both mental and physical impairments may need specific adaptations to dietary assessment methods. We must keep in mind that memory may already start declining after the age of 55 years, and dietary recall ability decreases with age. So the 24HDR and, in a lower extent, the 4DFR methods may be inappropriate, due to age-associated cognitive decline and short-term memory impairment. Even more, the validity of self-reported dietary information also diminishes with increasing age of the responder, due to memory loss or visual impairment. The oldest elderly can become easily fatigued and frustrated with long dietary interviews and may take longer time to complete the questionnaire. In these circumstances, with incompetent patients, the information can be needed to get obtainedthe information from caregivers and surrogate or proxy sources. Therefore, it is very important that the choice of dietary assessment method should take into account cognitive skills and other characteristics of the elderly population. Surprisingly, few studies have assessed the use and validity of dietary assessment methods in elderly people, particularly those classified in the oldest age group[7,8].

Measurement of energy intake

As previously stated, obese individuals underreport their food intakes by 20–50% and it has been estimated that, as the degree of obesity increases, the same occurs with the degree of underestimation of energy intake (EI) [9]. Such systematic reporting errors and reporting biases consequently alter the ability of researchers to determine intake in overweight and obese individuals, and it becomes clear that methods to collect self-reported EI data are not good in overweight and obese populations. So it is important to examine the extent and nature of underreporting of food intake in obese populations.

The measurement of energy expenditure (EE) with use of the doubly labeled water (DLW) method has been used to investigate the validity of self-reported

dietary intake. This method of validation is based on the assumption that EI is equal to EE when weight is stable. As previously outlined, the largest discrepancy between self-reported EI and EE relative to DLW occurs in obese. Hise et al have performed a study to validate EI estimated from a pre-coded food diary against energy expenditure (EE) measured with the DLW method in a group of elderly men, with overweight/ obesity[10]. They evaluated the validity of the combined use of observer-recorded weighed-food records and 24-hour snack recalls in estimating energy intakes in overweight and obese individuals. EI was measured over 2 week in a university cafeteria and a 24-h snack recalls were conducted. And they concluded that the combination of observer-recorded food records and 24-h snack recalls is a valid method for measuring EI.

But the use of DLW method is limited because of its high cost, and the need for specialised equipment and trained staff. To avoid these problems, a devide has been developed, the Sense Wear Pro3 Armband (SWA; BodyMedia Inc., Pittsburg, PA, USA) that can be used to register energy expenditure in healthy adults. A reasonable level of concordance was demonstrated between SWA and DLW methods (ICC = 0.63) for measuring daily EE in free-living adults during 10 days of monitoring[11]. So, SWA can be considered a relatively inexpensive and practical method to accurate monitor EE.

Stea el al[12] validated the EI, estimated from a pre-coded food diary (PFD) against EE measured with the SWA, in a group of Norwegian elderly men aged 60–80 years. Participants recorded their food intake for four consecutive days using food diaries and wore the SWA during the same period. The group average EI was 17% lower at baseline and 18% lower at post-test compared to measured EE. Mean difference from Bland-Altman plot for EI and EE was 21.5 MJ/day (61.96 SD: 27.0, 4.0 MJ/day) at baseline and 21.6 MJ/day (26.6, 3.4 MJ/day) at post-test. The intraclass correlation coefficient (ICC) was 0.30 (95% CI: 0.02, 0.54, p = 0.018) at baseline and 0.34 (0.06, 0.57, p = 0.009) at post-test. Higher values of underreporting was shown among overweight/obese compared to normal weight participants at both baseline and post-test (p< 0.001), respectively. So, the authors conclude that the PFD could be a useful tool for estimating energy intake in normal weight elderly men, but it seems to be less suitable for estimating energy intake in overweight/obese elderly men.

Measurement of protein intake

When measuring protein intake, biomarkers of meat intake, as 24 hours urinary Nitrogen, can be used. Using this biomarker of protein intake, a potentially positive association of protein intake with risk of diabetes in postmenopausal women after calibration and body mass index (BMI) adjustment was found in the WHI study. This result suggested that protein consumption could contribute to diabetes risk through mechanisms other than body fat deposition. And this new described association is important to consider when counseling persons at risk of developing diabetes. But again, this method can not be useful in elderly patients because of incontinence problems.

Measurement of micronutrients intake

This is an area of concern because there are some micronutrients with special importance in the elderly population. For example, B12 vitamin is related to cognitive decline, that can even arise without the typical haematological abnormalities. But the estimation of micronutrient intake is a difficult task and can present extra challenges in elderly people. Grootenhuis et al.[13] used a semiquantitative food frequency questionnaire for epidemiologic research among the elderly and validated it comparing with dietary history (DH). They found that good agreement of mean nutrient intake and high correlation coefficients between the estimates of the self-administered semi-quantitative questionnaire and the DH method, the absence of non-constant bias for most nutrients and the ability of the questionnaire to classify individuals adequately into broad categories, demonstrated an acceptable relative validity. Using 4-dayFDR as the reference method, Dumartheray et al.[14] demonstrated a good level of nutrient intake estimation by FFQ for the majority of the micronutrients assessed. This demonstrates that the variability of the nutrient consumption is related to energy intake. Messerer et al. [15] assessed the validity of a self-administered FFQ and showed that overall, adding information about dietary supplement use increased the validity of micronutrient estimates by 13% based on a self-administered FFQ. Klipstein-Grobusch et al.[16] evaluated the relative validity of micronutrient intake estimated by a FFQ adapted for dietary assessment in the elderly as compared to 15-day estimated dietary record (EDR). The correlation coefficients observed in the present study ranged from 0-5 to 0-9 for crude and from 0-4 to 0-8 for adjusted data, indicating relatively good validity and being similar to results of validation studies in which either a FFQ or DH were administered to an elderly population. van de Rest et al. developed a FFQ to assess folate intake over the past 3 months in Dutch elderly people and showed a weak positive correlation between folate intakes estimated with the FFQ and serum folate concentrations (r 0-14), but not erythrocyte folate (r 0-05)[17]. This could be explained by the fact that the serum folate reflects recent intake and the erythrocyte folate reflects long-term intake and in this study, FFQ assessed food intake in the previous 3 months.

Dietary intakes of b-carotene estimated by different FFQ can be validated against plasma concentrations of this micronutrient. Vioque et al. demons-

trated that plasma concentrations of carotenoids and vitamin C are better correlated with dietary intake in normal weight than overweight and obese elderly subjects and that the correlations between usual intake of this micronutrient assessed by FFQ and their plasma concentration changed when the participants were grouped by BMI category[18].

A systematic literature review identified studies validating the methodology used in elderly people for measuring usual dietary micronutrient intake[19]. The quality of each validation study selected was assessed using a EURRECA-developed scoring system. The validation studies were categorized according to whether the reference method applied reflected short-term intake (<7 d), long-term intake (>7 d) or used biomarkers (BM). A total of 33 publications were included, 25 used different FFQ, 6 diet histories (DH), one 24-h recall (24HR) and one videotaped dietary assessment method. A total of 5 publications analysed BM, which were used to validate four FFQ, and one 24HR, presenting very good correlations only for vitamin E. The analysis of weighted correlation coefficients classified by FFQ or DH showed that most of the micronutrients had higher correlations when the DH was used as the dietary method. Comparing only FFQ results showed very good correlations for measuring short-term intakes of riboflavin and thiamin and long-term intakes of P and Mg. When frequency methods are used, the inclusion of dietary supplements improves their reliability for most micronutrients. Comparing FFQ methods used for assessing micronutrient intake with short-term reference methods, very good correlations were observed for thiamin and riboflavin. Nevertheless, a poor correlation was observed for b-carotene. When FFQ using longterm intakes as reference methods are compared, we have observed that a greater number of micronutrients present good correlations. They are also very good for measuring long-term intake of P and Mg. Micronutrients with poor correlations were not observed when the reference method used reflected long-term intake. Micronutrient intake correlates better with long-term rather than short-term daily intake. Additionally, BM used as reference methods present very good correlations for vitamin E and poor correlations for folate. According to this systematic review, when comparing different validation methods, the DH presents better correlations when EDR are used as the reference method. When we analyse the mean of correlation coefficients weighted by study quality and their distribution by FFQ or DH as validated dietary methods, we observed that most of the micronutrients improved the correlation when the DH was used as the study instrument. Overall, when frequency methods are used for assessing micronutrient intake, the inclusion of dietary supplements improves their reliability for most nutrients, with notable differences observed for folate, retinol, vitamins A, D, E and Zn. So, future research to clarify the number of food items and frequency categories that are to be included in the questionnaires needs to be developed for this population group.

Fluid intake

Measurement of fluid intake is critical in the elderly because elderly population isn prone to dehydration. Several factors can favor dehydration: Hypodipsia, use of diuretics, incontinency, gastrointestinal diseases and hot environments. Several approaches have been used to assess beverage intake for the general population, but the validity of these approaches has not been well established in the aged population. Most of the studies about fluid intake have focused on assessment of beverage-associated nutrients, or alcohol[20], or have been performed with or for other segments of the population, as the children and adolescents[21]. In most of the studies, FFQ, multiple-day food records and 24-hour dietary recalls have been used to estimate beverage intake. Biomarkers of beverage intake are able to assess dietary intake / hydration status without the bias of self-reported dietary intake errors and also the intra-individual variability. Various biomarkers have been proposed to assess hydration, however, to date; there is a lack of universally accepted biomarker that reflects changes of hydration status in response to changes in beverage intake. A recent review has validated different beverage intake methods *vs*. hydration biomarker[22]. The authors conducted a review to find out the questionnaires of beverage intake available in the scientific literature to assess water beverage intake and hydration status, previouslyand validated-them against hydration biomarkers. Only two articles were selected, in which, two different beverage intake questionnaires designed to capture the usual beverage intake were validated against Urine Specific Gravidity biomarker. The "Water balance questionnaire" (WBQ)[23] reported no correlations in the first study and the Beverage Intake Questionnaire[24], a quantitative Food frequency questionnaire in the second study, also found a negative correlation. FFQ appears to measure better beverage intake than WBQ when compared with biomarkers. However, the WBQ seems to be a more complete method to evaluate the hydration balance of a given population. The authors conclude that further research is needed to understand the meaning of the different correlations between intake estimates and biomarkers of hydration in distinct population groups and environments.

Assesment of malnutrition in the elderly

Malnutrition is highly prevalent among hospitalized elderly patients, ranging from 30% to 50% depending on the patient population and the criteria used for diagnosis. The prevalence of malnutrition in com-

munity-dwelling elderly is lower, about 2%, and the risk of malnutrition is 24%. Home care elderly use to haves a prevalence of undernutrition around 109%, and risk of malnutrition up to 45%. Malnutrition is associated with functional and cognitive impairment. Thus, identifying at early stages those who are malnourished and at risk of malnutrition is important to treat them early at an early stage and to improve patients overall prognosis, reducingand reduce the health costs. Many nutrition screening and assessment tools are available, to identify the risk of malnutrition and to diagnose this condition. Ideally, nutritional assessment should be practical, easy to perform, non-invasive, well tolerated, inexpensive, requiring no use of devices or supplementary examinations, applicable at the bedside, showing appropriate sensitivity and specificity and yield immediate results. Subjective Global Assessment (SGA) is one of the most commonly used nutrition assessment tools and reliably detects patients with established malnutrition[25]. The Malnutrition Universal Screening Tool (MUST) was developed to detect both under-nutrition and obesity in adults[26]. The Nutritional Risk Screening (NRS) is the preferred screening tool for hospitalized patients[27]. TheBut Mini Nutritional Assessment (MNA) and its Short Form (MNA-SF) were specifically developed to assess nutritional risk in elders[28]. Both are sensitive, specific, and accurate in identifying nutrition risk. The MNA is a screening and assessment tool with a reliable scale and clearly defined thresholds, usable by health care professionals. A low MNA score is associated with an increase in mortality, and length of hospital stay. The MNA detects risk of malnutrition before severe change in weight or serum proteins occurs. The MNA can also be used as a follow up assessment tool. So, it should be included in the geriatric assessment and is proposed in the minimum data set for nutritional interventions.

The Geriatric Nutritional Risk Index (GNRI) is a tool initially proposed to predict nutrition-related complications in sub-acute care setting[29]. It has been validated in hospitalized elderly patients by testing its ability to predict patients outcome through the comparison with Mini Nutritional Assessment (MNA), in a prospective cohort with 131 patients (mean age 69.32 ± 8.17 years) admitted consecutively to the acute geriatrics medical ward. Patients were followed for 6 months for the occurrence of major health complications as prolonged length of stay, infectious complications and mortality. GNRI showed a higher prognostic value for describing and classification of nutritional status and nutritional-related complications in hospitalized elderly patients, in addition to its simplicity[30]. An study was performed to compare the correlation between MNA and GNRI with anthropometric, biochemical, functional status measure (Barthel Index) and nutritional relation complications (such as infection and bedsores) in a sample of older subjects admitted to hospital[31]. The concordance of MNA and GNRI was 39%. The most significant differences were detected in weight, BMI, arm and calf circumference and weight loss parameters. Barthel index was significantly different in both tests. The MNA and GRNI had significant correlations with albumin, total protein, transferring, arm and calf circumference, weight loss and BMI parameters. So, it would be reasonable to use GRNI in cases where MNA is not applicable, or even use GRNI as a complement to MNA in hospitalized elderly patients, because patients could benefit from more effective nutritional intervention.

Measuring obesity in the elderly: sarcopenic obesity

Obesity is recognized as a major risk factor in the development of cardiovascular diseases and diabetes, but in several chronic diseases, a higher BMI may be associated with a lower mortality and a better outcome compared with their normal-weight counterparts. This protective effect of obesity has been described as the "obesity paradox" or "reverse epidemiology". The obesity paradox was mostly reported in elderly. Lainscak et al evaluated nine large-scale studies about obesity paradox in chronic diseases[32]. Eight of the studies included subjects at mean age >62 years. The obesity paradox may be partly explained by the lack of the discriminatory power of BMI to differentiate between lean body mass and fat mass, because BMI does not take into account body fat distribution. In the elderly, the prevalence of abdominal obesity defined by waist circumference is higher than the prevalence of obesity defined by BMI[33]. Higher mortality in the low BMI categories may be due to the sarcopenic obesity that is characterized by low muscle mass and strength while fat mass may be preserved or even increased. Changes in muscle composition (fat infiltration into muscle or marbling) are also important. Sarcopenia exacerbates insulin resistance and dysglycemia in both nonobese and obese individuals, and increase the risk of adverse outcomes, such as physical disability, poor quality of life and death. So, in the elderly the body mass index is not useful and it is better to evaluate functional status, through the amount of muscle mass and its function, mainly strength and physical performance. The challenge is to determine how best to measure them accurately. Gait speed measurement has been demonstrated to be the most reliable way to screen sarcopenia in clinical practice. A cut-off point of >0.8 m/s identifies risk for sarcopenia[34]. A relationship between handgrip strength and mortality in the oldest old population has been described in the Leiden 85-plus study[35] and normal reference values for handgrip strength in healthy adult subjects using hand dynamometry have been established[36].

Body Shape Index (ABSI) is a promising index recently developed to quantify the risk associated with abdominal obesity, independently of body mass index[37] ABSI appears to outperform other popular

anthropometry-based measures of adiposity, such as Waist-Hip-Ratio. Several studies have found associations between ABSI and other adverse outcomes, as diabetes[38], metabolic syndrome[39], and high blood pressure[40] . Above average ABSI was associated with substantially higher risk of death in the National Health and Nutrition Examination Survey (NHANES) 1999–2004 sample[41]. Even more, ABSI was found to be a robust predictor of mortality hazard in the Health and Lifestyle Survey (HALS)[42,43], a large national sample of United Kingdom.

In summary, from this review we underline the difficultiesy in performing nutritional studies in the elderly population. Although important advances in knowledge have been achieved during the last two decades, further research is still needed to clarify the better and simpler methods to accurately estimate food and fluid intake in the elderly population, and to evaluate nutritional status.

References

1. World Health Organization (2013) The European Health Report 2012: charting the way to well-being. Copenhagen: World Health Organization Regional Office for Europe.
2. Granic A, Andel R, Dahl AK, Gatz M, Pedersen NL. Midlife dietary patterns and mortality in the population-based study of Swedish twins. *J Epidemiol Community Health* 2013;67(7):578-586.
3. Ford DW, Jensen GL, Hartman TJ, Wray L, Smiciklas-Wright H. Association between dietary quality and mortality in older adults: a review of the epidemiological evidence. *J Nutr Gerontol Geriatr* 2013;32(2): 85-105.
4. Tooze JA, Subar AF, Thompson FE, Troiano R, Schatzkin A, Kipnis V. Psychosocial predictors of energy underreporting in a large doubly labeled water study. *Am J Clin Nutr* 2004; 79(5):795-804.
5. Subar AF, Kipnis V, Troiano RP, Midthune D, Schoeller DA, Bingham S, et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. *Am J Epidemiol* 2003;158 (1):1-13.
6. Shahar DR, Yu B, Houston DK, Kritchevsky SB, Newman AB, Sellmeyer DE, et al. Misreporting of energy intake in the elderly using doubly labeled water to measure total energy expenditure and weight change. *J Am Coll Nutr* 2010; 29(1): 14-24.
7. Ortiz-Andrellucchi A, Sánchez-Villegas A, Doreste-Alonso, J de Vies J, de Groot L, Serra-Majem L Dietary Assessment Methods for micronutrient intake in elderly people: a systematic review. *Br J Nutr* 2009 Dec; 102 (Suppl 1): S118-149.
8. Long JD, Littlefield LA, Estep G, Martin H, Rogers TJ, Boswell C, et al. Evidence review of technology and dietary assessment. *Worldviews Evid Based Nurs* 2010; 7(4):191-204.
9. Livingstone MBE, Black AE. Markers of the validity of reported energy intake. *J Nutr* 2003;133:S895-S920.
10. Hise ME, Sullivan DK, Jacobsen DJ, Johnson SL, Donnelly JE. Validation of energy intake measurements determined from observer-recorded food records and recall methods compared with the doubly labeled water method in overweight and obese individuals. *Am J Clin Nutr* 2002;75(2):263-7.
11. Johannsen DL, Calabro MA, Stewart J, Franke W, Rood JC, et al.. Accuracy of armband monitors for measuring daily energy expenditure in healthy adults. *Med Sci Sports Exerc* 2010; 42(11):2134-40.
12. Stea TH, Andersen LF, Paulsen G, Hetlelid KJ, Lohne-Seiler H, Adnanes S, et al. Validation of a Pre-Coded Food Diary Used among 60-80 Year Old Men: Comparison of Self-Reported Energy Intake with Objectively Recorded Energy Expenditure. PLoS ONE. 2014;9(7): e102029. doi:10.1371/journal.pone.0102029.
13. Grootenhuis PA, Westenbrink S, Sie CM, de Neeling JN, Kok FJ, Bouter LM. A semiquantitative food frequency questionnaire for use in epidemiologic research among the elderly: validation by comparison with dietary history. *J Clin Epidemiol* 1995; 48(7):859-68.
14. Dumartheray EW, Krieg MA, Cornuz J, Whittamore DR, Lovell DP, Burckhardt P, et al. Validation and reproducibility of a semi-quantitative food frequency questionnaire for use in elderly Swiss women. *J Hum Nutr Diet* 2006; 19(5):321-330.
15. Messerer M, Johansson SE & Wolk A. The validity of questionnaire-based micronutrient intake estimates is increased by including dietary supplement use in Swedish men. *J Nutr* 2004;134(7):1800-5.
16. Klipstein-Grobusch K, den Breeijen JH, Goldbohm RA, Geleijnse JM, Hofman A, Grobbee DE, et al. Dietary assessment in the elderly: validation of a semiquantitative food frequency questionnaire. *Eur J Clin Nutr* 1998; 52(8): 588-96.
17. Van de Rest O, Durga J, Verhoef P, Melse-Boonstra A, Brants HA. Validation of a food frequency questionnaire to assess folate intake of Dutch elderly people. *Br J Nutr* 2007; 98(5):1014-1020.
18. Vioque J, Weinbrenner T, Asensio L, Castelló A, Young IS, Fletcher A. Plasma concentrations of carotenoids and vitamin C are better correlated with dietary intake in normal weight than overweight and obese elderly subjects. *Br J Nutr* 2007; 97(5):977-86.
19. Serra-Majem L, Frost Andersen L, Henríque-Sánchez P, Doreste-Alonso J, Sánchez-Villegas A, Ortiz-Andrelluchi A, et al. Evaluating the quality of dietary intake validation studies. *Br J Nutr* 2009; 102(Suppl 1): S3-S9.
20. Serra-Majem L, Santana-Armas JF, Ribas L, Salmona E, Ramon JM, Colom J, et al. A comparison of five questionnaires to assess alcohol consumption in a Mediterranean population. *Public Health Nutr* 2002;5(4):589-94.
21. Hedrick VE, Savla J, Comber DL, Flack KD, Estabrooks PA, Nsiah-Kumi PA, et al. Development of a brief questionnaire to assess habitual beverage intake (BEVQ-15): sugar-sweetened beverages and total beverage energy intake. *J Acad Nutr Diet* 2012;112(6):840-9.
22. Nissensohn M, Ruano C, Serra-Majem L. Validation of beverage intake methods vs. hydration biomarker: a short review. *Nutr Hosp* 2013;28(6):1815-9.
23. Malisova O, Bountziouka V, Panagiotakos DB, Zampelas A, Kapsokefalou M. The water balance questionnaire: design, reliability and validity of a questionnaire to evaluate water balance in the general population. *Int J Food Sci Nutr* 2012;63(2):138-44.
24. Hedrick VE, Comber DL, Estabrooks PA, Savia J, Davy BM. The beverage intake questionnaire: determining initial validity and reliability. *J Am Diet Assoc* 2010;110(8):1227-32.
25. Detsky AS, McLaughlin JR, Baker JP, Johnston N, Whittaker S, Mendelson RA, et al. What is subjective global assessment of nutritional status? *J Parenter Enteral Nutr* 1987;11(1):8-13.
26. Stratton RJ, King CL, Stroud MA, Jackson AA, Elia M. Malnutrition Universal Screening Tool' predicts mortality and length of hospital stay in acutely ill elderly. *Br J Nutr* 2006; 95(2):325-30.
27. Kondrup J, Rasmussen HH, Hamberg O, Stanga Z, Ad Hoc ESPEN Working Group. Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. *Clin Nutr* 2003;22(3):321-36.
28. Guigoz Y. The Mini Nutritional Assessment (MNA) review of the literature--What does it tell us? *J Nutr Health Aging* 2006; 10(6):466-85; discussion 485-7.
29. Bouillanne O, Morineau G, Dupont C, Coulombel I, Vincent JP, Nicolis I, et al. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. Am J Clin Nutr. 2005; 82(4):777-83.
30. Abd-El-Gawad WM, Abou-Hashem RM, El Maraghy MO, Amin GE. The validity of Geriatric Nutrition Risk Index: Simple tool for prediction of nutritional-related complication of hospitalized elderly patients. Comparison with Mini Nutritional Assessment. *Clin Nutr* 2014;33(6):1108-16.

31. Durán P, Villarroel R, Formiga F, Virgili N, Vilarasau C. Assessing risk screening methods of malnutrition in geriatric patients: Mini Nutritional Assessment (MNA) versus Geriatric Nutritional Risk Index (GNRI). *Nutr Hosp* 2012;27(2):590-8.
32. Lainscak M, von Haehling S, Doehner W, Anker SD. The obesity paradox in chronic disease: facts and numbers. *J Cachexia Sarcopenia Muscle* 2012;3(1):1-4.
33. Mathus-Vliegen EM; Obesity Management Task Force of the European Association for the Study of Obesity. Prevalence, pathophysiology, health consequences and treatment options of obesity in the elderly: a guideline. *Obes Facts* 2012;5(3): 460-83.
34. Cesari M[1], Kritchevsky SB, Penninx BW, Nicklas BJ, Simonsick EM, Newman AB, et al. Prognostic value of usual gait speed in well-functioning older people-results from the Health, Aging and Body Composition Study. *J Am Geriatr Soc* 2005 Oct;53(10):1675-80.
35. Ling CH, Taekema D, de Craen AJ, Gussekloo J, Westendorp RG, Maier AB. Handgrip strength and mortality in the oldest old population: the Leiden 85-plus study. *CMAJ* 2010;23;182(5): 429-35.
36. Luna-Heredia E[1], Martín-Peña G, Ruiz-Galiana J. Handgrip dynamometry in healthy adults. *Clin Nutr* 2005;24(2):250-8.
37. Ahima RS, Lazar MA, The health risk of obesitybetter metrics imperative. *Science* 2013; 23;341(6148):856-8.
38. He S, Chen X. Could the new body shape index predict the new onset of diabetes mellitus in the Chinese population? *PLoS ONE* 2013;8(1):e50573.
39. Matsha TE, Hassan MS, Hon GM, Soita DJ, Kengne AP, Erasmus RT. Derivation and validation of a waist circumference optimal cutoff for diagnosing metabolic syndrome in a South African mixed ancestry population. *International Journal of Cardiology* 2013;168(3):2954-5.
40. Duncan MJ, Mota J, Vale S, Santos MP, Ribeiro JC. Associations between body mass index, waist circumference and body shape index with resting blood pressure in Portuguese adolescents. *Annals of Human Biology* 2013; 40(2):163-7.
41. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. *PLoS ONE* 2012;7(7):e39504.
42. Krakauer NY, Krakauer JC. Dynamic Association of Mortality Hazard with Body Shape. Li S, ed. *PLoS ONE* 2014;9(2):e88793.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):91-98
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Screeners and brief assessment methods

Carmen Pérez Rodrigo[1], Luis Juan Morán Fagúndez[2], Pilar Riobó Serván[3] and Javier Aranceta Bartrina[4,5,6]

[1]Fundación FIDEC. Bilbao (Spain). [2]Sociedad Andaluza de Nutrición Clínica y Dietética (SANCYD). 3Endocrinology and Nutrition Department. Hospital Fundación Jiménez Díaz- IDC-Salud. [4]Departamento de Medicina Preventiva y Salud Pública. Universidad de Navarra. [5]Fundación para la Investigación Nutricional, Parc Científic de Barcelona. [6]CiberOBN, Instituto de Salud Carlos III, Madrid.

Abstract

In the last two decades easy-to-use simple instruments have been developed and validated to assess specific aspects of the diet or a general profile that can be compared with a reference dietary pattern as the Mediterranean Diet or with the recommendations of the Dietary Guidelines. Brief instruments are rapid, simple and easy to use tools that can be implemented by unskilled personnel without specific training. These tools are useful both in clinical settings and in Primary Health Care or in the community as a tool for triage, as a screening tool to identify individuals or groups of people at risk who require further care or even they have been used in studies to investigate associations between specific aspects of the diet and health outcomes. They are also used in interventions focused on changing eating behaviors as a diagnostic tool, for self-evaluation purposes, or to provide tailored advice in web based interventions or mobile apps. There are some specific instruments for use in children, adults, elderly or specific population groups.

(*Nutr Hosp* 2015;31(Supl. 3):91-98)

DOI:10.3305/nh.2015.31.sup3.8757

Key words: *Dietary assessment. Screening. Rapid assessment. Brief instruments.*

MÉTODOS DE CRIBADO Y MÉTODOS DE EVALUACIÓN RÁPIDA

Resumen

En las dos últimas décadas se han desarrollado y validado instrumentos sencillos que permiten valorar aspectos concretos de la ingesta dietética o bien un perfil general que puede compararse con patrones dietéticos de referencia como la Dieta Mediterránea o bien con las recomendaciones de las Guías Alimentarias. Son instrumentos rápidos, sencillos y fáciles de utilizar por personal no especializado sin necesidad de un entrenamiento específico. Estas herramientas son de utilidad tanto en el ámbito clínico como en Atención Primaria o en la comunidad como instrumento de triage, como herramienta de cribado con el fin de identificar individuos o grupos de población con riesgo que requieran mayor atención o incluso se han utilizado en estudios para investigar entre aspectos concretos de la dieta y resultados de salud. También se utilizan en intervenciones sobre cambio de conductas alimentarias como herramienta diagnóstica o de autoevaluación, o para facilitar consejo personalizado en intervenciones a través de páginas web o de aplicaciones móviles. Existen algunos instrumentos específicos para su utilización en niños, en adultos, en ancianos o en grupos específicos de población.

(*Nutr Hosp* 2015;31(Supl. 3):91-98)

DOI:10.3305/nh.2015.31.sup3.8757

Palabras clave: *Análisis de la ingesta. Cribado. Evaluación rápida. Instrumentos breves.*

Abbreviations

CDC: Centres For Disease Control And Prevention's.
CADET: Child And Diet Evaluation Tool.
CNQ: Child Nutrition Questionnaire.
DILQ: Day In The Life Questionnaire.
DINE: Dietary Intervention In Primary Care.
DSQ: Dietary Screener Questionnaire.
FEAHQ: Family Eating And Activity Habits Questionnaire.
HBSC: Health Behaviour In School-Aged Children.
FFQ: Food Frequency Questionnaires.
PRA: Participatory Rural Appraisal.
PREDIMED: Prevención con Dieta Mediterránea.
RRA: Rapid Rural Appraisal.
RFMMB: Risk Factor Monitoring And Methods Branch.
SNAPTM: Synchronised Nutrition And Activity Programme.

Correspondence: Carmen Pérez Rodrigo.
Fundación FIDEC. Gurtubay s/n.48010 Bilbao (Spain).
E-mail: carmenperezrodrigo@gmail.com

Rapid Assessment Methods were designed by Chambers and colleagues in the 70s for use in rural communities in developing countries and were modified later in the 80s. These methods, Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA), based on qualitative evaluation methods, were developed to be used by fieldworkers in contexts with limited resources, lack of skilled trained personnel to conduct large surveys in order to identify problems and follow up, but where information is required for immediate action and decision adoption[1].

Data collected by these methods help to draw a situational analysis map, identify and prioritize problems as well as to identify at risk groups. However, short methods are not useful to detect individuals at risk who may need immediate intervention due to their physiological status, condition or any other circumstances. The rapid assessment questionnaires developed over the last decades have attempted to answer those needs[2].

Rapid assessment tools are described as questionnaires intended to identify key risk factors for malnutrition or inadequate consumption patterns for specific food groups. Based on these risk factors, appropriate algorithms are developed to compute scoring scales associated to each screening tool. Scores are usually categorized according to range levels in the scale and the subsequent corresponding appropriate actions or decisions to be adopted. Many of these instruments are designed in a user friendly format, so they can be used by nurses or social workers in their routine practice in Primary Health Care, in community settings for health promotion purposes and community interventions[3,4].

The time and resources available in clinical practice, especially in Primary Health Care, make it difficult to implement comprehensive nutritional assessments. In addition, healthcare professionals often are not particularly well trained and skilled in nutritional assessment methodology. Therefore, easy-to-use rapid assessment tools ready to be used by staff without a specific training or specialized qualification are highly valuable[5].

Nutrition screening tools had a major development in three main areas. On the one hand, in clinical practice to identify patients in situations that compromise their nutritional status and require an effective intervention either with a preventive or treatment aim, such as cardiovascular risk, cancer patients, candidates for certain surgery treatment patients or any other specific condition.

On the other hand, several tools have been developed for implementation in the elderly. Due to the specific physiological, clinical and socioeconomic characteristics associated with ageing processes, the elderly is an important at risk group and it is necessary to identify individuals who may be in situations vulnerable for malnutrition to provide them with adequate social and health care support.

Assessment of food habits is particularly interesting in childhood and adolescence to inform monitoring of adequate growth and development and for health promotion and nutrition education purposes. More recently new rapid assessment and self-evaluation tools have been developed in the context of health promotion interventions focused on modifying eating behaviours. Table I summarizes the different types of screeners developed in recent years with some examples, scope, targeted population group and main characteristics.

Short dietary assessment instruments

For some research and/or public health purposes a full-length questionnaire is not practical. Therefore, brief assessments and screening tools have been developed, usually to assess just one or two nutrients or food groups. They generally ask about frequency of consumption but do not include portion size. This kind of tools are useful to identify individuals with a very low or high intake. Brief instruments can be simplified, targeted food frequency questionnaires (FFQ) or questionnaires that focus on specific eating behaviors other than the frequency of consuming specific foods[2-4].

Most of the focus in brief instrument development has been on fruits and vegetables and fats, but others have been developed for protein, calcium, sugar sweetened drinks and other food intake. Often, only 15 to 30 foods might be required to account for most of the intake of a particular nutrient. Food frequency type instruments to measure fruit and vegetable consumption range from a single overall question to 45 or more individual questions[6,7].

Uses

These instruments can be useful in situations that do not require either assessment of the total diet or quantitative accuracy in dietary estimates. For example, a brief diet assessment of some specific components might be used to screen large numbers of individuals and rapidly identify and focus attention on those subjects or groups at greatest need for intervention[3].

Brief instruments focusing on specific aspects of a dietary intervention have also been used to track changes in diet. However, it has been argued that responses to questions of intake that is directly related to intervention messages may be biased and that these instruments lack sensitivity to detect change. Use of a screener as the sole measure of change is not recommended when evaluating the intervention, because exposure to the intervention itself can create differential response bias in reporting in the intervention group relative to the control group[2,4].

Brief instruments of specific dietary components such as fruits and vegetables, food habits of particular interest such as breakfast consumption or specific food

Table I
Type of Rapid nutrition and diet assessment instruments, target population and uses

Type of questionnaire	*Examples*	*Target group*	*Uses*
Community screener	NSI Levell I (DETERMINE)	Elderly	Primary Health Care Social Services
	Healthy Eating Index	Children Adults	Primary Health Care School Health
	KIDMED Kreceplus	Children and young people	Primary Health Care School Health Health Promotion
	CADET CNQ	Children	Primary Health Care School Health Health Promotion
	MEDAS	Adults	Primary Health Care
	DINE	Adults	Primary Health Care Health Promotion
Surveillance	Dietary Screener in the NHANES 2009-10	Adults Children	Public Health Health Promotion
	Diet screener in HBSC	Adolescents	Public Health Health Promotion
	Diet screener in NHS	Adolescents Adults	Public Health Health Promotion
	Dietary Screener in the 2010 NHIS Cancer Control Supplement (CCS)		Public Health Health Promotion
Malnutrition screener	Subjective Global Assessment	Hospital patients Elderly	Primary Health Care Hospital Homes for elderly
	MNA MNA-SF	Elderly Patients	Homes for elderly Day Care centers Primary Health Care Hospital
	MUST	Hospital patients	Hospital
	NSI. Level II and Level III	Elderly	Primary Health Care Hospital
Health promotion and tailored advice	Pro Children	Children Adults	School Health Health Promotion

behaviours are often used for population surveillance. In the USA, the Risk Factor Monitoring and Methods Branch (RFMMB) has developed several short instruments that assess intake of fruits and vegetables, percentage energy from fat, fibre, added sugars, whole grains, calcium, dairy products, and red and processed meats which are used in the Centres for Disease Control and Prevention's (CDC) Behavioural Risk Factor Surveillance System[2-4,6,7]. The Dietary Screener Questionnaire (DSQ) is one of the instruments developed by the RFMMB focused on the intakes of fruits and vegetables, dairy/calcium, added sugars, whole grains/fiber, red meat, and processed meat. The tool consists of 26-items which ask about the frequency of consumption in the past month of selected foods and drinks[4].

Large studies such as National Health Surveys in many countries, the Health Behaviour in School-aged Children (HBSC) and other surveillance surveys include such instruments as well[2,3]. Brief instruments can also be used to examine relationships between some specific aspects of diet and other exposures[4]. Finally, some groups use short screeners to evaluate the effectiveness of policy initiatives[7].

Brief instruments often combine food frequency questions and behavioural questions to assess multiple dietary patterns, even questions to reflect emotional eating and impulsive snacking behaviours. Some screeners have simplified answer options to reduce respondent burden by asking questions that require only Yes or No answers. The same approach has been used as a modification of the 24-hour recall. The instruments

present a pre-coded close-ended food list and ask whether the respondent ate that food item the previous day, sometimes including portion size questions[4,7].

Adequate brief instruments can be used in estimating dietary intakes of components of food patterns, such as the Mediterranean dietary pattern or USDA food patterns. They can also be used in assessing adherence to Dietary Guidelines recommendations, estimating cost of healthy foods and diets[3,4].

Diet related risks were identified as the top risk factor accounting for most attributable burden of disease in terms of percent disability-adjusted life years (DALYs) in Spain and in many other countries in 2012. A high body mass index was next and physical inactivity was the sixth risk factor. Evidence supports that a low consumption of fruit and vegetables, a trend to a positive energy balance due to a high energy intake and low physical activity levels alongside a sedentary lifestyle, low fiber intake and a high fat intake are among the main diet related risk factors associated to chronic disease and DALYs[8].

A number of brief instruments have been developed and tested for screening purposes and behaviour change interventions. These have been particularly useful in interventions including self-evaluation, goal setting and tailored advice actions, either in a traditional format, website based or even in more recent interventions using new technologies, such as those implementing apps and serious games for mobile or tablet devices[9, 10].

A recent review of studies investigating the relationship between the food environment and several dietary outcomes reported that in two thirds of the studies included in the review the dietary outcomes were assessed using a brief instrument, such as a screener or one or two items. The most commonly studied dietary components in such studies were fruit and/or vegetables; sugar sweetened beverages and fast food. The authors reported their concern about the potential bias in the estimates[7].

Resulting estimates based on those questionnaires may be quantitative or qualitative, depending on the instrument.

Validity

Screeners are shorter and less detailed than a total dietary assessment, therefore less accurate. However, calibrating a screener against the more precise 24-hour recall can help ensure that a screener is providing the best and most accurate estimates possible. Many short questionnaires using a food frequency approach have been developed and compared with multiple days of food records, dietary recalls, complete FFQs, or biomarkers. Single-exposure abbreviated FFQs have been developed and tested for protein, calcium, iron, isoflavones, phytoestrogens, soy foods, folate, sugar snacks, heterocyclic aromatic amines, and alcohol[11].

Some tools have been evaluated in cross-sectional general population studies. That is the case for the KIDMED questionnaire developed in Spain to assess adherence to the Mediterranean Diet, which was evaluated in the enKid population study. Other instruments have been validated in self-selected samples in intervention research[12].

Estimates of intake from short dietary assessment instruments are not as accurate as those from more detailed methods. This kind of assessment instruments may be most useful for characterizing median intakes in a population; discriminating among individuals or populations with regard to higher vs. lower intakes; examining interrelationships between diet and other variables; and comparing findings from a smaller study to a larger population study[2,4]. However, short dietary assessment instruments generally are not useful for characterizing a population's usual intake distribution. Such information is needed to estimate prevalence of intakes above or below a given level. They cannot be used either to accurately assess an individual's intake and may not be appropriate to measure change in intervention studies[2,4].

Validation studies of the CDC and 5-A-Day brief instruments to assess fruit and vegetable intake have suggested that they often underestimate actual intake, unless portion size adjustments are considered[2,6,7,13]. Following cognitive research findings, the revised version which included portion size questions was used in some studies suggesting better performance. However, results in community interventions were mixed. Fruit and vegetable consumption was significantly overestimated relative to multiple 24-hour recalls in some comparisons. Furthermore, the screener indicated change in consumption in both men and women while the 24-hour recalls did not show any[2,6].

A 17 item fat screener was used as an initial screen for high fat intake in the Women's Health Trial and in the CDC's Behavioral Risk Factor and Surveillance System for nutritional surveillance. However, results in a sample of medical students showed that the screener substantially underestimated percentage energy from fat and was only modestly correlated ($r = 0.36$) with multiple 24-hour recalls. In samples of men participating in intervention trials, the screener was not as precise or as sensitive as complete FFQs[2,11,14].

MEDFICTS (meats, eggs, dairy, fried foods, fat in baked goods, convenience foods, fats added at the table, and snacks) is a questionnaire developed to assess adherence to low-fat (≤ 30% energy from fat) diets which asks about frequency of intake and portion size of 20 individual foods, major food sources of fat and saturated fat in the U.S. diet. The initial evaluation of MEDFICTS showed high correlations with food records. In additional cross-sectional studies, the MEDFICTS underestimated percentage energy from fat; it was effective in identifying individuals with very high fat intakes, but it was not effective in identifying individuals with moderately high fat diets or correctly

identifying those individuals consuming low-fat diets. In a longitudinal setting, positive changes in the MEDFICTS score have been correlated with improvements in serum lipids and waist circumference among cardiac rehabilitation patients[2,15].

A 20-item screener developed and tested in the German site of the EPIC study correlated with a complete FFQ. The validation of a 16-item percentage energy from fat screener in an older U.S. population showed correlations of 0.6 with 24-hour recalls, but variable performance in intervention studies[2].

Interventions are often designed to target specific food preparation or consumption behaviors, such as trimming the fat from red meats, removing the skin from chicken, or choosing low-fat dairy products. Many questionnaires have been developed in various populations to measure these types of dietary behaviors, and many have been found to correlate with fat intake estimated from other more detailed dietary instruments or with blood lipids[16].

The Eating Behaviors Questionnaire measures five dimensions of fat related behavior: avoid fat as a spread or flavoring, substitute low-fat foods, modify meats, replace high-fat foods with fruits and vegetables, and replace high-fat foods with lower-fat alternatives. An updated modified version was tested in African-American adolescent girls and correlated with multiple 24-hour dietary recalls. A subset of 30 items from the Sister Talk Food Habits Questionnaire developed for African- American women correlated with change in BMI as strongly as did the original 91 items[17].

Several multifactor short instruments have been developed and evaluated, many combining fruits and vegetables with fiber or fat components. Other short questionnaires assess additional components of the diet. Prime-Screen consists of 18 FFQ items asking about the consumption of fruits and vegetables, whole and low-fat dairy products, whole grains, fish and red meat, and sources of saturated and trans fatty acids. It also includes seven supplement questions. The average correlation with nutrient estimates from a full FFQ was 0.6. The 5-Factor Screener used in the 2005 National Health Interview Survey Cancer Control Supplement assessed fruits and vegetables, fiber, added sugar, calcium, and dairy servings[18].

Brief assessment instruments for use in children

Childhood and adolescence deserve special consideration. It is a key stage for the promotion and consolidation of food habits. Social changes, different ways of organizing family life as well as other factors are driving changes in eating habits and lifestyles in Spain as in many other countries.

Brief instruments are useful tools to identify individuals and groups who require further attention and intervention for involvement in behavior change strategies and interventions. The adapted version of the Healthy Eating Index for use among children and adolescents and the KIDMED questionnaire are examples of such tools targeted to this population group.

The USDA developed the Healthy Eating Index (HEI) with the aim of monitoring adherence to the Dietary guidelines for Americans. This index has been used in adults and children. Feskanich et al. validated and adapted version of the HEI to be used among children and adolescents (YHEI). The revised version consists of 13 components and a score ranging 0-100. Components 1 to 7 score 0-10; components 8 to 13 score a highest of 5[19].

YHEI components include: 1) Consumption of whole grains (2 or more servings a day score highest 10, and 0 servings / day score 0), 2) Vegetables and salads (3 or more servings score 10 points , 0 servings score 0), 3) Fruits (three or more servings score 10 points), 4) Dairy (3 or more servings score 10 points), 5) Ratio of protein foods (servings of chicken, fish, eggs, nuts, seeds and legumes, divided by the servings of beef, pork, lamb and offal, score the highest 10 for a ratio equal to or greater than 2), 6) Consumption of salty snacks, pastries and confectionery (0 per day score highest 10, and more or equal to 3 score the lowest 0), 7) Sugary drinks (same scoring that snacks), 8) Use of multivitamin supplements (Daily scores 5, never 0), 9) Margarine and butter (Never scores 5, 2 or more per day scores 0), 10) Fried foods away from home (Never scores 5, daily scores 0), 11) Visible animal fat (trim all fat scores 5, eat all fat scores 0), 12) Breakfast consumption (5 or more times a week scores 5, never scores 0) and 13) Family dinner (Daily scores 5 and never scores 0).

The KIDMED screener was designed to assess adherence to Mediterranean Diet in children and adolescents. The instrument was based on Kreceplus, a screener developed jointly by the Spanish Society of Community Nutrition and the Spanish Association of Pediatrics for use in Primary Health Care and Health Promotion settings as a tool to identify and monitor selected energy balance behaviours. The traditional pattern of DM includes a high consumption of fruits and vegetables, olive oil, fish, legumes, grains and nuts, and dairy, and promotes household food consumption. Conversely, snacks, and pastries, sweets or fast food are not characteristic elements of the DM. Therefore, KIDMED index was built from these premises. A KIDMED score below 4 is labelled low adherence to a Mediterranean Dietary Pattern. The scale highest score is 10[12].

Some of these instruments have been specially developed and tested to be implemented in behaviour change interventions targeted to children and adolescents[20], such as Pro Children aimed to increase consumption of fruit and vegetables in European 10-12 year-old children and other intervention projects[21].

In the UK and in other countries as well, a number of screeners have been developed for different purposes. Child and Diet Evaluation Tool (CADET)

is a tick-list record for all foods consumed over one 24-hour period, with a retrospective breakfast section. The instrument consist of two questionnaires, one to be completed at home by the parent or carer, and one for completion at school by a lunchtime supervisor or classroom assistant. The questionnaire was initially developed to evaluate the National School Fruit and Vegetable Scheme and was targeted to 3–7 year olds[22].

The questionnaires assess dietary intake of 115 food items over a 24-hour period with a focus on fruit and vegetables. It includes additional questions about dietary behaviours, attitudes and socio-economic characteristics. Portion sizes are based on mean portion sizes in the National Diet and Nutrition Survey and are age and gender specific. According to the validation study, it is considered appropriate for assessing behavioural change in dietary patterns at a population level or to rank populations according to dietary intake. It is appropriate for use with children from diverse social and ethnic backgrounds across a range of settings. However, it is not considered suitable for monitoring diet-related targets in a population.

Day in the Life Questionnaire (DILQ) (7-9 years) was developed as a supervised classroom activity to measure fruit and vegetable consumption in the previous 24 hours. It is self-completion questionnaire consisting of 17 items, including pictures and words to aid recall and improve completion. The DILQ (9–11 years) is a modified version that contains 23 items[23].

Synchronised Nutrition and Activity Programme (SNAPTM) is a web-based programme that uses a typical 24-hour recall method to assess dietary intake and physical activity in 7–15 year old children through a typical school day. It measures intake of 40 different food and nine different drink items in the previous 24 hours. It allows for the inclusion of any other food/drink not included in the list. Visual memory prompts are provided. The SNAPTM also records physical activity in the previous 24 hours. The questionnaire is likely to be suitable for the evaluation of school-based interventions[24].

Child Nutrition Questionnaire (CNQ) is a 14-item questionnaire to be completed by children with support from a helper. It was developed to examine dietary patterns that are known to increase the risk of weight gain in 10–12 year olds. It measures the consumption of sweetened beverages and non-core foods such as chocolate, lollies and hot dogs as well as fruit, vegetables and water. It also includes questions on the frequency of specific 'healthy' behaviours; attitudes towards the consumption of fruit and vegetables; and the day-to-day availability of fruit and vegetable. The CNQ was developed in Australia so it may need to be validated for use in the UK. The estimated completion time is 20 minutes[25]

Family Eating and Activity Habits Questionnaire (FEAHQ) is a 21-item self-administered questionnaire designed for co-completion by parents or carers and of 6-11 year-old obese children. It was developed to examine environmental factors and family behaviours associated with weight gain and weight loss in children[26].

The FEAHQ has four separate scales based on those factors most likely to be associated with weight change including: activity level, stimulus exposure, eating related to hunger and eating style. The instrument was considered appropriate for monitoring behavioural change over time as weight loss in a child was associated with an improvement in scores. The FEAHQ was developed in Israel.

Brief assessment instruments for use in adults

Valid dietary assessment tools are needed to facilitate dietary counseling in high risk populations. Nutrition counseling for adults and underserved groups often occurs in clinical settings with time and resource limitations, dietary assessment tools for this setting should be brief[27]. The Dietary Risk Assessment is one such tool, developed for non–dietetics-trained health professionals (eg. nurses and physicians) who provide dietary counseling to underserved patients. To help guide counseling, Dietary Risk Assessment response options are arranged in three columns. The left column indicates the most healthful dietary practices, whereas responses in the right or middle columns indicate less healthful practices[26].

A literature review conducted in 2005 identified some 71 methods[5]. Most of them included some anthropometry and sociocultural aspects related to food behavior. Sometimes they include biomarkers or more complex anthropometrical measurements.

A more standardized protocol about application procedures and advice to provide users according to the scoring. Many have not assessed the validity and reliability of the method and often not investigated the sensitivity, specificity and acceptability of these tools In the Prevención con Dieta Mediterránea (PREDIMED) trial 14-point Mediterranean Diet Adherence Screener (MEDAS) was validated and used to identify subjects' adherence to the intervention diet, a Mediterranean dietary pattern[28].

Dietary Intervention in Primary Care (DINE) is a 19-item questionnaire developed for use in interview-administered. It measures an individual's intake of total fat and dietary fibre, categorized as low, medium or high. Specific foods are included which account for 70% of the fat and fibre in a typical UK diet. The tool has been validated with good correlation with a validated four-day semi-weighed food diary. An experienced interviewer can complete it in 5–10 minutes[26].

Web-based tailored interventions aimed to modify food behavior, physical activity and other lifestyles in adults have also used screeners of brief instruments[29].

Several screening tools focused on malnutrition targeted to be used in old adults have been validated, such as DETERMINE your health or MNA. These instruments will are discussed in another paper in this issue.

References

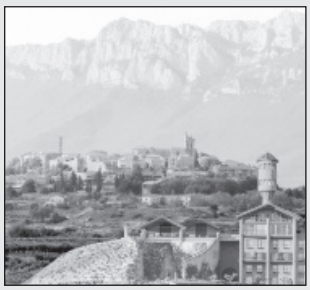
1. Scrimshaw NS, Gleason GR (eds). Rapid Assessment Procedures - Qualitative Methodologies for Planning and Evaluation of Health Related Programmes International Nutrition Foundation for Developing Countries (INFDC), Boston, MA. USA 1992. Disponible en URL : [http://www.unu.edu/unupress/food2/UIN08E/uin08e0x.htm] (Accessed 12 jannuary 2015).
2. Thompson FE, Subar AF. Dietary assessment methodology. In: Coulston AM, Boushey CJ, Ferruzzi MG, eds. Nutrition in the prevention and treatment of disease. 3rd ed. New York: Academic Press, 2012:5–46.
3. Aranceta Bartrina J, Serra Majem Ll. Métodos de evaluación rápida, cribado o identificación rápida de pacientes en riesgo nutricional. En: Serra Majem Ll, Aranceta Bartrina J (eds). Nutrición y salud pública. Métodos, bases científicas y aplicaciones (2ª edición). Barcelona: Elsevier, 2006: 192-198
4. National Cancer Institute, Division of Cancer Control and Population Sciences, Applied Research Program Short Dietary Assessment Instruments [http://appliedresearch.cancer.gov/diet/screeners/] (Accessed 10 January 2015)
5. Green SM, Watson R. Integrative literature reviews and meta-analyses Nutritional screening and assessment tools for use by nurses: literature review Journal of Advanced Nursing 2005; 50: 69 (doi:10.1111/j.1365-2648.2004.03350.x)
6. Thompson FE, Subar AF, Smith AF, Midthune D, Radimer KL, Kahle LL, Kipnis V. Fruit and vegetable assessment: performance of 2 new short instruments and a food frequency questionnaire. *J Am Diet Assoc* 2002 Dec;102(12):1764-72
7. Kirkpatrick SI, Reedy J, Butler EN, Dodd KW, Subar AF, Thompson FE, McKinnon RA. Dietary Assessment in Food Environment Research: A Systematic Review. *Am J Prev Med* 2014;46(1):94–102.
8. GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age–sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. ***Lancet*** 2015; 385: 117–71
9. Roberts K, Flaherty SJ. Review of dietary assessment methods in public health. Oxford: National Obesity Observatory, 2010
10. Schulz DN, Kremers SP, Vandelanotte C, van Adrichem MJ, Schneider F, Candel MJ, de Vries H Effects of a Web-Based Tailored Multiple-Lifestyle Intervention for Adults: A Two-Year Randomized Controlled Trial Comparing Sequential and Simultaneous Delivery Modes *J Med Internet Res* 2014;16(1):e26
11. Jilcott SB, Keyserling TC, Samuel-Hodge CD, Johnston LF, Gross; Ammerman AS. Validation of a Brief Dietary assessment to guide counseling for cardiovascular disease risk reduction in an underserved population *J Am Diet Assoc* 2007;107:246-255.
12. Serra-Majem L, Ribas L, Ngo J, Ortega RM, Garcia A, Perez-Rodrigo C, Aranceta J. Food, youth and the Mediterranean Diet in Spain. Development of KIDMED, Mediterranean Diet Quality Index in children and adolescents. *Public Health Nutr* 2004;7(7):931-935.-
13. Kim DJ, Holowaty EJ. Brief, validated survey instruments for the measurement of fruit and vegetable intake in adults: a review. *Prev Med* 2003; 36: 440-447.
14. Kristal AR, Shattuck AL, Henry HJ, Fowler AS. Rapid assessment of dietary intake of fat, fiber, and saturated fat: validity of an instrument suitable for community intervention research and nutritional surveillance. *Am J Health Promot* 1990; 4: 288-295
15. Mochari H, Gao Q, Mosca L. Validation of the MEDFICTS dietary assessment questionnaire in a diverse population, *J Am Diet Assoc* 2008; 108: 817-82
16. Thompson FE, Midthune D, Williams GC, Yaroch AL, Hurley TG, Resnicow K, et al., Evaluation of a short dietary assessment instrument for percentage energy from fat in an intervention study, *J Nutr* 2008; 138: 193S-199S.
17. Anderson CA, Kumanyika SK, Shults J, Kallan MJ, Gans KM, Risica PM. Assessing change in dietary-fat behaviors in a weight-loss program for African Americans: a potential short method. *J Am Diet Assoc* 2007; 107: 838-842.
18. National Cancer Institute, Division of Cancer Control and Population Sciences, Applied Research Program. Dietary Screener Questionnaire in the NHANES 2009-10. Available at: [http://appliedresearch.cancer.gov/nhanes/dietscreen/]. (Accessed 7 January 2015).
19. Feskanich D, Rockett RH, Colditz GA. Modifying the Healthy Eating Index to Assess Diet Quality in children and adolescents. *J Am Diet Assoc*, 2004; 104:1375-1383.
20. Oenema A, Brug J, Tan F. Shortterm impact of a web-based tailored nutrition intervention; main effects and mediators. *Ann Behav Med* 2005; 29:59-63.
21. Haraldsdottir J, Thorsdottir I, de Almeida MD, Maes L, Perez C, Elmadfa I, et al. Validity and reproducibility of a pre-coded questionnaire to assess fruit and vegetable intake in European 11- to 12-year-old schoolchildren, *Ann Nutr Metab* 2005; 49: 221-227.
22. Cade JE, Frear L, Greenwood DC. Assessment of diet in young children with an emphasis on fruit and vegetable intake: using CADET – Child and Diet Evaluation Tool. *Public Health Nutrition* 2006; 9(4):501–8.
23. Edmunds LD, Ziebland S. Development and validation of the Day in the Life Questionnaire (DILQ) as a measure of fruit and vegetable questionnaire for 7–9 year olds. *Health Educ Res* 2002; 17(2):211–20.
24. Moore HJ, Ells LJ, McLure SA, Crooks S, Cumbor D, Summerbell CD, Batterham AM. The development and evaluation of a novel computer program to assess previous-day dietary and physical activity behaviours in school children: The Synchronised Nutrition and Activity ProgramTM (SNAPTM). *Br J Nutr* 2008; 99(6):1266–74.
25. Wilson AM, Magarey AM, Mastersson N. Reliability and relative validity of a child nutrition questionnaire to simultaneously assess dietary patterns associated with positive energy balance and food behaviours, attitudes, knowledge and environments associated with healthy eating. *Int J Behav Nutr Phys Act* 2008; 5:5–16
26. National Obesity Observatory (NOO).Measuring diet and physical activity in weight management interventions. March 2011.London: NHS, 2011
27. Gans KM, Ross E, Barner CW, Wylie-Rosett J, Mc Murray J, Eaton Ch. REAP and WAVE: New tools to rapidly assess/discuss nutrition with patients. *J Nutr* 2003; 133: 556S-562S.
28. Schröder H, Fió M, Estruch R, Martínez-González MA, Corella D, Salas-Salvadó et al. A Short Screener Is Valid for Assessing Mediterranean Diet Adherence among Older Spanish Men and Women. *J Nutr*. 2011 Jun;141(6):1140-5. doi: 10.3945/jn.110.135566. Epub 2011 Apr 20.
29. Broekhuizen K, van Poppel MN, Koppes LL, Kindt I, Brug J, van Mechelen W. Can multiple lifestyle behaviours be improved in people with familial hypercholesterolemia? Results of a parallel randomised controlled trial. *PLoS One* 2012;7(12):e50032. doi: 10.1371/journal.pone.0050032. Epub 2012 Dec 12

DIETARY SURVEYS AND ENERGY BALANCE: METHODOLOGY, BIAS, ADJUSTMENT AND OTHER ISSUES

ENCUESTAS DIETÉTICAS Y BALANCE ENERGÉTICO: ASPECTOS METODOLÓGICOS, SESGOS, AJUSTES Y OTROS PROBLEMAS

"Consensus Meeting on the Methodology of Dietary Surveys, Classification of Physical Activity and Healthy Lifestyles"

"Reunión de Consenso sobre la Metodología de las Encuestas Alimentarias, Tipificación de la Actividad Física y Estilos de Vida Saludables"



Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):101-112
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Energy Balance, a new paradigm and methodological issues: the ANIBES study in Spain

Gregorio Varela Moreiras[1,2], José Manuel Ávila[2] and Emma Ruiz[2]

[1]*Department of Pharmaceutical and Health Sciences, Faculty of Pharmacy, CEU San Pablo University, Madrid (SPAIN).* [2]*Spanish Nutrition Foundation (FEN). Madrid (SPAIN).*

Abstract

Energy Balance **(EB) is an important topic to understand how an imbalance in its main determinants (energy intake and consumption) may lead to inappropriate weight gain, considered to be "dynamic"and not "static". There are no studies to evaluate EB in Spain and new technologies reveal as key tools to solve the common problems to precisely quantify energy consumption and expenditure at population level. Within this context, the increasing complexity of the diet, but also the common problems of under and over reporting in nutrition surveys have to be taken into account.**

The overall purpose of the ANIBES ("Anthropometry, Intake and Energy Balance in Spain") Study was to carry out an accurate updating of foods and beverages intake, dietary habits/ behaviour and anthropometric data of the Spanish population as well as the energy expenditure and physical activity patterns, by the use of new tested instruments (i.e. tablet device to assess energy intake and accelerometer to evaluate physical activity). This new ANIBES Study will contribute to a better knowledge of the different key factors contributing to EB in Spain.

(*Nutr Hosp* 2015;31(Supl. 3):101-112)

DOI:10.3305/nh.2015.31.sup3.8758

Key words: *Energy balance. Dietary intake. Physical activity quantification. New technologies. Nutrition surveys.*

BALANCE ENERGÉTICO, UN NUEVO PARADIGMA Y ASPECTOS METODOLÓGICOS: ESTUDIO ANIBES EN ESPAÑA

Resumen

El *balance energético* (BE) o equilibrio energético se refiere "simplemente" a que debemos ingerir la misma cantidad de energía que gastamos. Conocer el concepto de BE y aplicarlo a nuestras vidas es quizá el factor más importante para mantener una buena salud y tratar de prevenir la obesidad. Sin embargo, la teoría no es sencilla llevarla a la práctica ya que, por un lado, en este ya avanzado siglo XXI desconocemos todavía en gran medida lo que comemos, en definitiva, nuestra alimentación. Y ésta es cada vez más compleja, lo que dificulta sin duda controlar adecuadamente este lado de la "balanza", la ingesta. Pero además, en el otro lado, el correspondiente al gasto energético, aún es peor conocido y hay muy escasa información en la cuantificación adecuada del mismo. Debe recordarse, además, que no debemos estudiar aisladamente los componentes del BE, sino de manera integrada, y como interaccionan. Problemas como la infravaloración de la ingesta de energía, y la sobrevaloración del gasto, son frecuentes en la mayoría de las encuestas nutricionales, impactando más en aquellos grupos de población en los que el control del BE resulta aún más necesario. El empleo de las nuevas tecnologías abre numerosas posibilidades para las encuestas de balance energético. Precisamente, la innovadora metodología (empleo de "tablet" para cuantificación de la ingesta, y de acelerómetros para el nivel de actividad física) en el reciente Estudio ANIBES ("*Antropometría, Ingesta, y Balance Energético en España*"), representativo de la población española, y que hemos desarrollado, proporciona una herramienta útil y actualizada para un mejor conocimiento del *balance energético* de la población española, como se pone de manifiesto en el presente artículo.

(*Nutr Hosp* 2015;31(Supl. 3):101-112)

DOI:10.3305/nh.2015.31.sup3.8758

Palabras clave: *Balance energético. Encuestas nutriconales. Ingesta. Actividad física. Nuevas tecnologías.*

Correspondence: Gregorio Varela Moreiras.
Catedrático de Nutrición y Bromatología.
Director Dpto. CC. Farmacéuticas y de la Salud.
Facultad de Farmacia Universidad CEU San Pablo.
Urb. Montepríncipe, crta. Boadilla km. 5,3.
28668 Boadilla del Monte, Madrid. España.
E-mail: gvarela@ceu.es / gvarela@fen.org.es

Introduction and goals

Energy Balance (EB) is defined as the state achieved when energy intake equals energy expenditure and is considered to be "dynamic" and not "static"[1]. The concept of energy balance for regulating body weight is simple in principle. When energy expenditure exceeds energy intake, weight is lost. When energy intake exceeds energy expenditure, weight is gained[2]. Human physiology complies with the first law of thermodynamics, which states that energy can be transformed from one form to another but cannot be created or destroyed. A fundamental principle of nutrition and metabolism is that body weight change is associated with an imbalance between the energy content of food eaten and energy expended by the body to maintain life and to perform the variety of physical work. Such an EB framework is a potentially powerful tool for investigating the regulation of body weight[3].

Energy intake (EI) includes three major macronutrient groups—carbohydrates, proteins, and fats—and alcohol. Once ingested, the net absorption of the major macronutrient groups is variable and incomplete,with fecal losses accounting for 2–10% of gross intake [3,4]. The net absorption of dietary energy components varies among individuals and is dependent on the specific foods eaten, how they are prepared, and intestinal factors. The metabolizable energy of a diet represents the difference between the absolute energy of ingested substrates and the energy losses found in feces and urine. Commonly used energy densities for carbohydrate (4 kcal/g, 17 kJ/g), protein (4 kcal/g, 17 kJ/g), and fat (9 kcal/g, 38 kJ/g) represent population averages for metabolizable energy available to cells for conducting the different biological processes[4].

Digestibility depends on the composition of the food item and on its content of fiber and other indigestible components. Such components can mechanically limit the access of digestive enzymes to food that would potentially be digestible. These effects can have a large impact on the absorption of ingested macronutrients. The variability in absorptive efficiency depends on any additional factors (eg, gut flora, food preparation, diet composition), which may explain the individual differences in metabolizable energy. Other factors to influence EI are: the increasing complexity of the food market nowdays (i.e. over 30,000 available products for shopping); total intake; energy density; timing and composition of diet relative to physical activity; food liking and disliking; social and economical context; or current body weight and composition [3,4]. Absorbed carbohydrates, proteins, and fats are transformed in vivo to substrates that can ultimately either be oxidized to produce metabolically useful energy that drives biological processes or they may be stored [5].

Humans expend energy through resting metabolic rate (RMR), which is the amount of energy necessary to fuel the body at rest; the thermic effect of food (TEF), which is the energy cost of absorbing and metabolizing food consumed; and the energy expended through physical activity [2,6]. RMR is proportional to body mass, particularly the amount of fat-free mass. There is also, however, a large variability in RMR (250 kcal/d ;1000 kJ/d) that is not explained by differences in body composition[7].The TEF is proportional to the total food consumed and, in a typical mixed diet, makes up 8% to 10% of total energy ingested. Diet composition has a strong effect on TEF, and a hierarchy of macronutrient effects on the magnitude of TEF, the highest for protein and lowest for fat. Normally, TEF is assumed to be a fixed percentage of EI, but variation between and within individuals also occurs [7,8]. The energy for physical activity, the most variable component of energy expenditure, consists of the amount of physical activity performed multiplied by the energy cost of that activity and can be further partitioned into exercise energy expenditure and non exercise activity thermogenesis [9,10].

In summary, the key factors that may regulate the energy expenditure *side* of the balance are: resting metabolic rate; activities of daily living/level of sedentary behavior; metabolic cost of digestión, absorption and metabolism; amount (min/d); type, timing and intensity of physical activity; thermogenesis; and current body weight and composition.

The different components of the energy balance equation continuously change over time[11]. Beginning at conception, and remains positive, on average, throughout growth and development[12]. This positive energy imbalance is reflected by increasing body weight. If adult weight is then maintained over the long term, average EB approaches zero, and an approximate average state of energy balance should be present. However, most adults gain fat throughout their lives and in later life lose skeletal muscle; although the energy content of body fat change is much higher than that of lean tissue change. Thus, even with weight stability, "perfect" energy balance over the long term does not occur in most older adults [2,13,14].

In terms of a short term period, over a 24-h period, a typical person eats several meals during the day, and EB is strongly positive during and after each meal. Energy output is continuous but with increases due to episodic physical activity and reduction during sleep. In consequence, EB is thus highly variable even over just a 1-d period. In addition, most adults also vary their daily eating and activity patterns; thus, EB should be seen as a dynamic rather that a static state since it also varies from day to day, and EB may be achieved only when averaged over longer time periods. The energy content of a given meal is highly variable between individuals and highly variable between meals in an individual. However, the variation in total caloric intake summed across all meals over a day is far less variable. This suggests that there is meal-to-meal compensation of intake[13]. In addition to variation in intake between meals on a given day, we also vary the amount of food eaten each day. On the contrary, energy expenditure

rarely shows the same degree of variation across days. Hence, and importantly, we are almost perpetually in energy imbalance on the time scale of hours or days, and even through the whole life cycle.

Furthermore, we know that the components of energy balance can be influenced by changes in each other as a consequence of positive or negative EB, which act to defend body energy stores, to maintain energy balance, and to prevent shifts in body mass[2]. We know that if energy balance were not controlled by such a system and were subject *only* to behavioral mechanisms controlling food intake and energy expenditure, most people would routinely experience wide swings in body weight over short periods of time. Therefore, the relative stability of body weight from day to day is consistent with the view that EB is subject to physiological control.

The energy balance literature and information about how our modern lifestyle differs from decades ago, hypothesize that human physiology developed under circumstances that conferred an advantage for achieving energy balance at a relatively high level of energy expenditure or high energy flux, which was first shown by Mayer in the 1950´ by their observation that energy intake was better matched to energy expenditure when people were physically active[15]. It is well known that over the past century and continue, the physical activity level of most of the population has declined substantially. Although it is theoretically possible to avoid weight gain in this situation, the fact that few people have accomplished this suggests that it is difficult to maintain EB at a low energy throughput [16,17].

Food restriction is a common strategy for reducing excess body weight and/or treating obesity[18]. However, food restriction produces weight loss, but it also produces compensatory decreases in other components of energy balance, such as decreases in energy expenditure and body energy stores, and even an increase in hunger[4]. Because energy requirements fall with weight loss, a dangerous and unhealthy strategy for weight loss maintenance is trying to match a lower level of energy expenditure with a lower energy intake. It has to been remained that lowering energy intake is opposed by biology and the environment. An additional problem could be that at a reduced energy intake level, nutrients (mainly vitamins and minerals) dietary reference intakes may not be achieved, which may represent a key problem in some vulnerable groups (e.g. children and elderly). Finally, at high energy expenditure, it would be easier to comply with the principle that an adequate nutrition it is health but also pleasure. In consequence, it matters how EB is achieved, at high or low level[1].

It is therefore important to recognize that the EB system is interactive and complex: a change in one component can affect one or more other components. Recently, a Panel of Experts identified the following important gaps in our knowledge, and asked for future investigation[13]:

1. Although we know much from short-term studies about the major components of energy balance, our knowledge is still deficient regarding their interaction over the long term. Therefore, long-term, longitudinal studies to learn the details of the relations between components of energy balance and changes in body composition and weight among children and adults are needed.

2. It has been shown that biological and psychological factors affect the components of energy balance. But generally, these have been studied independently of one another and an integrative approach is required. We need to know the relative importance of preingestive factors on energy intake, energy balance, and the physiologic response to a meal.

3. Although our knowledge of the broader implications of physical activity and exercise have been investigated, we need to understand the effects of different doses (volume, intensity, pattern, timing) and types (endurance, resistance) of exercise on: a) total daily energy expenditure and its components, b) EI and food preferences, and c) body composition and body weight in children and adults.

4. The individual variation in weight-loss response to energy balance interventions is striking, and therefore we need to know the mechanism or mechanisms responsible for the underlying active compensatory differences in energy intake, food preferences, and body weight in children and adults. In particular, we have almost no information from energy balance studies subsequent to weight loss during the difficult period of weight maintenance.

5. And very important, measurements of energy input and output are neither precise nor accurate enough to allow the calculation of energy balance over the appropriate timeframe needed to understand the mechanisms responsible for excess weight gain. Accordingly, we need to develop new methods that can reliably measure energy balance over extended time periods in free-living people.

The EB is not well defined for the Spanish population and it is essential to approach it with the aim of being able to properly establish the energy requirements for our population and the subsequent Reference Intakes. It seems essential to improve the tools for studying the energy intakes and losses of "free living" independent subjects[13]. In this regard, the tools such as databases of the composition of quality foods, especially regarding energy and serving sizes, should be improved, as clearly stated at the recent (2013) Consensus Document and Conclusions on "Obesity and Sedentarism in the 21st Century: What can be done and what must be done?"[19].

Different valuable dietary surveys have been conducted in Spain, although to the best of our knowledge, no one has attempted to specifically approach EB. Briefly, the first Food Consumption Survey was performed in 1956 under the National Health Survey. Further, several Spanish Food Consumption and Nutrition

Surveys have been carried out (ENNAs; 1964-1965, 1980-1981 y 1990-1991) mainly in collaboration with the National Statistics Office (INE, Spain)[20-23]. From 1987 onwards, the current Ministry of Agriculture, Food and Environment (MAGRAMA) in Spain launches the National Food Consumption Survey (Panel), in for which the Spanish Nutrition Foundation (FEN) is responsible for analyzing the dietary patterns and energy/nutrients intake of the Spanish population since the year 2000 onwards[24]. At national level, the current AECOSAN (Spanish Agency for Consumer Affairs, Food Safety and Nutrition) recently carried out the ENIDE Survey (Encuesta Nacional de Ingesta Dietética) (AECOSAN, 2012)[25]. At present, the so-called ENALIA (Encuesta Nacional de Alimentación en la población Infantil y Adolescente) Survey in children and adolescents from Spain is being carried out also under the auspices of AECOSAN. The latter updates the reference survey in Spain in children and young people (2-24 years old) called EnKid[26], and the AVENA study, a multicenter nutrition survey in Spanish adolescents[27]. However, when approaching the other main EB determinant ("energy expenditure") studies are much less frequent even scarcer and lack of accuracy. The most recent National Health Survey in Spain (2013)[28] revealed that four out of ten persons (41.3%) of the adult Spanish population is considered as sedentary, higher for women (46.6%) than for men (35.9%) (they do not perform any kind of physical activity during their leisure time). Considering both their main and their leisure time activity, 40.9% of the adults (49.4% males, 32.4% females, aged 15-69 years) perform strenuous to moderate weekly physical activity. There is consensus at present that not only physical activity level but also inactivity and/or sedentary behavior should be taken into account and quantified [3,6].

The ANIBES ("Anthropometry, Intake, and Energy Balance in Spain") Study, aims at adding new scientific-based evidence to describe the interplay among energy intake, energy expenditure, and body energy stores and how an understanding of energy EB must be considered as an useful tool either at individual or population level.

Anibes study design and sampling procedure

The design of the ANIBES Study aimed a sample size which should be representative of all individuals living in Spain (excluding the autonomous cities of Melilla and Ceuta) aged 9-75 years, living in municipalities >2,000 inhabitants. The universe considered about 37 millions of inhabitants. The initial potential sample was 2,634 individuals, and the final sample was 2,009 individuals (2.23% error and 95.5% confidence interval). In addition, for the youngest groups (9-12, 13-17 and 18-24 years old), a boost was considered in order to have at least a n=200 per age group (error +/-6.9%) to increase the statistical power. Therefore, the random sample plus booster was 2,285 participants (Table 1).

Table I
Distribution of the sample for the ANIBES study.

		SAMPLE (n)		
		Initial targeted sample	*Final sample*	*Final + Boost*
	Base	*2634*	*2009*	*2285*
SEX	Men	1309	1013	1160
	Women	1325	996	1125
AGE (yr)	Infants 9 – 12	240	100	213
	Adolescents 13 – 17	246	124	211
	Adults 18 – 64	1911	1588	1655
	Elderly 65 – 75	237	197	206

In the ANIBES sample, 50.4% of adults (aged 9-75 years) were men and 49.6% were women. The sample reflects the distribution of males and females in the general population within Spain. A more detailed description of the sample for the ANIBES study is shown in Table 1.

The sample quotas according to the following variables were:

- Age groups (in years): 9-12, 13-17, 18-64 and 65-75.
- Gender: men and women.
- Region: 7 Nielsen areas (Northeast, Levant, South, West, North Central, Barcelona, Madrid) and Canary Islands.
- Habitats size: 2,000 to 30,000 inhabitants (rural population); from 30,000 to 200,000 inhabitants (semi-urban population) and over 200,000 inhabitants (city/town population).
- Additionally other factors for sample adjustment were considered: rate of unemployment; % of foreigners (immigrant population), level of physical activity, or, education and economical level.

Study was conducted through a stratified multistage sampling and for more coverage and representativeness, 128 sampling points were used, with 90 interviewers allocated in 11 areas and 12 coordinators, all previously trained by the *Spanish Nutrition Foundation* (FEN) (Figure 1). No previous pre-recruitment was considered, which minimized the risk of bias in responses.

The final protocol was approved by the Ethical Committee for Clinical Research of the Region of Ma-

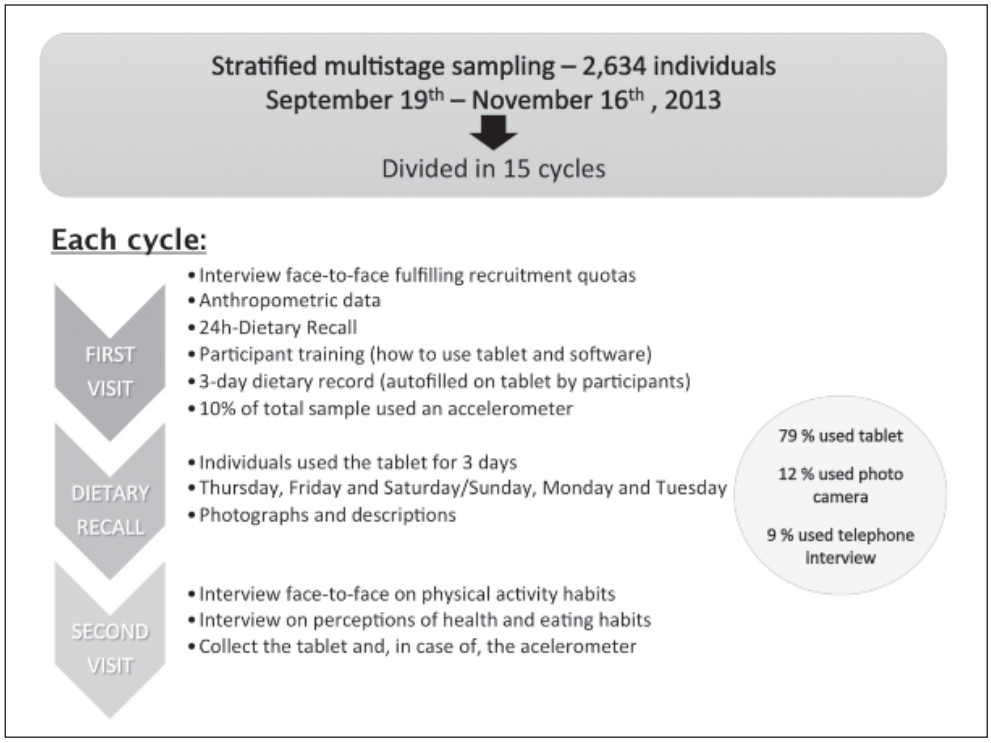


Fig. 1.—General scheme of the ANIBES Study in Spain.

drid (Spain). The final fieldwork was carried out from mid-September to November (three months), 2013.

Two **pilot studies** were previously carried out, as follows:

Once the methodology was developed, a first pilot study was carried out in June 2013. For this purpose, 2,060 individuals were contacted: 162 (7.8%) agreed to have the first visit/interview, 142 participated at the second visit/interview, but only 97 were able to make the three-days dietary record by using the tablet. Finally, only 57 participants were considered as fully eligible. Therefore, a high rate of non-responders was observed mainly in the older age groups and parents of children and adolescents. The first pilot study allowed reviewing several issues, both software and questionnaires.

Once the results from the pilot study were completed, several *working/discussion groups* were created in order to improve the study design, protocols, software and manuals. Therefore, four groups (one of interviewers; two mixed groups of young adult people from 25-35 years old; one group of parents with children aged 9-17 years) worked in order to improve the deficiencies observed during the fieldwork.

A second pilot study was carried out in order to evaluate the improvements after the first pilot study and comments and recommendations from the working groups. A total of 60 individuals (52 used tablet device; 5 photo camera; 3 by phone interview) participated. The second pilot study demonstrated the efficacy of the amendments made and validated the tools and questionnaires to be used later during the main fieldwork of the ANIBES Study.

Final Fieldwork

According to the number of interviews to be potentially targeted at the sampling point, one or more random initial routes for the sampling process were considered. The later criteria were not used for municipalities over 100,000 inhabitants where a postcode proportional criterion was considered. In the initial route, the apartment building or family housing was randomly selected, as well as the first household to be approached. Non-eligible addresses include vacant or derelict properties and institutions. If the *uptake* was positive, limits to be considered for a potential participant were:

Apartment building:

- 1-10 units, only one potential participant.
- 11-20 units, two potential participants as maximum.
- 21-50 units, three potential participants maximum.
- >50 units, four participants.

For family housing, one possible participant per 10 units was the rule used.

The survey was designed in order that no more than one adult and one child were selected from a household. This meant that adults living in households with one or more adults, and children in households with one or more children were less likely to be selected than were adults or children in single adult/child households.

All interviewers, call centre and dieticians-nutritionists working on the ANIBES study were briefed and trained before undertaking an assignment and were monitored during their assignment. All interviewers attended a two-day training course designed by the FEN

where they were fully briefed on the protocols and administration of the survey. Fieldworkers were also issued with comprehensive written instructions covering survey procedures and measurement protocols. The briefing sessions covered background and content, doorstep approach, questionnaire administration (including practice sessions), placement and collection of self-completions and ActiGraphs and the placement, checking and collection of the three-day food tablet diaries and 24h-dietary recall and training in anthropometric data collection. After the briefing, "early work" checks were carried out at the two pilot studies that were carried out.

In order to cover a broad range of dates and to optimize the devices to be used during the study, several stages were designed (Figure 1), and comprised of:

Stage 1: the interviewer visits

A letter and leaflet describing the purpose of the survey were previously posted in potential targeted apartment building/family housing at the sampling points. A few days later, interviewers visited the addresses to determine whether the address was private, residential and occupied. They then carried out the selection process as already explained.

Interviewers carried out two main visits to households who agreed to participate:

The **first visit** ("face-to-face") with an approximate duration of 60 minutes comprised the following items:

a) **Identification of the trained interviewer,** as a collaborator of the FEN. The interviewer explained the main goals of the study, the design and stages, the novelty of the tools to be used for collecting food intake and recording physical activity, as well as offered to have a feedback report at the end of the study that included main results, dietary and physical activity advice, etc. The potential participant also received a letter from the principal investigator of ANIBES Study, and was informed for participation in the study. At this point, the potential participant was asked to sign the letter of consent for participation in the study.

b) **Inclusion/exclusion questionnaire**: the interviewer verified through a filter questionnaire that the participant was eligible for the ANIBES Study after reviewing the inclusion/exclusion criteria.

Several exclusion criteria were applied:

Those individuals living in an institution (e.g. colleges; nursing homes, hospitals, etc.)

Individuals following a therapeutic diet due to a recent surgery or any medical prescription.

If they were suffering a transitory pathology (i.e. flu, gastroenteritis, chicken pox, etc.) at the time of the fieldwork.

Individuals employed in areas related to consumer science, marketing or the media.

However, individuals under the following conditions were considered eligible to be included:

Those following dietary advice such as for prevention of hypertension, diabetes, hypercholesterolemia or hyperuricemia.

Pregnant and lactating women.

With diagnosed allergy and/or food intolerance.

Suffering a metabolic disease such as hyperthyroidism or hypothyroidism.

c) **Anthropometric measurements:** the trained interviewer collected the different measures following the procedures tested before at the two pilot studies:

Height: by triplicate using a *Stadiometer model Seca 206 (Medizinische Messsysteme und Waagen seit 1840, Hamburg, Germany)*.

Weight: one determination in a weighing scale model *Seca 804* (*Medizinische Messsysteme und Waagen seit 1840, Hamburg, Germany)*. This scale provide information about BMI, percentage of body fat and percentage of body water.

Waist circumference: by triplicate using a tape measure model *Seca 201*.

d) **24-h Dietary Recall**: an *adhoc* questionnaire was designed and previously checked and modified at the pilot studies. During the interview the participant recalled the food intake for the past 24 hours (working days). Food quantities were assessed by using of household measures, food models, pictures, or the brands. No prior notification was given to the subjects about whether or when they would be interviewed about their food intake. Information on food consumption was recalled per day, per meal and in between meals. The 24-h dietary recall was designed to further verification of the information collected at the Tablet, but also to make the participant more familiar with the type of information to be recorded in the diet record during the three-days period.

e) **Tablet device for collection of dietary data: the three-day food diary**:

All the participants were provided with a tablet device (*Samsung Galaxy Tab27.0.*) and instructed on how to record by taking pictures of all foods and drinks consumed during these three days, both at home and outside. Pictures had to be taken before and after finishing. Additionally, a brief description of the meals, recipes, brands, etc. had to be also recorded with the device. A specific software ("IPSOS Mobile for ANIBES") was designed which allowed to save the uncompleted information before sending it for codification. The tablet was designed only to be used to collect information related to ANIBES Study and no other uses were allowed.

A toll-free telephone number attended by call center operators of ipsos, trained by dieticians-nutritionists, was also available for the participants in order to answer any questions about the softwa-

re, device working, food and beverage record, etc. Interviewers carried out a food diary check visit with participants on the second visit or third day of recording, either in person or over the telephone, with the aim of collecting missing details for foods recorded after initial codification process was completed and lack of information was detected. A manual of procedures to facilitate food collection was also given to the participants. Participants were also informed that an insurance would cover any accident or incidence with the devices, although they were asked for correct and watchful functioning and maintenance.

The different days of the week would (as far as possible) be equally represented as each cycle always included two working days (Monday and Tuesday or Thursday and Friday) and one weekend day (Saturday for Thursday and Friday cycle or Sunday for Monday and Tuesday cycle).

f) As an alternative to the tablet device, if the participant declared or demonstrated that he/she was unable to use it, other possibilities were offered: **photo camera and paper** or **telephone interview**. In both cases, the information to be collected was the same as with the tablet.

g) At the end of the first visit, the date for the second interviewer visit was agreed, as well as the telephone calls to be made for check up at the end of the collection of the data, if necessary.

h) **Accelerometer device to quantify physical activity level:** The objective physical activity measurements were obtained with an accelerometer ActiGraph (model GT3x y GT3x+; *ActiGraph, Pensacola, FL, USA*). This provides a measure of the frequency, intensity, and duration of physical activity and allows classification of activity levels as sedentary, light, moderate and vigorous. Individuals were asked to wear the ActiGraph on a belt above the right hip, during three consecutive full days including its cycle of the three days food & beverages dairy record by the tablet. Objective measurements of physical activity were taken using the ActiGraph, which recorded vertical movement, where the number of movements ('counts') increased with the intensity of activity. For any individual, the accelerometer recorded different periods during the day spent at different levels of activity, i.e. differing levels of 'counts per minute' (cpm), while they were being sedentary or engaging in light, moderate, or vigorous activity. This provided a measure of the frequency, intensity, and duration of physical activity and allowed classification of activity levels as sedentary, light, moderate and vigorous. Individuals were asked to wear the accelerometer on a belt above the right hip, during waking hours for three consecutive full days in parallel with the three days of food & beverages dairy record by the tablet. For the present study, the minimum wear time criterion for inclusion in analysis was set at three days. The average daily cpm for each participant was calculated as a weighted average based on the probability of wear/non-wear (for a minimum wearing time of at least eight hours per day). The participants were also provided with a sheet to be filled in with the periods (hours/minutes) of non-wear (shower, swimming, etc.). For those participants that agreed to wear the accelerometer (n=206) to quantify the physical activity, the device was activated coincident with the Tablet based three-day food diary**.** The subsample was selected following the same criteria for representativeness as for the total sample included in the study. After collecting the accelerometer devices at the second interviewer visit, they were sent to IPSOS in order to download the recorded information from the participant (physical activity, but also additional data such as sex, date of birth, height, and weight) and to recharge the battery for the next participant. The recorded information by the accelerometer in the subsample (167 adults and 39 children) was further used to validate the physical activity questionnaire administered to the whole sample, and to build a mathematical model to quantify energy expenditure in combination with different standard formulas.

The **second visit** ("face-to-face") with an approximate duration of 60 minutes comprised the following items: detailed interview about physical activity (IPAQ questionnaire for children and adolescents modified according to the HELENA study[29]), and a detailed interview by using validated questionnaires previously tested at the pilot studies, designed to gain insights from the participants on important food safety, nutrition and health-related topics, was also scheduled. In addition, the tablet device and the accelerometer were collected. Participants who were considered "fully productive" according to the completion of the stages, were asked whether they would like to receive feedback on the analysis of their diary and how was this compared to nutrient intake recommendations. The feedback also included general information related to healthy eating advice.

- A summary of the ANIBES fieldwork follows:
- Fieldwork dates: September 19th through November 16th, 2013, structured in 15 different cycles/stages.
- 90 interviewers and 12 coordinators.
- Equipments:
  - 426 *tablets devices*
  - 90 devices for anthropometric measurements (weighing scale, stadiometers, tape measure).
  - 87 accelerometers.
- Devices employed
  - 79% of the sample used *Tablet*
  - 12% used photo camera
  - 9% used telephone interview

A more detailed distribution of the devices used by sex and age group is shown in Table 2.

Table II
Devices used according to sex and age groups for the ANIBES study.

		SAMPLE (n)											
		Initial targeted sample				*Final Sample*				*Final sample + Boost*			
		DEVICE				*DEVICE*				*DEVICE*			
		Base	*TABLET*	*PHOTO CAMERA*	*TELEPHONE*	*Base*	*TABLET*	*CAMARA*	*TELEFHONE*	*Base*	*TABLET*	*CAMARA*	*TELEPHONE*
SEX	Base	2634	2077	320	237	2009	1568	253	188	2285	1804	279	202
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Men	1309	1038	156	115	1013	800	124	89	1160	922	143	95
		50%	50%	49%	49%	50%	51%	49%	47%	51%	51%	51%	47%
	Women	1325	1039	164	122	996	768	129	99	1125	882	136	107
		50%	50%	51%	51%	50%	49%	51%	53%	49%	49%	49%	53%
AGE (yr)	Base	2634	2077	320	237	2009	1568	253	188	2285	1804	279	202
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Children 9 – 12	240	201	29	10	100	82	15	3	213	178	27	8
		9%	10%	9%	4%	5%	5%	6%	2%	9%	10%	10%	4%
	Adolescents 13 – 17	246	221	21	4	124	113	8	3	211	190	18	3
		9%	11%	7%	2%	6%	7%	3%	2%	9%	11%	6%	1%
	Adults 18 – 64	1911	1571	207	133	1588	1300	176	112	1655	1361	180	114
		73%	76%	65%	56%	79%	83%	70%	60%	72%	75%	65%	56%
	Elderly 65 – 75	237	84	63	90	197	73	54	70	206	75	54	77
		9%	4%	20%	38%	10%	5%	21%	37%	9%	4%	19%	38%

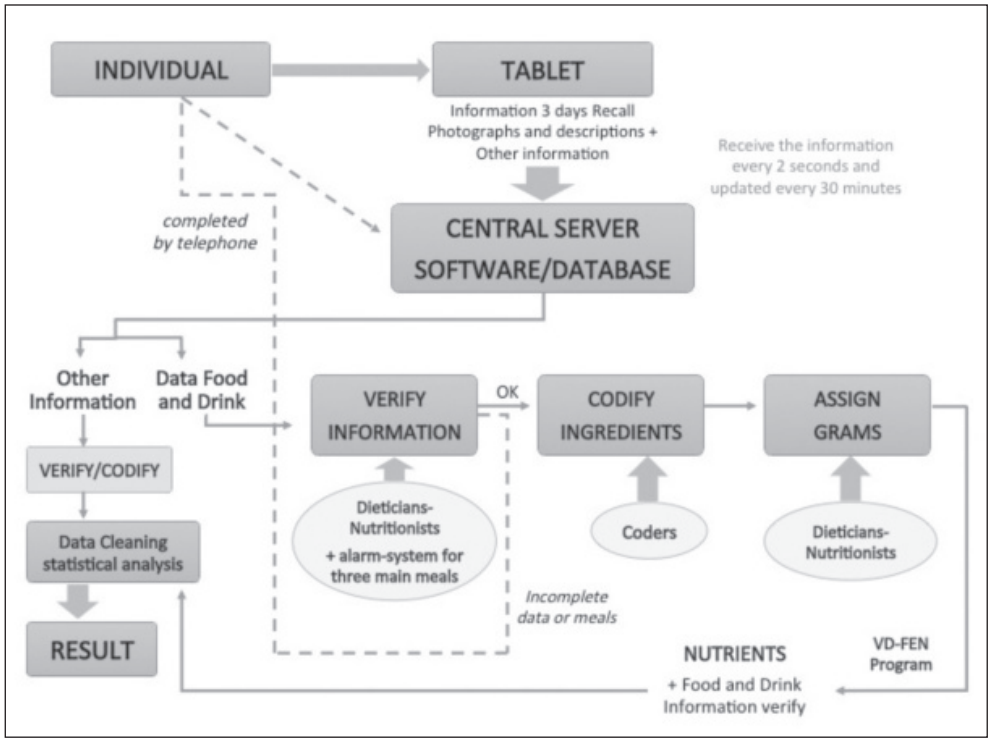


Fig. 2.—General scheme of the protocol followed for data collection, processing, cleaning, and codification during the ANIBES Study in Spain.

Data processing

Figure 2 shows an scheme for a better understanding of the data processing, quality control,cleaning of the data, and codification and verification stages.

The innovative technology used in this study allowed that all the collected information could be verified and codified in nearly *real time*. For that purpose, participants were asked to record everything eaten or drunk over three consecutive days. As already explained, when placing the *tablet* device, interviewers followed a protocol to explain the method, taking participants through the different sections including the instruction page, how to describe details of food and drink and portion sizes and several examples. In addition to the detailed information about what and how much was eaten, participants recorded for each eating occasion: where they were, who they were eating with and what they were doing (for instance, of they were watching TV or not). After each day, participants recorded if their intake was typical for that day (and if not, the reason why) and details of any dietary supplements taken. The software also contained a serie of questions about usual eating habits (for example, type of milk or fat spread usually consumed) to facilitate coding.

Food and beverage records were returned from the field in *real time* to be coded by trained coders and editors. For this purpose, an *ad hoc* Central Server software/database was developed by IPSOS (Java/IE10 compatible) in order to be able to work in parallel with the verification process followed by the codification. Within this context, the software was prepared to receive the information from the field tablets every two seconds, and updated every 30 minutes. The Central Server contained different modules to verify the information at individual level but also according to the specific cycle; food weight and intakes; food codification and the assigning weight in grams. If for any reason, the terminal was unable to be connected to the network, the recorded information by the participant was saved, and resubmitted once the problem was solved. The innovative Central Server system allowed checking the different cycles, the participants records, which meant that possible incidents were able to be fixed in a very short period of time. Finally, 189,600 inputs (ingredients) were managed from the 2,009 participants, about 73 items per participant, and 24.3 food/beverages items per person/day as mean.

Coders attempted to match each food or drink item recorded in the tablet device with a food/portion code. For composite items which could be split into their component parts, each individual component was assigned. If an item had been recorded and there was no suitable code or there was insufficient detail to code the food, the entry was flagged as a query. Each food code is linked to appropriate portion size descriptors, such as a tablespoon for rice or pasta, which are then linked to the correct weight for that descriptor. So if a participant recorded/described their food using household measures, coders under dieticians-nutritionists checking would be able to select the appropriate portion size. If the portion size was described as a weight, the weight would be entered directly into the system. Where the coder could not resolve the food or portion consumed, the entry was flagged as a query for action by a researcher who had greater nutrition knowledge and experience. The die-

ticians-nutritionists assigned appropriate codes for all flagged food and portion codes and checked any other queries raised by the coders. In general, where details for the coding of foods were missing, formally agreed default codes were used. Where portion sizes were missing, an estimate was made using the same weight if the food was consumed on another dietary day, or a portion size consistent with the participant's usual consumption (e.g. small, medium or large), or an age-appropriate average portion.

For new products still not included in the ANIBES program, supermarkets or retail markets were visited or the manufacturer contacted to obtain information on nutrient content in order to decide whether a new food code was needed. This decision was based on nutritional composition compared to that of existing codes, as well as the frequency of consumption. If a new food code was required, the nutrient content was entered into the database. In the case of school meals, school caterers information about the nutrient content and portion size of dishes was considered. For homemade dishes where a recipe had been recorded, the ingredients were entered individually using the appropriate cooked food codes, and all the codes for the dish were allocated to a recipe food group according to the type of dish. The weight of each cooked ingredient was calculated using the raw weights recorded by the participant, a weight loss factor for the whole dish if possible, and the weight of the portion consumed.

Quality control

The quality control of the collected information was supervised by trained dieticians-nutritionists, according to the following protocol:

a) The same dietician-nutritionist was responsible for checking the food records included by the participant during the three-day dietary food record study.

b) The initial quality control was based on the photographs and descriptions sent by the participants, but also the brief description that was asked before/after each meal and/or intake. Special care was given to validate some variables such as ingredients, brands of the processed and ready-to-eat foods, portion size or culinary technique in order to obtain accurate information for further codification.

c) The final approval of the received information was given by a dietician-nutritionist and supervisor.

It is also of importance that the used software had an alarm-system where no records from the different three main meals were available.

At the start of the coding process, dieticians-nutritionists worked together with the coders checking the information from the coders and giving them individual feedback on their work (food and portion code entries). Portion code errors (selecting the wrong portion size descriptor or entering an incorrect weight) were more common than selecting the wrong food code. Where errors were found they were corrected. These checks ensured that error rates were monitored for all the coders working on the project and helped identifying any coding issues. All of the entries flagged as a query by the coders were categorized into different query types, such as food code or portion code not available in the VD-FEN Software, recipes, missing or insufficient detail to code food or portion. Initial checks were carried out to highlight any missing data fields, such as incomplete eating context or nutrient variables, followed by a feasibility check of the maximum and minimum portion sizes entered within each subsidiary food group. Final quality checking was performed using each participant's mean energy and nutrient intake (all reported nutrients) over the food and beverages diary record period (three days). Extreme intakes were considered from the mean and all entries in this region were checked against the diary. All errors found were corrected to their appropriate entry as reflected by the diary entry. Intakes were also calculated.

Intakes of energy and nutrients were calculated from the food consumption records using a special adapted VD-FEN 2.1 (*Programa de Valoración Dietética de la FEN, Dietary Evaluation Program from the Spanish Nutrition Foundation*) software for ANIBES Study. Data obtained from food manufacturers were also used, as was nutritional information provided on food labels, and food photographic atlas to assign weighing grams for portion sizes. All data were carefully evaluated before being incorporated into the VD-FEN ANIBES Database, that is briefly stratified as:

- Level 1 – 16 food and beverage groups
- Level 2 – 29 food and beverage subgroups
- Level 3 – 761 food and beverages entries
- Company and brand
- Culinary treatment
- Household measure (tablespoons, glasses, cups, plates); typical/most used portion sizes and recipes from Spain; or conventional units/measures (e.g. 1 yogurt, 1 apple piece, half tomato, 1 slice of bread, 1 soda can, 1 biscuit, butter portion, etc.)

Data cleaning

Once the data from the Tablet devices were coded and transferred into the ANIBES Database, a data cleaning process was necessary as follows:

First data cleaning stage: Participants were considered as fully eligible if after a cautiously review of the information, it was verified that the three days were recorded. Where registers were above or below the three-days established period, the following criteria was adopted:

– If a participant only had records from two or less days, he/she was considered as not valid and eliminated from the final sample.

– If a participant registered four or more days, valid data were for those three collected days corresponding to the specific cycle of the participant, but always under the same scheme: 2 working days + 1 weekend day.

Second data cleaning stage: According to the recorded information, participants were removed from the final sample if:

– Unexplained behavior in energy intake and large intraindividual variations between days mostly when compared to the 24-h dietary recall. Moreover, when the known meal pattern of the participant was 3-5 intakes per day, but missing data was clearly observed in the register (i.e. only breakfast and/or one meal per day), he/she was removed from the final sample.

– Extremely low energy intakes recorded:

- Less than 500 kcal/day in two or three days of the period.
- Less than 500 kcal/day in one day, and <800 kcal/d in the remaining days.

Third data cleaning stage: Participants were considered valid if they fulfilled the following criteria:

Having fulfilled previous data cleaning stages.
Having completed successfully both visits during the fieldwork.
If the participants had valid data on: weight, height, waist circumference.

Once all data (three-days food dietary record and 24-h dietary recall) had been verified, cleaned up, and approved by the dieticians-nutritionists, the ANIBES Database was developed. Calculation of energy and nutrient intakes was performed by the VD-FEN 2.1 *Dietary Evaluation Programme from the Spanish Nutrition Foundation*, mainly based on the Food Composition Tables (Moreiras et al, 15 ed, 2011)[30], with several expansions and updates.

Conclusions

Energy balance is a framework that can be used to understand the interplay between energy intake, energy expenditure and energy storage that determines body weight.

A better understanding of energy balance can help develop more effective strategies for reducing obesity rates in individuals and populations.

Energy balance is a dynamic rather than a static process, with manipulations of one component of energy balance potentially influencing other components of energy balance.

The strengths of the design, protocol and methodology used in the ANIBES Study to approach for the first time the EB in Spain are the representative national sample targeted, the broad age range included (9-75 years), the geographical distribution (inland plus islands), the successful logistics for the 128 sampling points or the innovative and first time used tools to measure dietary intake (tablet device for *real time* dietary record combined with a 24-h dietary recall) or physical activity level (validated questionnaire and accelerometer device). The main drawbacks were the difficulties for some participants to use the technologies employed, or the lack of seasonality for food collection or measuring physical activity level. However, considering the carefully designed protocol based on best evidence available and previous experience, the ANIBES study will contribute to provide valuable useful data to inform food policy planning, food based dietary guidelines development and other health oriented policies

Acknowledgments

The authors would like to thank Professors Ángel Gil, Javier Aranceta, LLuis Serra-MAjem, Rosa M Ortega, and Marcela González-Gross, member of the ANIBES Scientific Committee, for their scientific advise and continous support. The authors are also grateful to Coca-Cola Iberia for its support and technical advice, specially to Dr. Rafael Urrialde, Isabel de Julián, and Estrella López Brea. The authors are also very grateful to IPSOS Spain, in special to Jesus Caldeiro and José Antonio Gutierrez, for continuous support in sampling procedure, fieldwork development, and design for the ANIBES Study. Finally, authors would like to thank Susana del Pozo, Teresa Valero, and Paula Rodriguez, staff members of the Spanish Nutrition Foundation (FEN).

References

1. Hill, J.O.; Wyatt, H.R.; Peters, J.C. Energy balance and obesity. *Circulation*. 2012, 126, 126-32.
2. Morton GJ, Cummings DE, Baskin DG, Barsh GS, Schwartz MW. Central nervous system control of food intake and body weight. *Nature* 2006;443: 289–95.
3. Hill, J.O.; Wyatt, H.R.; Peters, J.C. Using the energy gap to address obesity: a commentary. *J. Am. Diet. Assoc*. 2009, 109, 1848 –1854.
4. Hill JO, Levine JS, Saris WHM. Energy expenditure and physical activity. In: Bray G, Bouchard C. eds. *Handbook of Obesity.* 2nd ed. New York, NY: Marcel Dekker, Inc; 2003:631– 654.
5. Galgani J, Ravussin E. Energy metabolism, fuel selection and body weight regulation. *Int J Obes (Lond)*. 2008;32(7):S109–19.
6. Blair, S.N. Physical inactivity: the biggest public health problem of the 21st century. *Br. J. Sports Med*. 2009, 43, 1-2.
7. Johnstone AM, Murison SD, Duncan JS, Rance KA, Speakman JR. Factors influencing variation in basal metabolic rate include fat-free mass, fat mass, age, and circulating thryroxine but not sex, circulating leptin, or triiodothyronine. *Am J Clin Nutr* 2005;82:941–8.

8. Hall KD. Predicting metabolic adaptation, body weight change, and energy intake in humans. *Am J Physiol Endocrinol Metab* 2010;298:E449–66.
9. World Health Organization. *Physical status: the use and interpretation of anthropometry;* WHO Technical Report Series 854, WHO, *Geneva, Switzerland,* 1995.
10. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Ranking JW, Smith BK. American College of Sports Medicine. Position Stand: appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc*. 2009;41(2):459–71.
11. Hall KD, Sacks G, Chandramohan D, et al. Quantification of the effect of energy imbalance on bodyweight. *Lancet*. 2011; 378(9793):826–37.
12. Hall KD, Sacks G, Chandramohan D, Chow CC, Wang YC, Gortmaker SL, Swinburn BA. Quantifying the effect of energy imbalance on body weight change. *Lancet* 2011; 378:826–37.
13. Hall KD, Heymsfield SB, Kemnitz JW, Klein S, Schoeller DA, Speakman JR. Energy balance and its components: implications for body weight regulation. *Am J Clin Nutr.* 2012;95(4):989–94.
14. Heymsfield SB, Thomas D, Martin CK, et al. Energy content of weight loss: kinetic features during voluntary caloric restriction.*Metabolism*. 2012;61(7):937–43.
15. Mayer J, Purnima R, Mitra KP. Relation between caloric intake, body weight and physical work: studies in an industrial male population in West Bengal. *Am J Clin Nutr*. 1956; 4:169 –175.
16. Hill JO, Commerford R. Exercise, fat balance and energy balance. *Int J Sports Nutr*. 1996; 6:80 –92.
17. Hill, J.O.; Wyatt, H.R. Role of physical activity in preventing and treating obesity. *J. Appl. Phyisol*. 2005, 99, 765–770.
18. Wadden TA. Treatment of obesity by moderate and severe caloric restriction: results of clinical research trials. *Ann Intern Med*. 1993;13(suppl 2):91–93.
19. Dulloo AG, Jacquet J. Adaptive reduction in basal metabolic rate in response to food deprivation in humans: a role for feedback signals from fat stores. *Am J Clin Nutr*. 1998; 68:599–606.
20. Varela, G.; García, D.; Moreiras-Varela, O. *La Nutrición de los Españoles. Diagnóstico y Recomendaciones; Escuela Nacional de Administración Pública, Madrid,* 1971.
21. Varela, G.; Moreiras, O.; Carbajal, A.; Campo, M. *Encuesta de presupuestos familiares 1990-91; Spanish National Statistical Institute,* 1991; Vol I.
22. Varela, G.; Moreiras, O.; Carbajal, A.; Campo, M. *Encuesta de Presupuestos Familiares 1990-91. Estudio Nacional de Nutrición y Alimentación* 1991; *INE, Madrid,* 1995; Vol I.
23. Varela-Moreiras, G. La Dieta Mediterránea en la España actual. *Nutr Hosp*.2014,30(Supl. 2):21-28
24. Del Pozo, S.; García, V.; Cuadrado, C.; Ruiz, E.; Valero, T.; Ávila, J.M.; Varela-Moreiras, G. *Valoración Nutricional de la Dieta Española de acuerdo al Panel de Consumo Alimentario*; *Fundación Española de la Nutrición (FEN), Madrid,* 2012.
25. Agencia Española de Seguridad Alimentaria y Nutrición (AESAN). *Encuesta Nacional de Ingesta Dietética Española* 2011. Available at: http://www.aesan.msc.es/AESAN/docs/docs/notas_prensa/Presentacion_ENIDE.pdf
26. Serra-Majem, L.; Ribas Barba, L.; Aranceta-Bartrina, J.; Pérez-Rodrigo, C.; Saavedra Santana, P.; Peña- Quintana L. Obesidad en la infancia y adolescencia en España. Resultados del estudio enKid (1998–2000). *Medicina Clinica* 2003, vol. 121, no. 19, 725–732.
27. González-Gross, M.; Castillo, M.J.; Moreno, L.; Nova, E.; Gonzalez-Lamuño, D.; Perez-Llamas, F.; Gutiérrez, A.; Garaulet, M.; Joyanes, M.; Leyva, A.; Marcos, A.; and grupo AVENA. Alimentación y Valoración del Estado Nutricional de los Adolescentes Españoles (Proyecto AVENA). Evaluación de riesgos y propuesta de intervención. I. Descripción metodológica del estudio. *Nutr. Hosp*. 2003, 18, 15-27.
28. Ministerio de Sanidad, Consumo, Igualdad y Servicios Sociales. *Encuesta Nacional de Salud 2011-2012;* Ministerio de Sanidad, *Consumo, Igualdad y Servicios Sociales, Madrid,* 2013.
29. Booth, M.L.; Ainsworth, B.E.; Pratt, M.; Ekelund, U.; Yngve, A.; Sallis, J.F.; *et al*. International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise* 2003, 195(9131/03), 3508-1381.
30. Moreiras, O.; Carbajal, A.; Cabrera, L.; Cuadrado, C. *Tablas de composición de alimentos*, 15ª edición; Ed. Pirámide; Madrid, 2011.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):113-118
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Biases and adjustments in nutritional assessments from dietary questionnaires

Victoria Arija[1,2], Rosa Abellana[3], Blanca Ribot[1] and Josep Mª Ramón[4,5]

[1]Unitat de Nutrició i Salut Pública. Research Group in Nutrition and Mental Health (NUTRISAM). [2]Institut d'Investigació Sanitària Pere Virgili, Universitat Rovira i Virgili, Reus. [3]Departament de Salut Pública. Facultat de Medicina. Universitat de Barcelona. [4]Departament de Ciències Clíniques. Facultat de Medicina. Universitat de Barcelona. [5]Coordinador del Grup de recerca en prevenció clínica. Institut de recerca biomèdica de Bellvitge. Spain.

Abstract

In nutritional epidemiology, it is essential to use Food Consumption Assessment Methods that have been validated and accepted by the international community for estimating food consumption of individuals and populations. This assessment must be made with the highest quality possible so as to avoid, as far as possible, sources of error and confusion in the processes.

The qualities that are required in a measurement method are validity and accuracy; validity being the main factor. Lack of validity produces biases, or systematic errors. These can reside in the process of subject selection, or processes of information gathering where the lack of accuracy produces random errors.

For many nutrients, the intra-individual variances are due to many factors such as day-of-the-week or season, and could create problems in the data analyses. Adjustments are needed to minimize these effects.

Confounding factors may over- or under-state the real magnitude of the observed association, or even alter the direction of the real association. Total energy intake can be a confounding variable when studying a relationship between nutrient intake and disease risk. To control for this effect several approximations are proposed such as nutrient densities, standard multivariate models and the nutrient residual model.

(*Nutr Hosp* 2015;31(Supl. 3):113-118)

DOI:10.3305/nh.2015.31.sup3.8759

Key words: *Methods of evaluating food consumption. Evaluation of systematic nutritional errors. Biases. Random errors. Adjustments. Confounding factors. Quality. Exactness. Validity. Precision. Repetitiveness.*

SESGOS Y AJUSTES EN LA VALORACIÓN NUTRICIONAL DE LAS ENCUESTAS ALIMENTARIAS

Resumen

En la epidemiología nutricional es esencial la utilización de los Métodos Valoración del Consumo Alimentario validados y aceptados por la comunidad internacional para estimar el consumo alimentario de los individuos y grupos de población. Esta estimación debe hacerse con la mayor calidad posible, evitando, en la medida de lo posible, las fuentes de error y confusión en la medida del consumo alimentario.

Las cualidades que otorgan calidad a un método de medida son la validez y la precisión, siendo la validez la principal característica. La falta de validez produce sesgos o errores sistemáticos, los cuales pueden ser en el proceso de selección de los sujetos o en el proceso de obtención de la información; y la falta de precisión produce errores aleatorios.

Para muchos nutrientes, las variaciones intra-individuales debidas a muchos factores como el día de la semana o la estación del año, podrían crear problemas en los análisis de datos. Para minimizar este efecto se deben realizarse algunos ajustes en los análisis.

Los factores de confusión pueden exagerar o subestimar la verdadera magnitud de la asociación o incluso alterar la dirección de la asociación. El consumo total de energía puede ser una variable de confusión en el estudio de la relación entre la ingesta de nutrientes y el riesgo de enfermedad. Para controlar este efecto se proponen varias aproximaciones: la densidad de nutrientes, modelo multivariado estándar y el modelo residual de nutrientes.

(*Nutr Hosp* 2015;31(Supl. 3):113-118)

DOI:10.3305/nh.2015.31.sup3.8759

Palabras clave: *Métodos de valoración del consumo alimentario. Valoración nutricional errores sistemáticos. Sesgos. Errores aleatorios. Ajustes. Factores de confusión. Calidad. Exactitud. Validez. Precisión. Repetitividad.*

Correspondence: Victoria Arija.
Unitat de Nutrició i Salut Pública.
Universitat Rovira i Virgili, C/ Sant Llorenç 21.
43201 Reus, Spain.
E-mail: victoria.arija@urv.cat

Limitations in the correct assessment of the food consumption

In nutritional epidemiology, it is essential to correctly assess food consumption, to describe as well as to estimate its effect on health. Its measurement is complex and is not exempt from significant limitations. Therefore, to obtain data of quality special attention needs to be applied in minimizing errors of measurement. It is important to control the sources of error (systematic or random) and confounding factors that can occur at different stages of data acquisition in the research process, from the design of the study protocol to the publication of results. It is important to define clearly the goals of the study including: the design of the epidemiologic study; the selection, size and type of participants; the choice of methods for measuring the variables-of-interest under study.

Monitoring the correct implementation of the protocol during the fieldwork is fundamental if deviations from the previously-planned objectives are to be avoided and, if deviations do occur, to detect them early enough to introduce corrections. A further point in the research process is the analysis and interpretation of the results since it is vital to pay special attention to preventing and/or correcting for any errors, especially with respect to confounding factors.

Quality of methods of assessing food consumption: validity and accuracy

From among all the above factors, the method selected to assess food consumption is key to obtaining data of quality. However, there is no ideal method for assessing the habitual and/or spontaneous dietary intake of the subject. Indeed, there are various methods for assessing food consumption (MAFC) that have been internationally accepted as being appropriate in assessing individual food item consumption. These include: food records; 24h recalls; diet diaries; and food-frequency questionnaires. Each has its own strengths, weaknesses, and specific characteristics[1,2,3].

MAFC quality is reflected in two variables: validity and accuracy. Validity is the quality of measurement of what one really wishes to measure; accuracy reflects the concordance between several repeated measurements of the same variable with the same methodology. Lack of validity produces systematic errors and lack of accuracy produces random errors. Both errors can occur in intra- or inter-individually[4].

Bias, or systematic error, is distortion in the estimation that affects the measurement of the variable. These biases can be of selection, or of information. Selection bias is related to the type of epidemiologic study used in the investigation. The most common errors result from: the difficulties in obtaining a representative sample; the selection of the control group; controlling for loss-to-follow-up; selection of participants that excludes the ones with greater severity; an event occurring in one of the groups under greater surveillance; the detection bias; and the bias occurring because of volunteer involvement which is related to greater participation of cases[1,2,3].

Information biases occur in the data collection process. An important part of these biases are related to the skills and experience of the interviewer, or imprecision in quantifying the food portion size; or skills and motivation of the respondent. They can also result from the food composition tables used. Other errors can result from research data management throughout the process.

The validity of a method is assessed by comparing the results obtained by the method-of-study with those of a reference method, or gold standard. If the studied variable is quantitative, various statistical methods for the comparison of means can be used. If the variable is dichotomous, the sensitivity and specificity values of each method are compared. The method used as gold standard should estimate the intake in a different manner from the study-method in order to prevent the inclusion of the same type of error in both methods and, as such, erroneously assume that the method-of-study is valid[4].

In relation to accuracy, a random error is the difference due, simply, to chance between the value obtained from a subject's food consumption *vs*. the real value. Alternatively, it can be between the observed value in a sample compared to that corresponding to the overall population; which would increase the intra- and/or inter-individual variability. Random errors are caused by unknown factors affecting the measurement of the variable. This could include the mood of the interviewed subject on any of the assessment days artificially modifying the response. Whatever the cause, this random variability from unknown factors decreases the accuracy of the measurement and affects the mean and widens the confidence interval[1,2,3] (Fig. 1).

To estimate the variability of a method, the same measurement is repeated in the same individual and the correlation between the two measures is analyzed. The KAPPA Index is used if the variable is qualitative and, if the variable is quantitative, the intra-class correlation coefficient, or the graphical method of Bland and Altman, is used[4]. Some factors need to be considered in conducting this analysis of repeatability such as the real possibility that the events are repeatable. This can be difficult when assessing the diet at two different times since, although the method is very accurate, the accuracy could be affected due to the diet itself having been altered. It is advisable that the periods compared are not too close in time such that the interviewee remembers the previous measurement. Neither should the time interval be too distant that the dietary habits had changed. Willett et al. recommended spacing the measurements between 4 and 10 weeks[5]. Repeatability is also influenced by the degree of difficulty, or measurement variability. For example, a food frequency questionnaire (FFQ) that does not evaluate portion

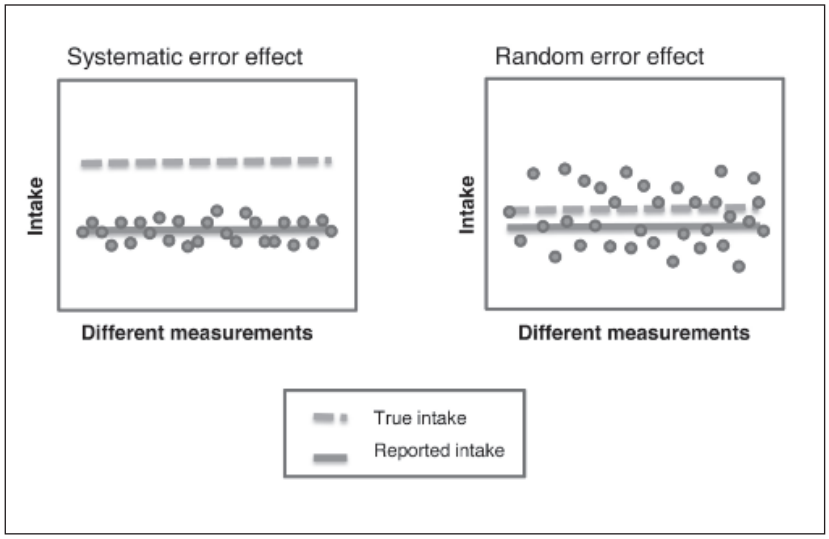


Fig. 1.—Representation of systematic and random errors.

size is more repeatable than one that does. Whether the design of the FFQ is clearer or more confusing for the understanding of the participant, the repeatability would change.

The most important error in the estimation of food consumption is the intra-individual random error. The variability caused by this error is greater the longer the time between measurements, since they include the intra-individual error and true dietary changes. This error can be decreased by increasing the number of days assessed. A comprehensive study addressing this issue indicated that the number of days depended on different situations. For example, in the assessment of different nutrients more days are needed in estimating the usual intake of some micronutrients than to estimate energy and macronutrients. In cross-sectional study designs aimed at obtaining mean intakes for groups of subjects, it is accepted that 1 or 2 days are needed. However, when evaluating the individual relationship between habitual intake and health concerns, more measurements are required. This can be between 3 and 7 days provided they are not consecutive and, as well, variability between days of the week and between seasons is taken into account. The decision on the number of days of measurement is limited in population studies since, if the number is high, the information recorded or reported by the subject may be modified due to the participant's tedium in response and, as well, the eating habits of the participants may change in order to simplify the consumption and ease the recording of intake[1,2,3].

It is important to highlight that, to confirm the method as being correct, the main feature to be considered is the validity i.e. good accuracy, by itself, is not enough.

Misclassification of the subjects; effect on results

Bias in the collection of information can lead to misclassification of the causal factor, the effect studied, or both. This misclassification between cases and controls or between exposed and non-exposed individuals may occur in analytical epidemiological studies; the outcomes may be modified. When misclassification occurs in a similar manner in all subjects or study groups, a non-differential misclassification may occur which could reduce the real difference, or association, between cause and effect. This bias is not related to either exposure or to the disease-under-study, but is inherent in the method of data collection itself. As such, the odds ratio, or the relative risk, tends to disappear and the studied effect can be lost. However, a differential misclassification will occur if the bias happens in only one of the study groups[1,2,3].

This bias is related to exposure and/or to the disease and may underestimate, or overestimate, the effect studied (Fig. 1). The result could be the observation of an apparent relationship when, in reality, it did not exist, or observing an apparent lack of relationship when, in reality, there is one. For example, if the relationship between consumption of cheese and the presence of migraine is to be assessed in an epidemiological case-control study and individuals with migraine respond with more interest regarding cheese consumption than controls, the effect would be overestimated. Similarly, when the dietary intake is assessed in obese and non-obese individuals, the effect may be underestimated since those with obesity tend to report lower consumption than the reality, as has been reported widely. The differential bias is not uniform[1,2,3].

Avoiding biases

To avoid these biases and, hence, to increase the validity and reliability of the results, control measures need to be included in the design of the study protocol, the conduct of fieldwork, as well as in the analysis and interpretation of results. In preparing the study protocol, it is essential to choose the most objective, and validated techniques of measurements. This decrea-

ses the variability caused by the method, taking into account the design and purpose of the study and the study population. Also, it is essential to include a standardization of how and when data are collected and, as well, standardization of the methodology among the interviewers since this would decrease the variability caused by the instrument of measurement and by the observer. Increasing the number of days on which the measurements are conducted would decrease intra-individual variability and increase the reliability of the data. Last but not least, we recommend the double entry of data into the database, data verification, database pruning, testing the quality of the collected data and, finally, using statistical procedures to adjust for measurement errors.

Recommendations for intra-individual variation control in dietary intake

The underlying assumption in assessing the nutritional status of a population is that, usually, individuals maintain their dietary habits and the population mean intake can be defined based on the usual intake of the individuals involved. Unfortunately, neither a single 24h dietary recall nor semi-quantitative frequency questionnaires accurately reflect an individual's true intake of a nutrient or dietary factor[5]. As a result, estimates of the population's mean intake or rate of nutrient deficiency (or excess) based on these data could be biased[6].

An individual intake varies from day to day and factors such as day of week or season contribute to this daily variation. A basic assumption is that the within-person variation is random, while the degree of random variation differs according to nutrient. One 24h dietary recall cannot characterize an individual's usual intake. For many nutrients, the intra-individual variances (within-person variance) are much larger than inter-individual variances (between-person variance) and could create problems in the analyses of data[7].

Analitical approach

In an approach to estimating the prevalence rate of nutrient deficiency of usual intakes, data from two or more daily consumption schedules for each person is needed, where the daily nutrient intake is the dependent variable[5,8].

The matrix format of the data should be organized following the format presented in Table I with repeated measurements for subjects considered as separate data.

The analysis can be summarized as follows:

- Firstly, analysis of data to ensure normality of distribution of intake. Logarithmic transformation is required if the data do not follow normal distribution.
- Estimate intra- and inter-individual variance.
- Compute the adjusted (for intra-individual variance) intake for each nutrient as:
  Estimate R as:
  (√Var between/Var between + Var intra) / (√Var between/0.5(Var between + Var intra)
  Secondly, create a new variable for each individual deviation from the mean value of the total, or a stratum
- Adjusted intake as:
  Adjusted intake = (observed intake-mean intake) * R value

Means of adjusted and unadjusted values must be the same (Fig. 2).

Confounding factors and adjustment for total energy intake in nutritional epidemiologic studies

In nutritional epidemiologic studies, misleading conclusions can be arrived-at if data are not properly analyzed and interpreted. In particular, the relationships between the diet (exposure) and disease risk can be distorted, or biased, by extraneous "confounding" factors. Failing to account for a confounding factor can lead to a spurious relationship being observed between exposure and disease risk i.e. a false correlation. The

Table I
Matrix format for analyses

Nutrient (N)	*Subject*	*Age group (factor)*	*Season*
V1	1	1	W
V2	1	1	S
V1	2	2	W
V2	2	2	S
V1	3	1	W
V2	3	1	S

W: Winter; S: Summer

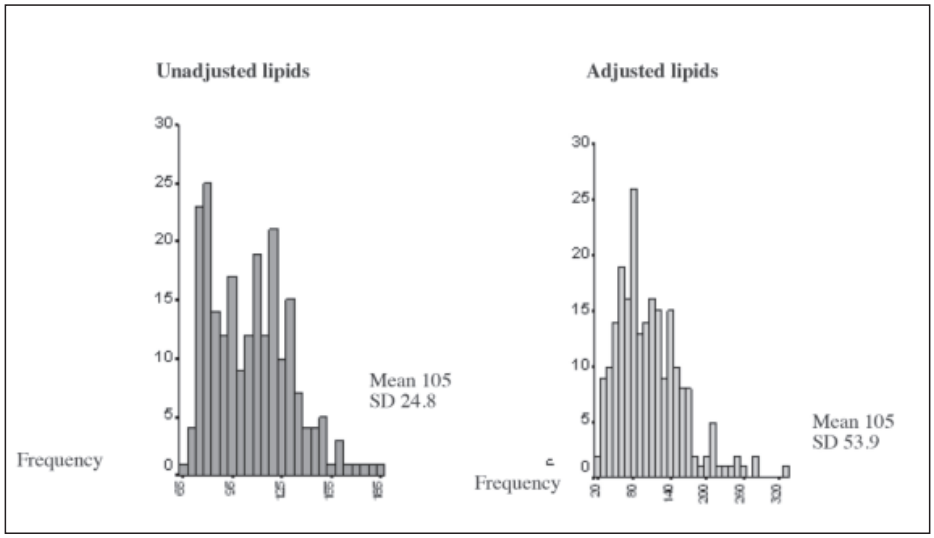


Fig. 2.—Example of unadjusted and adjusted values.

confounding factor can also cause an overestimate or underestimate of the real magnitude of the association, or even alter the direction of the real association.

A classic example of confounding factor effect was presented by Hulley and Cummings in 1993[9], in which the spurious association between drinking coffee and myocardial infarction was detected due to the confusion with the smoking habit effect. Specifically, this association was found because the number of smokers in the group of subjects who drank coffee was higher (380 *vs*. 120) than in the group that did not drink coffee (20 *vs*. 480). Further, the smokers had a higher incidence of myocardial infarction (10%) than non-smokers (1.7%). Hence, this different distribution of subjects according to the confounding factor (smoker status) in each group of coffee drinkers caused a spurious association between coffee-drinking and myocardial infarction.

Another example of confounding factor in which the real magnitude of the association is overstated was presented by Irala et al in 2001, when discussing the relationship between the neural tube defects of newborns and the mother's folic acid deficiency[10]. The effect of folic acid fortification was overestimated because mothers with normal values of folic acid also have several healthy behavior patterns such as a healthy diet, better genetic endowment, or lower prevalence of risk factors (tobacco or alcohol abuse) relative to mothers with folic acid deficiency.

In nutritional studies, the total energy intake can be a confounding variable when studying relationships between nutrient intake and disease risk. According to Willet et al in a studies in free-living human populations, the total energy intake is, largely, a consequence of variations in physical activity, body size and metabolic efficiency[11,12]. The confusion occurs when the total energy intake is associated with disease risk and nutrient intake. Total energy intake association with disease risk happens due to physical activity, body size or the metabolic efficiency being associated with disease probability. Total energy intake and nutrient intake are associated because either the nutrients directly contribute to the total energy or because the individuals who have a higher energy intake also have a higher intake of specific nutrients. The Willet et al study (1997) provided an example of total energy intake as a confounding factor in the relationship between nutrients and coronary artery disease[12].

Several approximations are proposed to adjust for the effect of the total energy intake. These include nutrient densities, standard multivariate models, and nutrient residual model.

Nutrient densities are computed by dividing the nutrient values by the total energy intake. As such, correlations between disease risk and nutrient densities, instead of the nutrient, are analyzed. The main problem in using these densities arises when the disease is also associated with the total energy intake. Under such circumstances, nutrient intake will be confounded (in opposite direction) by total energy intake because of it being divide by total energy.

If standard multivariate models are used, the total energy intake is included in a multivariable model along with the nutrient of interest. In such a model the association of nutrient intake and disease, measured by its regression coefficient, is controlled (or adjusted-for) by the total energy intake.

The nutrient residual model is calculated by using, as the independent variable, the residuals from the regression model of total energy intake, while absolute nutrient intake is the dependent variable. Since residuals have a mean value of zero, a constant to the residual is added. Willet et al[11] proposed the use of the mean of the nutrient as the constant value. Hence, the disease risk can be modelled as a function of the nutrient residual and the total. An advantage of this model is that both variables (nutrient residual and total energy) are uncorrelated, which is a desirable property for multivariable analysis in order to avoid problems of co-linearity.

References

1. Margetts BM. Basic issues in designing and interpreting epidemiological research. In: Margetts BM, Nelson M, ed. Design concepts in nutritional epidemiology. Oxford: *Oxford University Press* 1991: pp 13-52.
2. Cameron ME, Van Staveren WA. Manual on Methodology for food consumption studies. New York: *Oxford University Press* 1988.
3. Pérez C. Fuentes de error en la evaluación del consumo de alimentos. In: Serra-Majem L, Aranceta J, ed. Nutrición y salud pública: métodos, bases científicas y aplicaciones. Barcelona: *Elsevier* 2006: pp 245-253.
4. Argimón JM, Jiménez J. Sesgos. In: Argimón JM, Jiménez J, ed. Métodos de investigación clínica y epidemiológica. Madrid: *Elsevier* 2013: pp 270-277.
5. Willett W. Nutritional epidemiology. Oxford: *Oxford University Press* 2013.
6. Beaton GH, Milner J, Corey P, McGuire V, Cousins M, Stewart E et al. Sources of variance in 24-hour dietary recall data: implications for nutrition study design and interpretation. *Am J Clin Nutr* 1979; 32: 2546-2559.
7. Sempos CT, Johnson NE, Smith EL, Gilligan C. Effects of intraindividual and interindividual variation in repeated diet records. *Am J Epidemiol* 1985; 121: 120-30.
8. Liu K. Statistical issues in estimating usual intake from 24-hour recall or frequency data. In: Wright JD, Ervin B, Briefel RR ed. Consensus workshop on dietary assessment: Nutrition Monitoring and Tracking the Year 2000. Hyattsville: *National Center for Health Statistics* 1993: pp 92-97.
9. Hulley SB, Cummings SR. Diseño de la investigación clínica. Barcelona: *Doyma* 1993.
10. Irala J, Martínez-Gonzalez MA, Guillén F. ¿Qué es una variable de confusión? *Medicina clínica* 2001; 117: 377-385.
11. Willett WC, Staimpfer MJ. Total energy intake: Implications for epidemiologic analyses. *Am J Epidemiol* 1986;124:17-27.
12. Willet WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. *Am J Clin Nutr* 1997; 65: 1220-1228.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):119-127
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Misreporting in nutritional surveys: methodological implications

Itandehui Castro-Quezada[1], Cristina Ruano-Rodríguez[1,2], Lourdes Ribas-Barba[2,3] and Lluis Serra-Majem[1,2,3]

[1]Research Institute of Biomedical and Health Sciences, University of Las Palmas de Gran Canaria, Spain. [2]Ciber Fisiopatología Obesidad y Nutrición (CIBEROBN, CB06/03), Instituto de Salud Carlos III (ISCIII), Spanish Government, Madrid, Spain. [3]Community Nutrition Research Centre of the Nutrition Research Foundation, University of Barcelona Science Park, Spain.

Abstract

The reliability of the information collected in dietary assessment can be affected by different factors. One of the main sources of error in dietary assessment is misreporting which encompass under- and overreporting. Underreporting of food intake is one of the major problems in the assessment of habitual dietary intake. Physical and psychosocial characteristics that are related to energy underreporting include sex, age, weight, BMI, fear of negative evaluation and dieting among others. At present, diverse reference methods are employed to verify the results of dietary assessment and double labelled water is used as the gold standard method. Underreporting affects the estimation of nutrient intake and also alters associations between diet and disease assessed in epidemiological studies. Therefore, underreporting has to be considered and addressed by researchers through development and improvement of dietary intake adjustment methods, and taking advantage of the new technologies for assessing dietary intake in order to minimize underreporting bias.

(*Nutr Hosp* 2015;31(Supl. 3):119-127)

DOI:10.3305/nh.2015.31.sup3.8760

Key words: *Underreporting. Nutritional surveys. Dietary intake. Methodology.*

INFRADECLARACIÓN EN LAS ENCUESTAS ALIMENTARIAS: IMPLICACIONES METODOLÓGICAS

Resumen

La fiabilidad de la información recogida en la evaluación dietética puede verse afectada por diferentes factores. Una de las principales fuentes de error en la evaluación de la dieta es la declaración errónea de consumo de alimentos, que abarca la infradeclaración y sobredeclaración de la dieta. La infradeclaración de la ingesta de alimentos es uno de los principales problemas en la evaluación de la ingesta dietética habitual. Las características físicas y psicosociales que están relacionadas con la infradeclaración de energía incluyen el sexo, edad, peso, índice de masa corporal, el miedo a la evaluación negativa y estar bajo un régimen de dieta, entre otros. En la actualidad, se emplean diversos métodos de referencia para verificar los resultados de la evaluación dietética, no obstante, el método estándar es el agua doblemente marcada. La infradeclaración afecta a la estimación de la ingesta de nutrientes y también altera las asociaciones entre dieta y enfermedades en estudios epidemiológicos. Por lo tanto, la infradeclaración tiene que ser considerada y abordada por los investigadores a través del desarrollo y la mejora de los métodos de ajuste de la dieta y el aprovechamiento de las nuevas tecnologías para la evaluación de la ingesta dietética con el fin de minimizar el sesgo ocasionado por la infradeclaración.

(*Nutr Hosp* 2015;31(Supl. 3):119-127)

DOI:10.3305/nh.2015.31.sup3.8760

Palabras clave: *Infradeclaración. Encuestas nutricionales. Ingesta dietética. Metodología.*

Correspondence: Dr. Lluis Serra Majem.
Instituto Universitario de Investigaciones Biomédicas y Sanitarias.
Universidad de Las Palmas de Gran Canaria
C/ Dr Pasteur s/n. C. P. 35016.
Las Palmas de Gran Canaria, España.
E-mail: lluis.serra@ulpgc.es

Abbreviations

ANR: Average nutrient requirement.
BMI: Body mass index.
BMR: Basal Metabolic Rate.
DLW: Doubly Labelled Water.
ENCA: Encuesta Nutricional de Canarias (1997-8).
ENCAT: Encuesta Nutricional de Cataluña (2002-3).
ENKID: Encuesta Nutricional de la población infantil y juvenil española (1998-2000).
EPIC: European Prospective Investigation Into Cancer and Nutrition.
FFQ: Food Frequency Questionnaire.
IDEFICS: Identification and prevention of Dietary- and lifestyle-induced health Effects In Children and infants.
ICT: Information and communication technologies.
IDAMES: Innovative Dietary Assessment Methods in Epidemiological Studies and Public Health.
PDA: Personal digital assistants.
pTEE: Predicted total energy expenditure equations.

Background

In nutritional assessment, diverse methods are used to evaluate food and nutrient intake. It can be done via questionnaires (i.e. Food records, Dietary recalls, Food frequency questionnaires, Short questionnaires) or through biochemical methods. The selection of the appropriate method should consider the level of evaluation according to the target population, either individuals or groups. When nutrient intake is estimated, it can be compared to the nutrient requirement of the individual or population and therefore the probability of adequacy can be estimated. Nutritional adequacy enables to identify if there is sufficient intake of essential nutrients, needed to fulfill nutritional requirements for optimal health. Therefore, to assess dietary intake correctly is crucial to enhance the effectiveness of interventions and policies both at the individual and population level[1].

However, dietary intake assessment is a difficult task and different factors can affect the accuracy of the information collected. The reliability of dietary assessment can be affected by intra-individual variability, seasonal variability or misreporting. One of the main sources of error in dietary assessment is misreporting, comprising both under and overreporting[2]. Underreporting of food intake is one of the major obstacles preventing the collection of accurate habitual dietary intake data[3] (Figure 1). Although less frequent, overreporting is also a problem, and is related to certain individual characteristics, for instance in eating behaviors it is common to alter the consumption report of fruits and vegetables.

A recent study conducted in European countries, assessed the prevalence of low micronutrient intakes and the presence of underreporting by using nationally representative dietary survey data from Belgium,

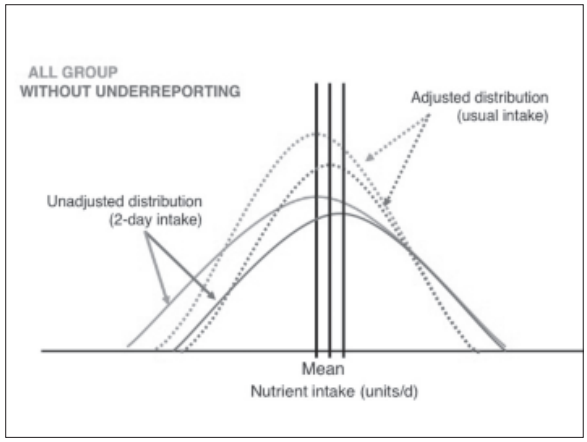


Fig. 1.—Underreporting effect on nutrient distribution.

Denmark, France, Germany, The Netherlands, Poland, Spain and the United Kingdom. The proportion of possible underreporters in children aged 1–3 years ranged from 0.6% in Belgium to 1.7% in The Netherlands. For those aged 4–10 years, it varied from 0.5% in Denmark to about 5% of the German girls. For participants aged from 11 to 17 years, the underreporting values ranged from 0.6% of the Dutch boys to 34% of the Danish boys. For women aged 14–50 years, it ranged from 1.1% in The Netherlands to 14% in Germany. For those aged 18–60 years, it ranged from about zero in the Dutch men to 26% in women from France. For elderly subjects over 60 years of age, it ranged from 0.4% of women in the Netherlands to 28% of women in Spain[4].

Misreporting affects not only the estimation of energy intake, but also in other nutrients[2]. Therefore, misreporting of food intake is a major challenge for nutrition research when evaluating the relationship between diet and health outcomes.

Characteristics of low energy reporters

In 2003, Livingston & Black reviewed the characteristics of low energy reporters in 25 adult studies[5]. Age and sex have been associated with energy underreporting. Some studies have found that women and elderly subjects are more likely to underreport energy intake. However, these associations are inconsistent and further investigation is needed in representative population samples that have identified underreporters at all levels of energy requirement. Another characteristic identified is weight status. Low-energy reporting has been associated with a high body mass index (BMI), and the probability that an individual will underreport rise as BMI increases[5]. Education and socioeconomic status are less predictable characteristics in low energy reporters; however, in some studies underreporting has been associated with low education or socioeconomic status. Subjects with lower levels of education and consequently reduced literacy skills might be expected

to result in underreporting. Nevertheless, subjects with more knowledge of health topics or diet consciousness[6] or those of higher socioeconomic status might have the same response[5]. Another aspects associated with misreporting include dieting, efforts to maintain weight stability, attempt to lose weight, self-perception of high weight and weight changer over 5 years[5].

Children and adolescents also tend to underreport energy intake. Higher weight, BMI and adiposity have been consistently associated with underreported energy intake[7]. In Spain, a study conducted in children and adolescents, the ENKID study (1998-2000) compared the psychosocial characteristics between underreporters and plausible reporters in children and youth aged 2-24 years. A higher probability to underreport was found for female group and for adolescents and young adults (14-24 years). According to geographical region, individuals from Canary Islands had higher odds to underreport, while children living in the Northern region had lower odds to underreport. Misreporting was also associated with skipping breakfast and having a high BMI or weight (over percentile 85)[8]. Another study conducted in adolescents has shown that obese participants were 5.0 times more likely to underreport energy intake than subjects with normal weight[9].

Some psychosocial characteristics have also been associated to low energy reporting such as eating restraint, social desirability, depression, anxiety and fear of negative evaluation[10]. For instance, higher social desirability, known as the tendency to respond to questions in a socially appropriate and accepted manner, has been related with a higher incidence of energy underreporting, especially in women[10].

Energy misreporting, specifically underreporting, also results from incomplete recordkeeping on the part of the subject due to one or many established factors, for example: recording fatigue, memory disturbances, misrepresentation of portion size consumed and "unconscious" omission of certain eating occasion or item[10]. In order to improve the estimation of portion size, some tools are used, for instance, the use of household measures, drawings and photographs or food models.

Since the characteristics of low energy reporters and associated physical and psychosocial factors play an important role in the observed reporting bias, further investigation is needed in order to properly account for such factors in future studies.

Reference Methods to identify energy misreporting

Nowadays there are a number of reference methods to verify the results of dietary assessment. Reference methods include urine nitrogen, total energy expenditure, resting metabolic rate and physical activity, and total water loss. The gold standard reference method for assessing total energy expenditure is doubly labelled water (DLW). This accurate and noninvasive method is used for validation of reported energy intake by subjects in free living situations[11].

In the DLW, subjects receive a loading dose of water labeled with the stable isotopes ^{2}H and ^{18}O, and these isotopes mix with the hydrogen and oxygen in body water within a few hours. As energy is expended, CO_2 and water are excreted. Urine samples are collected at baseline before administration of the dose and subsequently either daily or at the beginning and end of the measurement period. The urine samples are analyzed to determine the rate of disappearance of each isotope from the body. Usually, the measurement period in adults is 14 days. The energy expenditure calculated is then compared with the reported energy intake and the deviation is expressed as magnitude of misreporting (as a percentage of energy expenditure or as an absolute deviation in kJ or kcal)[2]. However, DLW cannot be widely used as validating method for energy intake, due to the high costs since it needs a sophisticated laboratory and analytical back-up[5].

Urinary nitrogen loss is used to validate reported protein intake. Healthy adults are in nitrogen balance, and nitrogen loss in urine was found to be 81± 5% of total nitrogen loss per 24 hours[11]. However, within-subject variation in daily nitrogen excretion of individuals may be large, and repeat collections of consecutive 24 hour urine samples are necessary if the method is going to be used to validate the protein intakes of individuals.

To assess the dietary intake of other nutrients (i.e. Na or K), the urinary excretion of such nutrients for which urine is the major excretory route has also been used as a biomarker. To measure dietary Na intake, Na excretion can be used, however, the day-to-day fluctuations in Na excretion are larger than those for nitrogen. Therefore more collections are needed to correctly characterize Na excretion in an individual[2].

The Goldberg cut-off method reports energy intake as a multiple of basal metabolic rate (BMR), and using this index (Energy intake/BMR) in comparison to expected energy expenditure as a validity check for negative bias in energy intake. The Goldberg equation calculates the confidence limits (cut-offs) that evaluate if mean reported energy intake is plausible as a valid measure of food intake even if chance has produced a dataset with a high proportion of genuinely low (or high) intake. Sensitivity of the Goldberg cut-off was improved when subjects were assigned to low, medium and high activity levels and different physical activity levels and cut-off values were applied to each level[2]. BMR for the calculation of the Goldberg cut-off can be either measured or estimated from predictive equations specific for age and sex, such as the Schofield equations[12]. In the method of indirect calorimetry that measures BMR, the subject must be in a fasting state and with minimal physical disturbance.

Finally, another method to validate reported dietary intake is to compare it with the actual intake of subjects. Actual intake is obtained by direct observation of people eating during the study period. This method attempts to measure absolute validity, but it is very time

consuming and presents some practical difficulties and limitations. Each individual with a sufficient diet that meets adequately the energy requirements presents a stable body weight during the trial[2]. However the use of this method can lead to bias in vulnerable groups, for example, in older persons with declining weight which is related to low energy intake, and under eating may be falsely perceived as underreporting[13].

Underreporting according to dietary assessment methods

Underreporting is prevalent and persists in diverse dietary assessment methods although in different proportions[5,14]. In 2009, an investigation evaluated the effects of different dietary assessment methods on assessing risk of nutrient adequacy with data of two regional representative surveys conducted in Spain[15.] The first survey, The Catalan Nutrition Survey Study on nutritional status and food habits of the Catalan population (ENCAT), was a cross sectional study, carried out in population aged 12–80 years. The second survey was The Canary Islands Nutrition Survey (ENCA), that evaluated nutritional status and food habits of the population from the Canary Islands, conducted on a random sample of the population aged 6–75 years. In total, 2542 subjects were included in the analyses[15]. In that investigation, Ribas-Barba *et al*. found that the percentage of underreporters changed depending on the instrument used, with values over 40% when using daily methods (one or two 24 hour recalls) and 28% when using the FFQ. When diet was assessed with dietary recalls, higher proportions of underreporters were found in women, on the contrary, when the FFQ was used, a higher proportion of underreporters was found for men (30.5%) than women (25.7%)[15].

In a systematic review conducted in 2009, the proportion of misreporters was compared for three methods: 24 hour recall, estimated and weighed food record[2]. The Authors did not found significant differences between the medians of percentage of misreporters for all three methods (around 30%). Regarding underreporters, not significant difference was found, however, a higher proportion was observed for weighed food record (18%) than the other two methods (13.4% in 24 hour recall and 12.2% in estimated food record). The result that the magnitude of misreporting was not lower for weighed record studies could be caused by a smaller number of weighed food record studies providing data on the percentage of underreporters, but it is possible that subjects in weighed food record studies did not underreport, but underrate as a result of a change in dietary habits to facilitate the reporting during the study[2].

Underreporting bias in estimating nutrient intake

Underreporting represents a problem for the estimation of nutrient intake in epidemiological studies since underreporting of energy intake usually is related with underreporting of some nutrients.

A study of Mexican-American women showed that estimated energy, protein, cholesterol, dietary fiber, and vitamin E intakes were significantly higher among the plausible reporters compared with the implausible energy intake reporters group. Most implausible reporters underreported energy intake (86%). There was a significant difference between the proportions of plausible versus implausible reporters meeting recommendations for several nutrients, with a larger proportion of plausible reporters meeting recommendations[16].

In children and adolescents, the ENKID study has also evaluated the differences in nutrient intake between plausible reporters and low energy reporters (Table I). Higher intakes were observed among plausible reporters for energy, carbohydrates, total fat intake, cholesterol, sodium, phosphorus and calcium when compared to estimated intakes including underreporters in the sample[8]. Similar results were observed in 96 adolescents from Brazil, where energy intake misreporting (under or overreporting) was identified in 65.6% of adolescents. Underreporters also showed higher rates of insufficient intake of carbohydrate, lipids and cholesterol intake than plausible reporters[9]. Another survey conducted in Australian children aged 2–16 years, revealed, that those classified as underreporters had significantly higher intakes of protein and starch but lower intakes of sugar and fat, as percentage from energy, than plausible reporters, whereas overreporters had higher fat and lower carbohydrate intakes[17].

In the analyses of the ENCAT and ENCA previously cited, the nutritional adequacy of Vitamin A, Vitamin C, Vitamin E, Thiamin, Riboflavin, Niacin, Vitamin B6 , Folate, Vitamin B12, Fe, Mg, P and Zn intake was estimated for the entire sample and excluding underreporters (defined by the Goldberg cut-off method) (Table II). The exclusion of underreporters substantially reduced inadequacy of intake for all vitamins assessed by daily methods (one 24 hour recall and a mean of two non-consecutive 24 hour recalls) and FFQ[15]. Data from daily methods adjusted for intra-individual variability were the least modified by underreporters. The highest reduction of inadequacy (above 10%) was found for thiamin, Mg, Zn and vitamin E (except in 24 hour recall adjusted by intra-individual variability)[15].

Implications of underreporting

The implications of underreporting are that they may alter diet and disease associations. Underreporting is a problem that has to be considered in nutritional studies, especially in some cases such as the evaluation of the relationship of dietary intake and obesity or studies examining the nutritional adequacy of the diet[5]. Furthermore, it is important for the creation and evaluation of dietary guidelines and nutrition policies.

Table I

*Energy and nutrient intake (percentile 95th) from the ENKID (n=1857) and ENCAT (n=1840) studies, in total sample, excluding underreporters, and difference between them**

Age group		*Men*			*Women*			*Total*		
		All	*Without underreporter*	*Diference*	*All*	*Without underreporter*	*Diference*	*All*	*Without underreporter*	*Diference*
		P 95	*P 95*	*All-Without under.*	*P 95*	*P 95*	*All-Without under.*	*P 95*	*P 95*	*All-Without under.*
4-10 y ENKID	Energy (kcal)	2382,3	2388,8	-6,5	2228,7	2232,7	-4,1	2318,9	2323,4	-4,5
	Calcium (mg)	1197,0	1197,4	-0,4	1132,2	1137,0	-4,7	1167,4	1187,8	-20,4
	Magnesium (mg)	326,0	327,3	-1,3	296,3	297,2	-0,9	309,4	312,2	-2,7
	Iron (mg)	16,1	16,2	-0,1	13,6	13,6	0,0	15,4	15,5	0,0
	Phosphorus (mg)	1675,4	1677,5	-2,1	1542,1	1548,3	-6,2	1625,1	1627,5	-2,4
	Total Vitamin A (μg)	705,5	702,9	2,6	595,4	603,6	-8,2	643,9	645,1	-1,2
	Vitamin B6 (mg)	2,3	2,3	0,0	2,0	2,0	0,0	2,2	2,2	0,0
	Niacin (mg)	26,3	26,4	-0,1	24,0	24,1	-0,1	25,3	25,4	-0,2
	Vitamin E (mg)	8,6	8,7	-0,1	10,1	10,1	0,0	9,1	9,2	-0,1
11-17 y ENKID	Energy (kcal)	3026,7	3125,8	-99,1	2329,6	2343,8	-14,2	2863,5	2910,3	-46,8
	Calcium (mg)	1356,5	1386,0	-29,5	1075,7	1087,2	-11,6	1267,6	1292,1	-24,5
	Magnesium (mg)	379,0	382,8	-3,8	293,2	295,4	-2,2	358,8	363,2	-4,4
	Iron (mg)	20,4	20,7	-0,3	14,4	14,6	-0,2	19,0	19,3	-0,3
	Phosphorus (mg)	2001,7	2027,5	-25,8	1572,8	1590,4	-17,6	1880,1	1919,8	-39,7
	Total Vitamin A (μg)	766,4	774,9	-8,5	557,1	560,1	-3,0	666,0	677,0	-11,0
	Vitamin B6 (mg)	2,4	2,4	0,0	1,8	1,8	0,0	2,2	2,3	0,0
	Niacin (mg)	30,7	30,8	-0,1	25,6	25,9	-0,2	29,6	29,7	-0,1
	Vitamin E (mg)	10,3	10,3	0,0	9,4	9,8	-0,4	10,0	10,0	0,0
18-80 y ENCAT	Energy (kcal)	2874,3	3001,0	-126,6	2293,8	2435,4	-141,6	2658,5	2830,2	-171,7
	Calcium (mg)	1201,6	1278,3	-76,8	1052,3	1113,3	-61,0	1107,6	1203,8	-96,2
	Magnesium (mg)	395,8	410,0	-14,1	350,1	367,7	-17,6	374,4	404,6	-30,2
	Iron (mg)	12,0	12,7	-0,7	9,6	10,2	-0,6	11,0	11,8	-0,8
	Phosphorus (mg)	15,7	16,3	-0,6	13,1	13,6	-0,5	15,1	15,6	-0,6

Table I (cont.)

*Energy and nutrient intake (percentile 95th) from the ENKID (n=1857) and ENCAT (n=1840) studies, in total sample, excluding underreporters, and difference between them**

Age group		*Men*			*Women*			*Total*		
		All	*Without underreporter*	*Diference*	*All*	*Without underreporter*	*Diference*	*All*	*Without underreporter*	*Diference*
		P 95	*P 95*	*All-Without under.*	*P 95*	*P 95*	*All-Without under.*	*P 95*	*P 95*	*All-Without under.*
	Total Vitamin A (μg)	1802,3	1885,2	-82,9	1502,4	1576,3	-73,9	1690,6	1799,0	-108,4
	Vitamin B6 (mg)	402,4	418,3	-15,9	285,0	298,1	-13,1	360,4	380,3	-19,9
	Niacin (mg)	313,1	321,5	-8,4	288,7	295,5	-6,8	303,2	310,6	-7,4
	Vitamin E (mg)	26,5	28,5	-2,0	21,4	22,1	-0,8	25,1	26,3	-1,2

*Data from two 24-hour recalls adjusted for intra-individual variability. Identification of underreported food intake was conducted by the EI/BMR (energy intake/Basal Metabolic Rate) ratio: less than 1.14.
ENKID: Habitos alimentarios y estado nutricional de la población infantil y juvenil española (1998-2000)
ENCAT: Enquesta Nutricional de la població catalana (2002-2003)

Table II

Analysis of Spanish Population aged 12–80 years (n= 2615) with intakes below average nutrient requirement (ANR) cut point in the entire sample and excluding underreporters.

	One 24Hour Recall (%)			*Two 24 Hour Recall (%)*			*24HR adjusted for intraindividual variability (%)*			*FFQ (%)*		
	All	*Without underreporters*	*Difference*	*All*	*Without underreporters*	*Difference*	*All*	*Without underreporters*	*Difference*	*All*	*Without underreporters*	*Difference*
Vitamin A	52.1	41.7	10.4	47.9	38.9	9.0	57.7	52.7	5.0	15.6	9.9	5.7
Vitamin C	39.1	32.8	6.3	33.0	29.7	3.3	22.9	21.3	1.6	9.4	7.3	2.1
Vitamin E	78.8	66.2	12.6	80.6	70.3	10.3	96.7	94.2	2.5	50.8	40.2	10.6
Thiamin	35.4	14.1	21.3	30.7	13.1	17.6	16.3	4.8	11.5	19.2	8.4	10.8
Riboflavin	16.0	4.6	11.4	12.5	4.0	8.5	2.8	0.6	2.2	5.8	1.3	4.5
Niacin	15.7	6.0	9.7	9.8	2.9	6.9	0.4	0.1	0.3	4.1	0.9	3.2
Vitamin B6	20.4	6.5	13.9	16.7	5.8	10.9	4.1	0.7	3.4	6.7	1.6	5.1
Vitamin B12	13.9	5.3	8.6	6.7	2.7	4.0	0.2	0.0	0.2	0.9	0.1	0.8
Mg	59.3	37.5	21.8	61.0	43.4	17.6	71.1	58.9	12.2	37.8	24.9	12.9
Zn	43.1	23.5	19.6	41.7	23.0	18.7	42.0	25.7	16.3	31.2	15.1	16.1

A recent investigation within the frame of the European Prospective Investigation Into Cancer and Nutrition-Spain (EPIC) has evaluated the effect of accounting for misreporters in the associations between some dietary factors and BMI[18]. Misreporters were identified by comparing reported energy intakes with estimated energy requirements obtained by three methods: 1) the original Goldberg method 2) using basal metabolic rate equations that are more valid at higher BMIs and 3) doubly labeled water-predicted total energy expenditure equations (pTEE). The results indicate that after excluding implausible reporters using each approach, coefficients for several diet-BMI associations changed in magnitude or direction. The consideration for misreporters yielded associations between diet and BMI that were more consistent with previous findings. For example, among women, initially negative associations between BMI and energy intake became positive (Figure 2), a neutral association with fruit became negative and a positive association with vegetables became negative. Although all methods had consistent effects on estimates, the magnitude of these diet-BMI associations was generally stronger when we used the pTEE and revised Goldberg methods than when the standard Goldberg method was used. In contrast, excluding subjects with extreme energy intakes by using recommended cutoffs had no meaningful effect[18].

Similar results were observed in 5357 European children aged 2–9 years[19]. The IDEFICS study (Identification and prevention of Dietary- and lifestyle-induced health Effects In Children and infantS) investigated the effect of handling implausible reporters in the association between dietary intakes (total energy, soft drinks, fruits/vegetables) and overweight/obesity. In the basic model, no significant association was found for energy intake and soft drink intake with overweight/obesity and a significant positive association between overweight/obesity and fruit/vegetable intake was found. However, when underreporters and overreporters were excluded, a positive association between energy intake and overweight/obesity was observed[19]. This finding was also observed when models were adjusted for misreporting, energy intake and overweight/obesity were associated and even more pronounced compared with the model excluding misreporters. Moreover, after adjustment for the propensity score, which combined various indicators for misreporting into one summary measure, Authors found a positive association between soft drinks and overweight/obesity and a negative association was found for fruit/vegetable intakes[19]. The adjustment for propensity score is an alternative that could be useful to minimize misreporting error. Nevertheless, Börnhorst *et al.* recommend that future studies have to be careful when applying the propensity score approach, which requires the identification of the relevant determinants of misreporting according to the study population. Therefore, the effectiveness of the propensity score adjustment in adolescent and adult populations is a task for future research[19].

SOLUTION: New technologies for assessing intake?

Given all the previously recognised limitations, research has focused on refining assessment methods to more accurately evaluate food intake. What could be the solution? The possibilities of developing new applications of information and communication technologies (ICT) to improve dietary as well as physical activity assessment have been explored.

Adaptations of technology have led to extensive changes in how dietary assessment is performed. The most common objective has been to reduce the costs of both the collection and processing of dietary intake information due to the amounts and complexity of data usually involved. The early Framingham and Tecumseh community studies were the first to establish cohorts for the express purpose of examining diet and

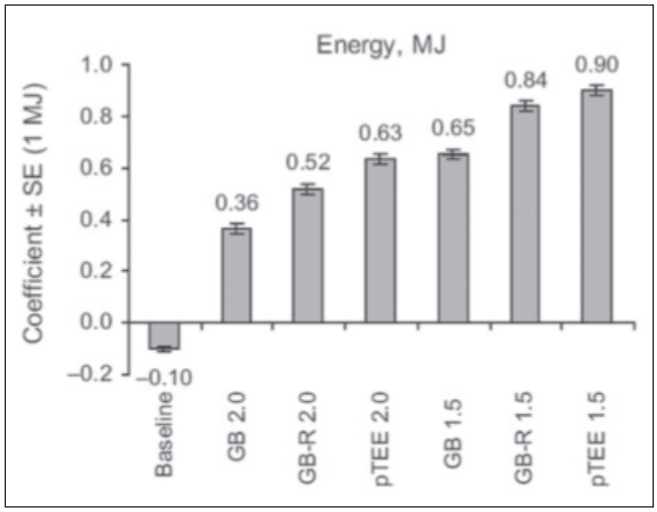


Fig. 2.—Associations between energy intakes and body mass index among women, determined using alternative adjustments for estimated under- and overreporting in the Spanish cohort of the European Investigation Into Cancer and Nutrition[18]. Coefficients from multivariable linear regression models were adjusted for age, center, height, activity, educational level, smoking status, season, alcohol intakes, parity, diabetes, and use of special diets.
Abbreviations: SE, standard error; GB 1.5, Goldberg method with 1.5-standard-deviation cutoffs; GB 2.0, Goldberg method with 2.0-standard-deviation cutoffs; GB-R 2.0, revised Goldberg methods with 2.0-standard-deviation cutoffs; pTEE 2.0, pTEE method with 2.0-standard-deviation cutoffs.

disease relationships, but their tools were interviewer administered, and the data processed manually[20].

The application of ICT in dietary and physical activity assessment offers several potential advantages. Innovative methodological approaches can improve data quality, consistency and completeness. Furthermore, new technologies hold considerable promise for reducing costs as the presence of trained interviewers is not required for a complete interview. Moreover, computerised assessment can save considerable time in data coding as data are immediately stored. Because of less respondent burden, it may be possible to collect long-term data on both food intake and physical activity[1].

New technologies may also help to simplify the self-monitoring process, which increases compliance and validity of self-reported food and energy intake[21]. ICT may enhance dietary intake assessment by simplifying the process and making it less time consuming to monitor food intake, as well as increasing the subject's motivation to complete the task. As such, willingness to record intake may increase and therefore more reliable data are obtained.

Old methods done in new ways:

ICT was applied in FFQ, 24HR and diet histories. Self-administered computerised assessment makes it possible for participants to register and assess their dietary intake at their own pace and convenience. Furthermore, computerised assessment tools can directly calculate nutrient intake and energy expenditure, which makes it possible for immediate feedback[1, 22].

However, some subjects may need more instructions before or during completion of the questionnaire. Applying alerts to warn subjects of improbable answers could also decrease the problem of overreporting as well as reduce the amount of data cleaning by researchers. These types of questionnaires may be useful for web-based data collection and could be applied as an alternative to in-person or self-administered questionnaires in studies where participants attend a central study visit site, as well as for questions on sensitive topics. When using computerised self-assessment, questions about risky or sensitive behaviours may be answered more truthfully[23].

A disadvantage of self-administered computerised assessment is that it requires the user to have a minimum level of knowledge about computer use. Certain population groups may have difficulty using a computerised assessment tool, for example, older and less educated individuals[23]. This is less problematic in interviewer-administered computerised assessment tools.

Personal digital assistants PDA

A PDA is a handheld computer that can be used for various purposes. This technology has been applied for data collection in medical settings for over 15 years[24]. PDA with specifically designed dietary software program can be used to register and self-monitor dietary intake. Subjects are required to record their food intake immediately after consumption by scrolling through a list of foods or by selecting a food group and then a specific food item. After food item selection, portion sizes are entered.

PDA-based food records have several advantages as individuals can be provided with immediate feedback and data stored on the PDA can be reviewed at any point in time. Although the advantages of PDA show their potential to improve data quality, there are several limitations. The use of PDA-based food records increases the respondent burden compared with paper diaries. Studies report subjects having difficulty using the search function and experienced inability to find certain foods[25, 26]. Furthermore, like paper diaries, PDA-based food records require participants to be literate. As such, older or less educated individuals might have difficulty using a PDA for recording food intake[1].

Digital photography

The main advantage of digital photography is the possibility to collect dietary intake data from large groups relatively quickly, with minimal disruption and impact on the eating behaviour of participants. Because data are immediately stored on the computer, the researchers have more time to analyse and process the obtained data. Furthermore, the participants' identities can be kept anonymous, which can be seen as an advantage. Studies show that digital photography is a reliable and valid tool to measure food intake in dining facilities both in adult- and school-age populations.

New measurement methods:
Barcode scanner/ Smart card

An advantage of using the smart card system to measure food choice is that it can collect long-term data from large groups on individual food behaviour. Furthermore, the costs are relatively low as smart cards are inexpensive and fewer researchers are needed since data are stored when the diner uses the smart card to pay for the meal. More research is needed to determine whether this tool can be applied to measure food intake in a variety of population groups.

Summarizing, several dietary-assessment tools applying ICT have been developed and some have shown to be valid and reliable for diverse purposes and target groups. Recently, results from the European Commission project, Innovative Dietary Assessment Methods in Epidemiological Studies and Public Health (IDAMES)[27], concluded that web based approach in adult study populations it might take

more time to have participation rates similar to paper versions. In terms of feasibility, more than two contacts (24-hour recalls) will result in a drop of participation, favouring a non-linear calibration approach and that it is still unclear whether web based or other new technologies can provide ranking instruments better than FFQs in respect to ranking and feasibility. In general, which tool is the most suitable to collect dietary data depends on the objectives of the study and the target group. Before selecting a given tool, it is important to review the advantages and disadvantages of each method[27].

References

1. Ngo J, Engelen A, Molag M, Roesle J, García-Segovia P, Serra-Majem L. A review of the use of information and communication technologies for dietary assessment. *Br J Nutr* 2009;101 Suppl 2:S102-12
2. Poslusna K, Ruprich J, de Vries JH, Jakubikova M, van't Veer P. Misreporting of energy and micronutrient intake estimated by food records and 24 hour recalls, control and adjustment methods in practice. *Br J Nutr* 2009;101 Suppl 2:S73-85.
3. Macdiarmid J, Blundell J. Assessing dietary intake: Who, what and why of under-reporting. *Nutr Res Rev* 1998;11(2):231-53.
4. Mensink GB, Fletcher R, Gurinovic M, Huybrechts I, Lafay L, Serra-Majem L, et al. Mapping low intake of micronutrients across Europe. *Br J Nutr* 2013;110(4):755-73.
5. Livingstone MB, Black AE. Markers of the validity of reported energy intake. *J Nutr* 2003;133 Suppl 3:895S-920S.
6. Rasmussen LB, Matthiessen J, Biltoft-Jensen A, Tetens I. Characteristics of misreporters of dietary intake and physical activity. *Public Health Nutr* 2007;10(3):230-7.
7. Forrestal SG. Energy intake misreporting among children and adolescents: a literature review. *Matern Child Nutr* 2011;7(2):112-27.
8. Serra-Majem L, Ribas L, Pérez-Rodrigo C, García-Closas R, Peña-Quintana L, Aranceta J. Determinants of nutrient intake among children and adolescents: results from the enKid Study. *Ann Nutr Metab* 2002;46 Suppl 1:31-8.
9. Santos LC, Pascoal MN, Fisberg M, Cintra IP, Martini LA. Misreporting of dietary energy intake in adolescents. *J Pediatr (Rio J)* 2010;86(5):400-4.
10. Maurer J, Taren DL, Teixeira PJ, Thomson CA, Lohman TG, Going SB, et al. The psychosocial and behavioral characteristics related to energy misreporting. *Nutr Rev* 2006;64(2 Pt 1):53-66. PubMed PMID: 16536182.
11. Westerterp KR, Goris AH. Validity of the assessment of dietary intake: problems of misreporting. *Curr Opin Clin Nutr Metab Care* 2002;5(5):489-93.
12. Food and Agriculture Organization of the United Nations. Human Energy Requirements: Report of a Joint FAO/WHO/ONU Expert Consultation. FAO/WHO/ONU, editor. *Rome, Italy: Food and Agriculture Organization of the United Nations* 2001.
13. Shahar DR, Yu B, Houston DK, Kritchevsky SB, Newman AB, Sellmeyer DE, et al. Misreporting of energy intake in the elderly using doubly labeled water to measure total energy expenditure and weight change. *J Am Coll Nutr* 2010;29(1):14-24.
14. Subar AF, Kipnis V, Troiano RP, Midthune D, Schoeller DA, Bingham S, et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. *Am J Epidemiol* 2003;158(1):1-13.
15. Ribas-Barba L, Serra-Majem L, Roman-Vinas B, Ngo J, Garcia-Alvarez A. Effects of dietary assessment methods on assessing risk of nutrient intake adequacy at the population level: from theory to practice. *Br J Nutr* 2009;101 Suppl 2:S64-72.
16. Banna JC, Fialkowski MK, Townsend MS. Misreporting of Dietary Intake Affects Estimated Nutrient Intakes in Low-Income Spanish-Speaking Women. *J Acad Nutr Diet* 2014. doi: 10.1016/j.jand.2014.06.358.
17. Rangan A, Allman-Farinelli M, Donohoe E, Gill T. Misreporting of energy intake in the 2007 Australian Children's Survey: differences in the reporting of food types between plausible, under- and over-reporters of energy intake. *J Hum Nutr Diet* 2014;27(5):450-8.
18. Mendez MA, Popkin BM, Buckland G, Schroder H, Amiano P, Barricarte A, et al. Alternative methods of accounting for underreporting and overreporting when measuring dietary intake-obesity relations. *Am J Epidemiol* 2011;173(4):448-58.
19. Börnhorst C, Huybrechts I, Hebestreit A, Vanaelst B, Molnár D, Bel-Serrat S, et al. Diet-obesity associations in children: approaches to counteract attenuation caused by misreporting. *Public Health Nutr* 2013;16(2):256-66.
20. Thompson FE, Subar AF, Loria CM, Reedy JL, Baranowski T. Need for technological innovation in dietary assessment. *J Am Diet Assoc* 2010;110(1):48-51.
21. Kroeze W, Werkman A, Brug J. A systematic review of randomized trials on the effectiveness of computer-tailored education on physical activity and dietary behaviors. *Ann Behav Med* 2006;31(3):205-23.
22. Lagerros YT, Mucci LA, Bellocco R, Nyrén O, Bälter O, Bälter KA. Validity and reliability of self-reported total energy expenditure using a novel instrument. *Eur J Epidemiol* 2006;21(3):227-36.
23. Edwards SL, Slattery ML, Murtaugh MA, Edwards RL, Bryner J, Pearson M, et al. Development and use of touch-screen audio computer-assisted self-interviewing in a study of American Indians. *Am J Epidemiol* 2007;165(11):1336-42.
24. Koop A, Mösges R. The use of handheld computers in clinical trials. *Control Clin Trials* 2002;23(5):469-80.
25. Welch J, Dowell S, Johnson CS. Feasibility of using a personal digital assistant to self-monitor diet and fluid intake: a pilot study. *Nephrol Nurs J* 2007;34(1):43-8.
26. Yon BA, Johnson RK, Harvey-Berino J, Gold BC, Howard AB. Personal digital assistants are comparable to traditional diaries for dietary self-monitoring during a weight loss program. *J Behav Med* 2007;30(2):165-75.
27. Innovative Dietary Assessment Methods in Epidemiological Studies and Public Health I. *WebHome* 2015 [cited 2015]. Available from: http://nugo.dife.de/wiki/bin/view/IDAMES/.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):128-144
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Indicators for the evaluation of diet quality

Ángel Gil[1], Emilio Martinez de Victoria[2] and Josune Olza[1]

[1]Department of Biochemistry and Molecular Biology II, School of Pharmacy, Institute of Nutrition and Food Technology, Centre for Biomedical Research, University of Granada, Granada. [2]Department of Physiology, School of Pharmacy, Institute of Nutrition and Food Technology, Centre for Biomedical Research, University of Granada, Granada. Spain.

Abstract

The role of diet quality and physical activity in reducing the progression of chronic disease is becoming increasingly important. Dietary Quality Indices or Indicators (DQIs) are algorithms aiming to evaluate the overall diet and categorize individuals according to the extent to which their eating behaviour is "healthy". Predefined indexes assess dietary patterns based on current nutrition knowledge and they have been developed primarily for nutritional epidemiology to assess dietary risk factors for non-communicable diseases. There are many different types of DQIs. There are three major categories of DQIs: a) nutrient-based indicators; b) food/food group based indicators; and c) combination indexes, the vast majority of DQIs, which often include a measure of diet variety within and across food groups, a measure of adequacy i.e. nutrients (compared to requirements) or food groups (quantities or servings), a measure of nutrients/foods to consume in moderation, and an overall balance of macronutrients. The Healthy Eating Index (HEI), the Diet Quality Index (DQI), the Healthy Diet Indicator (HDI) and the Mediterranean Diet Score (MDS) are the four 'original' diet quality scores that have been referred to and validated most extensively. Several indexes have been adapted and modified from those originals. In particular, many variations on the MDS have been proposed, included different alternate MDS and Mediterranean Diet Adherence Screener (MEDAS). Primary data source of DQI's are individual dietary data collection tools, namely 24 h quantitative intake recalls, dietary records and food frequency questionnaires. Nutrients found in many scores are total fat, saturated fatty acids or the ratio of monounsaturated fatty acids to saturated fatty acids or the latter SFA to polyunsaturated fatty acids. Cholesterol, protein content and quality, complex carbohydrates, mono- and disaccharides, dietary fibre and sodium are also found in various scores. All DQIs, except those that only contain nutrients, include the components fruits and vegetables; additional attributes are legumes or pulses, nuts and seeds. Meat and meat products, namely red and processed meat, poultry, and milk and dairy products are also included in many scores. Other foods contained in some DQIs e.g. MDS are olive oil and fish. Nowadays,

Correspondence: Prof. Angel Gil.
Department of Biochemistry and Molecular Biology II, Institute of Nutrition and Food Technology, Centre of Biomedical Research, University of Granada.
Avda. del Conocimiento s/n, 18016 Armilla, Granada, Spain.
E-mail: agil@ugr.es

INDICADORES DE EVALUACIÓN DE LA CALIDAD DE LA DIETA

Resumen

El papel de la calidad de la dieta y de la actividad física en la reducción de la progresión de las enfermedades crónicas es cada vez más importante. Los indicadores o índices de calidad de la dieta (DQIs) son algoritmos destinados a evaluar la calidad global de la dieta y categorizar a los individuos en función de si su patrón de alimentación es más o menos saludable. Los índices predefinidos evalúan diferentes patrones dietéticos basados en los conocimientos actuales de la Nutrición y se han desarrollado básicamente para la epidemiología nutricional con objeto de determinar factores de riesgo de enfermedades crónicas no transmisibles (ECNTs).Existen muchos tipos de DQIs. Se distinguen tres categorías principales: a) basados en nutrientes; b) basados en alimentos o grupos de alimentos; y c) índices combinados. A estos últimos pertenecen la mayoría de los DQIs, los cuales incluyen además una medida de adecuación de la dieta a las recomendaciones dietéticas, una medida del consumo moderado y un balance general de ingesta de macronutrientes. El indicador de alimentación saludable (HEI), el índice de calidad de la dieta (DQI), el indicador de dieta saludable (HDI) y la puntuación de dieta mediterránea (MDS), son los cuatro indicadores originales que se han referenciado y validado más extensamente. Otros muchos índices se han adaptado a partir de ellos. En particular se han propuesto numerosas variaciones del MDS que incluyen varios índices alternativos y el recientemente denominado MEDAS que valora el grado de adherencia a la dieta y hábitos de vida mediterráneos. La fuente primaria de los DQIs son las herramientas para recoger datos individuales de ingesta tales como el recordatorio de ingesta cuantitativa de 24 h, los registros dietéticos y los cuestionarios de frecuencias de consumo de alimentos. Los nutrientes que se incluyen en numerosos DQIs son grasa total, ácidos grasos saturados o la proporción ácidos grasos monoinsaturados a ácidos grasos saturados o de estos últimos a ácidos grasos poliinsaturados, colesterol, contenido y calidad de las proteínas Los hidratos de carbono complejos, mono- y disacáridos, fibra dietética y sodio se incluyen también en algunos indicadores. Todos los DQIs, excepto aquellos en los que sólo se incluyen nutrientes, tienen como componentes el consumo de frutas y verduras; atributos adicionales son las legumbres, frutos secos y semillas. El consumo de carne y de productos cárnicos, especialmente carnes rojas y procesadas, carnes de ave y leche y productos lácteos se incluye también en varios índices Otros alimentos incluidos en algunos indicadores, p.e. en el MDS son el aceite

there is interest in defining more than DQIs, healthy life indices (HLIs), which give information on behaviours associated with specific patterns and beyond dietary habits they include physical activity, rest and selected socio-cultural habits. The Mediterranean Lifestyle (MEDLIFE) index has been recently created based on the current Spanish Mediterranean food guide pyramid and it includes both the assessment of food consumption directly related to the Mediterranean diet, physical activity and rest and other relevant cultural information. However, a global HLI should consider, based on the Iberoamerican Nutrition Foundation (FINUT) Pyramid of Healthy Lifestyles, in addition to food groups and nutrients, selected items on food safety e.g. consumption rate of proceed foods, food handling, preparation and storage and access to drinking water, selected food habits, including alcoholic beverage and salt consumption patterns, purchase of seasonal and local foods, home cooking and conviviality, as well as patterns of physical activity, sedentary and rest habits and some selected sociocultural habits, particularly those related to food selection, religious beliefs and socializing with friends.

(*Nutr Hosp* 2015;31(Supl. 3):128-144)

DOI:10.3305/nh.2015.31.sup3.8761

Key words: *Diet. Food. Food habits. Health. Lifestyles. Nutrients.*

de oliva y el pescado. Actualmente hay interés más que en definir nuevos DQIs en establecer índices de calidad de vida (HLIs), que suministren información, además de sobre nutrientes y alimentos consumidos, sobre patrones de comportamiento específicos asociados con los hábitos de alimentación, con la actividad física y el descanso y con ciertos hábitos de vida socio-culturales. El índice de calidad de vida mediterránea (MEDLIFE), recientemente creado, está basado en la pirámide de alimentos de la dieta mediterránea e incluye tnato la evaluación del consumo de alimentos relacionados con la dieta mediterránea como información en relación a la actividad física y el descanso y otra información cultural relevante. Sin embargo, un índice global de estilos de vida saludable, basada en la pirámide de la Fundación Iberomericana de Nutrición (FINUT), además de grupos de alimentos y de nutrientes, debería incluir aspectos relacionados con la seguridad alimentaria p.e. consumo de alimentos procesados, manejo preparación y almacenamiento de los alimentos, y acceso al agua potable, hábitos alimentarios, incluyendo patrones de consumo de bebidas alcohólicas y de sal, compra de alimentos estacionales y locales, cocinado en el hogar y convivialidad, así como patrones de actividad física, sedentarismo y descanso y algunos hábitos socioculturales, particularmente aquellos relacionados con la selección de alimentos, creencias religiosas y socialización con amigos.

(*Nutr Hosp* 2015;31(Supl. 3):128-144)

DOI:10.3305/nh.2015.31.sup3.8761

Palabras clave: *Alimentos. Dieta. Estilos de vida. Hábitos alimenticios. Salud. Nutrientes.*

Abbreviations

AA: amino acids.
AHEI: alternative healthy eating index.
AMDR: acceptable macronutrient distribution range.
aMED: alternate Mediterranean diet index.
BV: biological value.
CHD: coronary heart disease.
CQI: carbohydrate quality index.
CVD: cardiovascular disease.
DASH: Dietary Approaches to Stop Hypertension.
DHA: docosahexaenoic acid.
DIAAS: digestible indispensable amino acid score.
DQI: diet quality index.
DQIr: dietary quality index revised.
DRI: dietary reference intake.
E: energy.
EPA: eicosapentaenoic acid.
FBQI: food-based quality index.
FCTs: food-nutrient conversion tables.
FFQs: food frequency questionnaires.
FINUT: Iberomerican Nutrition Foundation.
FPI: food pyramid index.
GI: glycaemic index.
GL: glycaemic load.
HDI: healthy diet indicator.
HDL-C: high-density lipoprotein cholesterol.
HEI: healthy eating index.
HFI: healthy food index.
HI: healthy lifestyle index.
HLIs: healthy lifestyle indicators.
IEC: ionic exchange chromatography.
IPAQ: international activity questionnaire.
LA: linoleic acid.
LCPUFA: long chain polyunsaturated fatty acids.
LDL-C: low-density lipoproteins cholesterol.
LNA: alfa-linolenic acid.
MDS: Mediterranean diet score.
MDS-a: adapted Mediterranean diet score.
MEDAS: Mediterranean diet adherence screener.
Med-DQI: Mediterranean dietary quality index.
MEDLIFE: Mediterranean lifestyle index.
MET: metabolic equivalents.
MUFA: monounsaturated fatty acids.
NCCDs: non-communicable chronic diseases.
NPR: net protein retention.
NPU: net protein utilization.
NRF: nutrient rich food.
P: S: polyunsaturated: saturated fatty acid ratio.
PDCAAS: protein digestibility corrected amino acid score.
PER: protein efficiency ratio.
PREDIMED: Prevención con Dieta Mediterránea.
PUFA: polyunsaturated fatty acids.

SFA: saturated fatty acids.
TFA: *trans* fatty acids.
USDA: United States Department of Agriculture.

Introduction

Despite the multiple nutritional recommendations and food guidelines, the pandemic of non-communicable chronic diseases (NCCDs) continues in both developed and developing countries[1]. The role of diet quality and physical activity in reducing the progression of chronic disease is becoming increasingly important. The evidence supporting the importance of a healthy lifestyle (healthy diet, physical activity, avoiding alcohol, not smoking, and effectively managing stress) as a part of wellness programs and of interventions for primary and secondary prevention of NCCDs is strong, compelling, and continuously growing[2]. Good health and optimal functionality across the lifespan are achievable goals but require a lifestyle approach including a total diet that is energy balanced and nutrient dense[3], as well as regular physical activity and exercise, which contribute to counterbalance the energy intake and to the regulation of body weight and a number of physiological functions[4].

Certain dietary patterns consumed around the world are associated with beneficial health outcomes. Patterns of eating that have been shown to be healthful include the Mediterranean-style dietary patterns[5] and the Dietary Approaches to Stop Hypertension (DASH)-style dietary patterns[6]. However, the daunting public health challenge is to accomplish population-wide adoption of healthful dietary patterns within the context of powerful influences that currently promote unhealthy consumer choices, behaviours, and lifestyles[3]. Indeed, there is a need to be able to simply and cheaply monitor diet quality in populations world-wide. Dietary Quality Indices or Indicators (DQIs) aim to evaluate the overall diet and categorize individuals according to the extent to which their eating behaviour is "healthy". Predefined indexes assess dietary patterns based on current nutrition knowledge and they have been developed primarily for nutritional epidemiology to assess dietary risk factors for NCCDs, but their use is expanding. Beyond the evaluation of the diet quality there is a need to evaluate global healthy lifestyles. Hence, the main goal of the present article is to summarize the relevance of the most important DQIs and Healthy Lifestyle Indicators (HLIs) used worldwide (Fig. 1), with particular emphasis on Mediterranean patterns and to discuss some methodological aspects for the evaluation of the quality of the main nutrients.

Diet quality indicators

In the past decade several researchers have attempted to develop a measure of diet quality, indeed, there is a myriad of DQIs. The use of DQIs becomes more widespread and tailored to the specific purpose and populations. However, different approaches are mainly due to arbitrary choices because of lacking knowledge on healthy diets and unsolved methodological issues. The ways of dealing with differences in energy intake, scoring each component, and combining the different components into one measure are aspects that still need further research[7].

Kant (1996) was the first to review the indexes related to the overall diet quality and he expectedly found that the definition of diet quality depended on attributes selected by the investigators[8]. This review was followed eight years later by a review of dietary patterns, both empirically derived and theoretically defined, and health outcome[9]. Later, Waijers et al. (2007) reviewed 20 distinct indexes of overall diet quality and they concluded that existing indexes do not predict disease or mortality significantly better than individual dietary factors, but they can be useful to measure the extent to which individuals adhere to dietary guidelines[10]. Thus, those DQIs need to be used and interpreted with care. Arvaniti and Panagiotakos (2008) also reviewed 23 commonly used dietary indices, which mostly overlapped Waijers review[11]. Fransen et al. (2008) provided

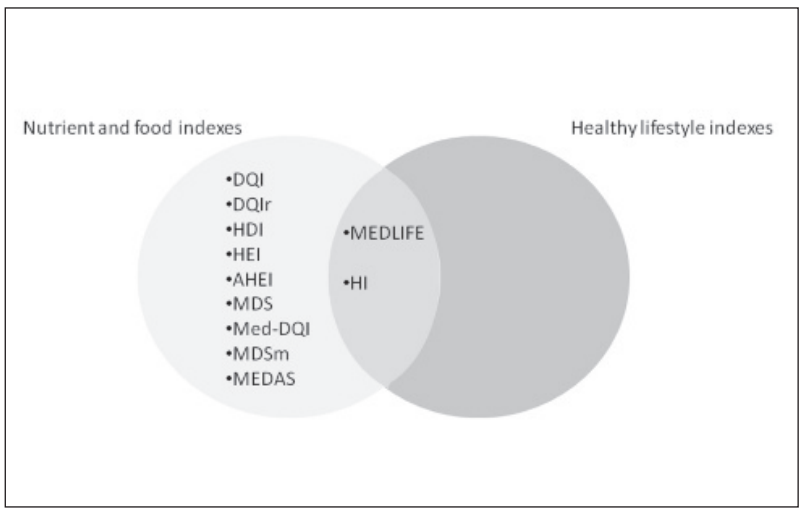


Fig. 1.—Dietary Quality Indices.
DQI: dietary quality index; DQIr: dietary quality index revised; HDI: healthy diet indicator; HEI: healthy eating index; AHEI: alternative healthy eating index; MDS: Mediterranean diet score; Med-DQI: Mediterranean dietary quality index; MDS: Mediterranean diet score modified; MEDAS: Mediterranean diet adherence screener; MEDLIFE: Mediterranean Lifestyle Index and HI: Healthy Lifestyle Index.

an overview of the different dietary quality indices that had been developed for the general adult population and were based on the American dietary guidelines and the Mediterranean diet and, additionally, they included other DQIs indices for special populations with special attention to the makeup of the score and methodological issues[7]. More recently, Alkerwi (2014) has reviewed the concept of diet quality and discussed several debated key points to understand the reasons behind the confusion generated by multiple DQIs and addressed the complexity of how to define and quantify this concept. This author concluded that an integrated approach that combines all the different characteristics of diet quality is needed to successfully measure the concept of overall diet quality and that apart from nutritional characteristics there is a need to score other facets of diet quality, including food safety, organoleptic and sociocultural aspects, (which have currently no quantifiable thresholds or criteria)[12].

The Healthy Eating Index (HEI)[13], the Diet Quality Index (DQI)[14], the Healthy Diet Indicator (HDI)[15] and the Mediterranean Diet Score (MDS)[16] are the four 'original' diet quality scores that have been referred to and/or validated most extensively. Several indexes have been adapted and modified. In particular, many variations on the MDS have been proposed; four distinct adaptations are all referred to as adapted MDS (MDS-a)[10].

There are many different types of DQIs. One major category is formed by nutrient-based indicators, which require the conversion from food weights to nutrient content using food-nutrient conversion tables (FCTs), comparison to requirements, adequacy ratios, etc., e.g. revised DQI. Food/food group based indicators form another category; they use dietary guidelines for recommended portions and frequencies or simple food groups count. The Food-Based Quality Index (FBQI), the Healthy Food Index (HFI) and the Food Pyramid Index (FPI) consist solely of food groups or foods and the MDS mainly contain food groups, supplemented with a ratio reflecting the fatty acid composition of the diet and alcohol, whereas two adapted MDS contain foods only (revised by Waijers et al.)[10].

The vast majority of DQIs e.g. original DQI, HEI and HDI, are included in a category of combination indexes, which often include a measure of diet variety within and across food groups, a measure of adequacy i.e. nutrients (compared to requirements) or food groups (quantities or servings), a measure of nutrients/foods to consume in moderation, and an overall balance of macronutrients. Public health nutritionists have historically recommended variety or diversity in dietary patterns as one means of fostering an optimal diet. The underlying concept was that no one food contained all of the necessary nutrients and that variety in dietary sources was needed to ensure a "balanced" diet[17]. Unfortunately, there is no a standardized approach to content and to scoring and scores are based on frequency, number of portions, assigned weights, etc. Indeed, different DQ scores are not comparable and are often country-specific. Table I summarizes the most useful QDIs for the evaluation of the quality diet.

Primary data source of DQI's are individual dietary data collection tools, namely 24 h quantitative intake recalls, dietary records and food frequency questionnaires (FFQs). FFQs concentrate on foods/nutrients of special interest while 24h recalls collect information on complete intake – all food eaten and their quantities. The main purpose for collecting detailed quantitative food intake data was and is still to investigate associations between nutrients, foods or other elements of the diet and health outcomes. DQIs have been repeatedly validated against outcomes. Dietary intake surveys are also undertaken to provide estimates of national nutritional status. More recent uses of individual dietary intake surveys include identification of vehicles for food fortification and evaluation of the risks related to possible hazards in food.

Kennedy *et al*. (1995) developed a single summary index of diet quality the HEI[13]. The HEI is an index ranging from zero to 100, which is based on ten individual components, the individual component scores can vary from zero to ten. The first five components of the HEI are based on the five major food groups of the US Food Guide Pyramid, whereas components six to ten are based on aspects of the US Dietary Guidelines. Variety is one of the 10 components of the HEI. The HEI has been shown to correlate positively and significantly with most nutrients in the diet, with the body mass index (BMI, kg/m^2) of study subjects and with the individuals "self perception" of their diets.

In an attempt to improve the original HEI, McCullough et al, (2002) created a 9-component Alternate Healthy Eating Index (AHEI)[18]. This index was designed to target food choices and macronutrient sources associated with reduced chronic disease risk and was also developed based on dietary guidelines and the food guide pyramid proposed by the US Department of Agriculture[13] (USDA) and emphasizes the consumption of plant foods and unsaturated oils. Higher AHEI scores were associated with lower concentrations of biomarkers of inflammation and endothelial dysfunction and therefore may be useful as an useful tool for reducing the risk of diseases involving such biological pathways[19].

The DQI[14] later revised in 1999 and 2003, is based on similar guidelines than those of HEI and AHEI from the National Research Council of the USA, but also includes iron and calcium[20]. It has two variety components overall food group and within food group diversity; eight adequacy components (to increase in diet) i.e. 1) vegetables, 2) fruits, 3) grains, 4) fibre, 5) protein, 6) iron, 7) calcium, and 8) Vitamin C; five moderation components (to decrease in diet) i.e. 1) total fat, 2) saturated fat, 3) cholesterol, 4) sodium, and 5) empty calories (foods with low nutrient density); and two overall balance components i.e. macronutrient ratio and fatty acid ratio. The original DQI was revised to reflect current dietary guidance, to incorporate improved methods of estimating food servings and to develop and incorporate measures

Table I
Diet Quality Indicator components and scoring criteria

Index	*Components*	*Criteria/Scoring*		*Reference*
Mixed Nutrient and Food Indexes				
Diet Quality Index (DQI)				14
	Total fat	< 30 energy %	0	
		30–40 energy %	1	
		> 40 energy %	2	
	Saturated fatty acids	< 10 energy %	0	
		10–13 energy %	1	
		>13 energy %	2	
	Cholesterol	< 300 mg	0	
		300–400 mg	1	
		> 400 mg	2	
	Fruit and vegetables	5 + servings	0	
		3–4 servings	1	
		0–2 servings	2	
	Complex carbohydrates	6 + servings	0	
		4–5 servings	1	
		0–3 servings	2	
	Protein	≤ 100% RDA	0	
		100–150% RDA	1	
		≥ 150% RDA	2	
	Sodium	< 2400 mg	0	
		2400–3400 mg	1	
		> 3400 mg	2	
	Calcium	≥ RDA	0	
		2/3 RDA	1	
		< 2/3 RDA	2	
Diet Quality Index revised (DQIr)				20
	Total fat ≤ 30%	≤ 30 energy %	10	
		> 30 energy %	5	
		> 40 energy %	0	
	Saturated fatty acids ≤ 10% energy intake	≤ 10 energy %	10	
		10, ≤ 13 energy %	5	
		> 13 energy %	0	
	Cholesterol	≤ 300 mg	10	
		> 300, ≤ 400 mg	5	
		> 400 mg	0	
	2-4 servings fruits per day	≥ 100%		
		99%- 50%	0-10*	
		< 50%		
	3-5 servings vegetables per day	≥ 100%		
		99%- 50%	0-10*	
		< 50%		
	6-11 servings grains per day	≥ 100%		
		99%- 50%	0-10*	
		< 50%		
	Calcium intake (based on 1989 RDA p/age)	≥ 100%		
		99%- 50%	0-10*	
		< 50%		

Table I ***(cont.)***
Diet Quality Indicator components and scoring criteria

Index	*Components*	*Criteria/Scoring*		*Reference*
	Iron intake (based on 1989 RDA p/age)	≥ 100% 99%- 50% < 50%	0-10*	
	Dietary diversity score	≥ 6 ≥ 3, < 6 < 3	0-10	
	Dietary moderation score	≥ 7 ≥ 4, < 7 < 4	0-10	
*Depending on energy intake				
Healthy Diet Indicator (HDI)				15
	Saturated fatty acids	0-10 energy %	1	
	Polyunsaturated fatty acids	3-7 energy %	1	
	Protein	10-15 energy %	1	
	Complex carbohydrates	50-70 energy %	1	
	Dietary fibre (g)	27-40 energy %	1	
	Fruits and vegetables (g)	> 400 g/d	1	
	Pulses, nuts, seeds (g)	> 30 g/d	1	
	Mono- and disaccharides	0-10 energy %	1	
	Cholesterol (mg)	0-300 mg/d	1	
If % or quantities are not in the ranges, score = 0				
Healthy Eating Index (HEI)				13
	Grains	6-11 servings	0-10	
	Vegetables	3-5 servings	0-10	
	Fruits	2-4 servings	0-10	
	Milk	2-3 servings	0-10	
	Meat	2-3 servings	0-10	
	Total Fat	< 30 energy %	0-10	
	Saturated fatty acids	< 10 energy %	0-10	
	Cholesterol	< 300 mg	0-10	
	Sodium	< 2400 mg	0-10	
	Variety	16 different food items/3d	0-10	
The criteria for scoring depend on the energy intake. 0 servings score=0.				
Alternative Healthy Eating Index (AHEI)				18
	Vegetables	0 servings 5 servings	0 10	
	Fruits	0 servings 4 servings	0 10	
	Nuts and soy protein	0 servings 1 servings	0 10	
	Ratio of white to red meat	0 4	0 10	

Table I ***(cont.)***
Diet Quality Indicator components and scoring criteria

Index	*Components*	*Criteria/Scoring*		*Reference*
	Cereal fibre g/d	0	0	
		15	10	
	Trans Fat	≥ 4 energy %	0	
		≤ 0.5 energy %	10	
	Polyunsaturated: saturated fatty acids ratio	≤ 0.1	0	
		≥ 1	10	
	Duration of multivitamins use	< 5 years	0	
		≥ 5 years	10	
	Alcohol	Men: 0 or > 3.5 Women: 0 or > 2.5	0	
		Men: 1.5-2.5 Women: 0.5-1.5	10	
Intermediate intakes are scored proportionately between 0-10				
Mediterranean Diet Score (MDS)				16
	Monounsaturated: Saturated fatty acid ratio	< median	0	
		> median	1	
	Legumes	< median	0	
		> median	1	
	Cereals	< median	0	
		> median	1	
	Fruits and nuts	< median	0	
		> median	1	
	Vegetables	< median	0	
		> median	1	
	Meat and meat products	> median	0	
		< median	1	
	Milk and dairy products	> median	0	
		< median	1	
	Alcohol	> median	0	
		< median	1	
Mediterranean- Diet Quality Index (Med-DQI)				21
	Saturated fatty acids	< 10 energy %	0	
		10–13 energy %	1	
		> 13 energy %	2	
	Cholesterol	< 300 mg	0	
		300–400 mg	1	
		> 400 mg	2	
	Meats	< 25 g	0	
		25-125 g	1	
		> 125 g	2	
	Olive oil	> 15 ml	0	
		15-5 ml	1	
		< 5 ml	2	
	Fish	> 60 g	0	
		60-30 g	1	
		< 30 g	2	
	Cereals	> 300 g	0	
		300-100 g	1	
		< 100 g	2	
	Vegetables + fruits	> 700 g	0	
		700-400 g	1	
		< 400 g	2	

Table I ***(cont.)***
Diet Quality Indicator components and scoring criteria

Index	*Components*	*Criteria/Scoring*		*Reference*
Mediterranean Diet Score modified (MDS mod)				22
	Vegetables	< median	0	
		≥ median	1	
	Legumes	< median	0	
		≥ median	1	
	Fruits and nuts	< median	0	
		≥ median	1	
	Dairy products	< median	0	
		≥ median	1	
	Cereals	< median	0	
		≥ median	1	
	Meat	≥ median	0	
		< median	1	
	Fish	< median	0	
		≥ median	1	
	Ratio monounsaturated: saturated lipids	< median	0	
		≥ median	1	
	Alcohol	Men (10-50 g/d)	1	
		Women (5-25 g/d)	1	
Mediterranean Diet Adherence Screener (MEDAS)				23
	4 or more tablespoons of olive oil/d		1	
	2 or more servings of vegetables/d		1	
	3 or more pieces of fruit/d		1	
	<1 serving of red meat or sausages/d		1	
	<1 serving of animal fat/d		1	
	< 100 mL of sugar-sweetened beverages/d		1	
	7 or more servings of red wine/wk		1	
	3 or more servings of pulses/wk		1	
	3 or more servings of fish/wk		1	
	fewer than 2 commercial pastries/wk		1	
	3 or more servings of nuts/wk		1	
	2 or more servings/wk of a dish with a traditional sauce of tomatoes, garlic, onion, or leeks sautéed in olive oil		1	
	Use of olive oil as principal source of fat		1	
	Kind of meat preferable consumed		0-1	
Healthy Lifestyle Indexes				
Mediterranean Lifestyle Index (MEDLIFE)				25
Block 1: Mediterranean food consumption				
	Sweets	≤ 2 servings/week	1	
	Red meat	< 2 servings/week	1	
	Processed meat	≤ 1 serving/week	1	

Table I ***(cont.)***
Diet Quality Indicator components and scoring criteria

Index	*Components*	*Criteria/Scoring*		*Reference*
	Eggs	2–4 servings/week	1	
	Legumes	≥ 2 servings/week	1	
	White meat	2 servings/week	1	
	Fish/seafood	≥ 2 servings/week	1	
	Potatoes	≤ 3 servings/week	1	
	Low-fat dairy products	2 servings/d	1	
	Nuts and olives	1–2 servings/d	1	
	Herbs, spices and garnish	≥ 1 serving/d	1	
	Fruit	3–6 servings/d	1	
	Vegetables	≥ 2 servings/d	1	
	Olive oil	≥ 3 servings/d	1	
	Cereals	3–6 servings/d	1	
Block 2: Mediterranean dietary habits				
	Water or infusions	6–8 servings/d or ≥3 servings/week	1	
	Wine	1–2 servings/d	1	
	Limit salt in meals	Yes	1	
	Preference for whole grain products	Yes/fibre >25 g/d	1	
	Snacks	≤ 2 servings/week	1	
	Limit nibbling between meals	Yes	1	
	Limit sugar in beverages (including sugar-sweetened beverages)	Yes	1	
Block 3: Physical activity, rest, social habits and conviviality				
	Physical activity (>150 min/week or 30 min/d)	Yes	1	
	Siesta/nap	Yes	1	
	Hours of sleep	6–8 h/d	1	
	Watching television	< 1 h/d	1	
	Socializing with friends	≥ 2 h/weekend	1	
	Collective Sports	≥ 2 h/week	1	
Healthy Lifestyle Index (HLI)				2
	Fruit/vegetables	≥ 4.5 cups/ day	0-5	
	Fish	≥ 3.5 oz/week	0-5	
	Fibre-rich food	≥ three 1 oz equivalent servings/day	0-5	
	Nominal sodium	<1,500 mg/day	0-5	
	Sugar sweetened beverages	≤ 36 oz/week	0-5	
	Physical activity was divided in light, moderate, or vigorous and transformed in metabolic equivalents (MET) following the Guidelines for Analysis of the International Activity Questionnaire (IPAQ)			
	Subjective stress, including fatigue and bodily complaints, was estimated by a battery of tests			

Metrics for these three lifestyle domains (diet, exercise, stress) are normalized to 1/3 and then combined into a single, composite index of healthy lifestyle, which ranged from 0 to 100 (higher scores indicate healthier conditions).

of dietary variety and moderation. The scoring of the original scale was reversed in direction and expanded to a 100-point scale to improve interpretability[20].

A specific Mediterranean-DQI (Med-DQI) has been devised[21]. Olive oil was added with a score increasing with a lower intake. Protein was replaced by meat, because fish was added with an opposite gradient. Each nutrient or food group was assigned three scores (0, 1 and 2) on the basis of recommended guidelines where these exist (cholesterol, SFA), or by dividing the population's consumption into tertiles where there was no specific recommendation for the food.

The HDI was calculated for the dietary pattern, using the World Health Organisation's guidelines for the prevention of chronic diseases. A dichotomous variable was generated for each food group or nutrient that was included in these guidelines. If a person's intake was within the recommended range this variable was coded as 1; otherwise it was coded as 0.The HDI was the sum of all these dichotomous variables, including saturated fatty acids, polyunsaturated fatty acids, cholesterol, protein, complex carbohydrates, monosaccharides and disaccharides, dietary fibre, fruits and vegetables, pulses, nuts and seeds[15].

The traditional Mediterranean diet has been defined and reasonably scored in terms of eight component characteristics (MDS): high monounsaturated to saturated fat ratio, moderate ethanol consumption, high consumption of legumes, high consumption of cereals (including bread and potatoes), high consumption of fruits, high consumption of vegetables, low consumption of meat and meat products, and low consumption of milk and dairy products[16]. Later, a revised scale indicating the degree of adherence to the traditional Mediterranean diet included fish intake[22]. A value of 0 or 1 was assigned to each of nine components with the use of the sex-specific median as the cut-off. For beneficial components (vegetables, legumes, fruits and nuts, cereal, and fish), persons whose consumption was below the median were assigned a value of 0, and persons whose consumption was at or above the median were assigned a value of 1. For components presumed to be detrimental (meat, poultry, and dairy products, which are rarely non-fat or low-fat in Greece), persons whose consumption was below the median were assigned a value of 1, and persons whose consumption was at or above the median were assigned a value of 0. For ethanol, a value of 1 was assigned to men who consumed between 10 and 50 g per day and to women who consumed between 5 and 25 g per day. Finally, for fat intake, they used the ratio of monounsaturated lipids to saturated lipids, rather than the ratio of polyunsaturated to saturated lipids, because in Greece, monounsaturated lipids are used in much higher quantities than polyunsaturated lipids. Thus, the total Mediterranean-diet score ranged from 0 (minimal adherence to the traditional Mediterranean diet) to 9 (maximal adherence).

The Alternate Mediterranean Diet Index (aMED) was adapted by Fung et al. (2005) from the original MDS to use with a food-frequency questionnaire (FFQ) developed in the United States, by introducing some modifications such as eliminating the dairy group, separating nuts and fruits into two groups, and assigning a score to a moderate alcohol intake. As for the AHEI, aMED scores were associated with lower concentrations of biomarkers of inflammation and endothelial dysfunction[19].

More recently, a 14-point Mediterranean Diet Adherence Screener (MEDAS)[23] questionnaire was used in the "Prevención con Dieta Mediterránea" (PREDIMED) study, a primary prevention nutrition-intervention trial[24]. The MEDAS consists of 12 questions on food consumption frequency and 2 questions on food intake habits considered characteristic of the Spanish Mediterranean diet. Each question was scored 0 or 1. One point was given for using olive oil as the principal source of fat for cooking, preferring white meat over red meat, or for consuming: 1) 4 or more tablespoons (1 tablespoon = 13.5 g) of olive oil/d (including that used in frying, salads, meals eaten away from home, etc.); 2) 2 or more servings of vegetables/d; 3) 3 or more pieces of fruit/d; 4) <1 serving of red meat or sausages/d; 5) <1 serving of animal fat/d; 6) <1 cup (1 cup = 100 mL) of sugar-sweetened beverages/d; 7) 7 or more servings of red wine/wk; 8) 3 or more servings of pulses/wk; 9) 3 or more servings of fish/wk; 10) fewer than 2 commercial pastries/wk; 11) 3 or more servings of nuts/wk; or 12) 2 or more servings/wk of a dish with a traditional sauce of tomatoes, garlic, onion, or leeks sautéed in olive oil. If the condition was not met, 0 points were recorded for the category. The final PREDIMED score ranged from 0 to 14[23].

Healthy lifestyles Indicators

The Mediterranean Lifestyle (MEDLIFE) index has been created based on the current Spanish Mediterranean food guide pyramid. MEDLIFE is a twenty-eighteen derived index consisting of questions about food consumption (fifteen items), traditional Mediterranean dietary habits (seven items) and physical activity, rest and social interaction habits (six items); each item scored 0 or 1, and the final MEDLIFE index ranged from 0 (worst) to 28 (Table I). Indeed, MEDLIFE includes both the assessment of food consumption directly related to the Mediterranean diet and information on behaviours associated with the Mediterranean lifestyle beyond dietary habits, to include physical activity, rest, social habits and conviviality. This, it is expected to be a more holistic tool to measure adherence to the Mediterranean lifestyle in epidemiological studies[25].

Recently, Lucini et al. (2014) have tested whether a simple web-based healthy lifestyle index, using self-reports, could be related to indices of cardiovascular health and metabolic syndrome and could be employed in large wellness programs intended to promote healthy lifestyle[2]. Healthy diet score was graded from 0 to 5

(best value), focusing rather on alimentary style than of specific food elements; one point was added whenever each of the following elements was present: fruit/vegetables 4.5 cups/day, fish 3.5 oz/week, fibre-rich food three 1 oz equivalent servings/day, nominal sodium \1,500 mg/day (operationally, it was considered as threshold the habit of adding salt without prior tasting food or eating processed meats, or snacks and potato chips daily), and sugar sweetened beverages 36 oz/week; the following thresholds were used for poor, intermediate, and ideal healthy diet: <2 and >3). Exercise was estimated from self-reported weekly minutes of activity. Physical activity was divided in light, moderate, or vigorous and transformed in metabolic equivalents (MET) following the Guidelines for Analysis of the International Activity Questionnaire (IPAQ)[2]. Subjective stress, including fatigue and bodily complaints, was estimated by a battery of tests. Metrics for these three lifestyle domains (diet, exercise, stress) were normalized to 1/3 and then combined into a single, composite index of healthy lifestyle, which ranged from 0 to 100 (higher scores indicating healthier conditions). The authors consider that the simplicity of obtaining and using this index and the statistically significant link with traditional clinical indicators of risk, particularly with cardiovascular risk factors, might support its use as a tool to help manage behaviour in health promotion and prevention strategies to apply to large populations[2].

Food and food groups and diet quality

Fruits and vegetables as well as whole grains are known to have a role in the prevention on NCCDs[1]. Therefore, all DQIs, except those that only contain nutrients, include the components fruits and vegetables, either grouped together (DQI, MDQI, MDS-a I, HDI) or separately (all other indexes). The MDS contain an additional attribute 'legumes'. The HDI contains an item 'pulses, nuts and seeds'. If not considered individually, nuts are added to the fruit group (MDS, some MDS-a) or to the legumes (revised by Waijers et al.)[10]. However, the DQI, HEI, MDS and HDI do not distinguish between whole and refined cereals.

Meat and meat products, namely red and processed meat, poultry, and milk and dairy products are also included in many scores. The inclusion of meat in moderate amounts is considered healthy; however, high consumption of red meat and processed meats is associated to increased prevalence of some NCCDs (USDA Report, 2010). Likewise, the inclusion of dairy products in DQIs is complex as skimmed and half-skimmed dairy products and fermented milk products have been associated with the protection of some NCCDs, but other dairy products, namely creams, butter and some cheeses are very rich in SFA. Other foods contained in some DQIs e.g. MDS are olive oil, fish and nuts[16, 25].

The association of alcohol consumption with health can be described as U-shaped. An average daily intake of one to two alcoholic beverages is associated with the lowest all-cause mortality and a low risk of diabetes and coronary heart disease among middle-aged and older adults. However, there is strong evidence that heavy consumption of four or more drinks a day for women and five or more drinks a day for men has harmful health effects[3]. Indeed, alcohol has been included in the Mediterranean indexes as moderate wine consumption.

As commented earlier, some DQIs have included a variable representing dietary variety in their indices, in addition to foods or nutrients[13,14,20].

Nutrient density and diet quality

The concept of nutrient density was used as the cornerstone of the USDA dietary guidelines 2005 (MyPyramid). Diet quality indices assess the overall nutritional quality of the total diet; in contrast, food quality indices, like nutrient density, measure the quality of individual foods based on their content in nutrients according to the nutrient profile. These nutrient profiling techniques can also be applied to meal, menus and total diet[26].

Fulgoni et al. (2010) have developed and validated a Nutrient Rich Food (NRF) index, the NRF9.3, using the algorithms with the best predictive relationship with the HEI[27]. The NRF9.3 index is based in nine positive or encouraged nutrients (protein, fibre, vitamins A, C and E, calcium, iron, potassium and magnesium) and three nutrients to limit (saturated fat, added or total sugars and sodium). The sum of percentages of daily values for the nine positive nutrients minus the sum of the percentages of maximum recommended values for three nutrients to limit with all the daily values calculated for 100 kcal or reference amount customarily consumed and capped at 100%.

The NRF index has been analyzed with the NHANES data and an association between the consumption of nutrient dense foods, lower energy intakes, higher diet quality overall and improved health outcomes was found. Diet awarded higher NRF scores were associated with higher HEI values[27]

Nutrients and diet quality

Nutrients found in many scores are total fat, SFA or the ratio of monounsaturated fatty acids (MUFA) to SFA, cholesterol. Protein content and protein quality, complex carbohydrates, mono- and disaccharides, dietary fibre and sodium are also found in various scores[7,10,25].

Fat and fatty acids

The acceptable macronutrient distribution range for total fat intake ranges between 20% and 35% of ener-

gy (E). Total fat intake should be greater than 15%E to ensure an adequate intake of essential fatty acids and energy and to facilitate the absorption of lipid soluble vitamins. While for most individuals engaged in moderate physical activity 30%E is recommended, for those associated with a high physical activity level it can amount to 35%E. The upper value of acceptable macronutrient distribution range should consider energy balance and diet quality. However, high fat intakes are habitually accompanied by increased saturated fat, cholesterol and energy density[28].

The fatty acid composition of the diet is considered to be an important health determinant. Intakes of dietary fatty acids and cholesterol are major determinants of cardiovascular disease (CVD) and type 2 diabetes, two major causes of morbidity and mortality in both developed and developing countries[1]

Intake of SFA is generally recognized to be deleterious, and is included as a single item in the DQI, HEI, Med-DQI, HDI and DGI (Waijers et al, 2007). Higher consumption of MUFA and PUFA has been reported to be associated with reduced CVD risk[28]. There is convincing evidence that replacing SFA (C12:0–C16:0) with MUFA reduces low-density lipoprotein cholesterol (LDL-C) concentration and total/high-density lipiprotein cholesterol (HDL-C)[28]. Hence, the MDS contain 'the ratio MUFA:PUFA' as an index item, whereas the Alternative Healthy Eating Index (AHEI) contains 'the ratio of PUFA:SFA', P:S criterium for minimum score of 0, P:S ≤0.1; criterium for maximum score of 10, P:S ≥1.

There is convincing evidence that *trans* fatty acids (TFA) from commercial partially hydrogenated vegetable oils increase coronary heart disease (CHD) risk factors and CHD events – more so than had been thought in the past[1,28]. There also is probable evidence of an increased risk of fatal CHD and sudden cardiac death in addition to an increased risk of metabolic syndrome components and diabetes. The TFA intake from all sources should be no more than 1%E. Indeed, the TFA content has been considered in a number of DQIs e.g. AHEI and aMED.

There is also convincing evidence that linoleic acid (LA) and alfa-linolenic acid (LNA) are indispensable since they cannot be synthesized by humans and acceptable intakes have been defined for both fatty acids. The minimum intake levels for essential fatty acids to prevent deficiency symptoms are estimated at a convincing level to be 2.5%E LA plus 0.5%E ALA.

Replacing SFA with PUFA decreases the risk of CHD. Based on epidemiological studies and randomized controlled trials of CHD events, the minimum recommended level of total PUFA consumption for lowering LDL-C and total cholesterol concentrations, increasing HDL-C concentrations and decreasing the risk of CHD events is 6%E. Based on experimental studies, risk of lipid peroxidation may increase with high (>11%E) PUFA consumption[28].

The available evidence indicates that 0.5–0.6%E ALA per day corresponds with prevention of deficiency symptoms. The total n-3 fatty acid intake (ALA, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)) can range between 0.5–2%E, whereas the minimum dietary requirement for ALA (>0.5%E) prevents deficiency symptoms in adults. The higher value of 2%E includes the recommendation for ALA and n-3 long chain (LC)-PUFA (Acceptable Macronutrient Distribution Range (AMDR) for EPA and DHA 0.250 g–2.0 g) can be part of a healthy diet. While ALA may have specific properties, there is evidence that the n-3 LCPUFA can contribute to the prevention of CHD and possibly other degenerative diseases associated with aging. For adult males and non-pregnant/non-lactating adult females 0.250 g/day of EPA plus DHA is recommended.

While the total intake of PUFA has been included in some DQIs, the specific intakes of LA, LNA and n-3 LC-PUFA are not specifically considered but some new DQIs have included fish as an important food group as it is a source of n-3 fatty acids

Two processes contribute to the development of ischaemic heart disease: atherosclerosis and thrombosis. The type of dietary fat consumed may contribute to both of these processes, some fatty acids having a greater role in atherogenesis while others have a greater role in thrombogenesis. Of the SFA, only those with a chain length of 12, 14 or 16 C atoms have a cholesterol-raising effect and are thus atherogenic. SFA with a chain length of 14, 16 or 18 C atoms have been suggested to be thrombogenic. Both MUFA and n-6 PUFA have been shown to reduce plasma total cholesterol and LDL-C concentrations and n-3 LC PUFA have minimal effect on plasma cholesterol level but reduce plasma triacylglycerols thromboxane B, and platelet activity and prolong bleeding time and clotting time[1,27,29]. In an attempt to take into account the different effects of the various fatty acids, Ulbricht & Southgate (1991) proposed two indices which might better characterize the atherogenic and thrombogenic potential of the diet than simple approaches such as total SFA or P: S ratio[30].

Atherogenicity index= (l2:0+(4 x l4:0)+ 16:O) / (n-6 PUFA +n-3 PUFA + MUFA)

Thrombogenic index= (14:0+ 16:0+18:0) / [(0.5 MUFA) + (0.5 n-6 PUFA) + (3 n-3 PUFA) + (n-3 PUFA/n-6 PUFA)]

Finally, dietary cholesterol intake has been included in the composition of predefined indices of diet quality e.g. DQI, HEI, HDI.

Protein

The world's population increases rapidly in spite of the constraints of limiting land, water and food resources. Indeed, it is more important than ever to be able to define accurately the amount and quality of protein required to meet human nutritional needs and describe appropriately the protein supplied by food ingredients, whole foods, sole-source foods and mixed diets. The

match between dietary supply and human protein needs is vital to support the health and well-being of human populations.

Proteins play an essential role as structural and functional components of the body. Proteins in food provide amino acids (AA) which are the precursors of nucleic acids, hormones, coenzymes and other essential molecules (DRI, IOM, USA). The human body is not capable of accumulate proteins, and for that reason it is important to have a continual supply to maintain its physiological functions. If this supply is not provided according to the individuals' requirements, the body's development and functions can be compromised[31].

The dietary reference intake for total protein is about 0.8 g/ kg body weight for adults aged more than 19 yr, about 12% of energy intake[32]. Animal sources of protein, including meat, poultry, seafood, milk, and eggs, are the highest quality proteins. Plant proteins can be combined to form complete proteins if combinations of legumes and grains are consumed. Plant-based diets are able to meet protein requirements for essential AA through planning and offer other potential benefits, such as sources of fibre and nutrients important in a health-promoting diet.

The protein quality evaluation aims to determine the capacity of food protein sources and diets to satisfy the metabolic demand for AA and nitrogen. Thus any measure of the overall quality of dietary protein, if correctly determined, should predict the overall efficiency of protein utilization. Safe or recommended intakes can then be adjusted according to the quality measure, so that demands can be met[33]. The protein quality of a mixed diet should have a biological value > 0.7. It is calculated as animal protein + vegetal protein divided by total protein.

There are different methods to determine the protein quality that can be used individually or combined. Although the most important aspect of a protein from a nutritional point of view is its AA composition, the digestibility can influence the bioavailability of AA, and that is why this aspect needs to be taken into account to determine the protein quality.

In order to evaluate the quality of the protein in the diet, it is essential that the AA compositions be accurately determined. In recent years, there have been several advances in this respect and nowadays the methods are very good and standardized[34].

The methods for AA determination consist in two main steps

– Hydrolysis of AA

There are different kinds of hydrolysis according to the AA. a) Hydrolysis for the non-oxidized protein to determine all AA, except for tryptophan, methionine and cysteine; b) Acidic hydrolysis for the non-oxidized protein to determine methionine and cysteine; and c) Basic hydrolysis for the non-oxidized protein to determine tryptophan.

– Separation detection and quantification of AA

After the hydrolysis, separations of the AA need to be done. For this step, an ionic exchange chromatography (IEC) is performed using either a cation exchange resin with a post-column derivatisation [with an AA analyser or a high-performance liquid chromatography (HPLC)] or a pre-column derivatisation followed by a reversed phase-LC.

To be able to detect small differences in protein quality, a strict standardization of the experimental procedures is needed[35]. The biological assays, is a group of standardized methods that are designed in growing animals. Among the most common are the protein efficiency ratio (PER), the net protein retention (NPR), the net protein utilization (NPU) and the biological value (BV).

PER: Osborne et al. developed it in 1919 as a measure of the nutritive value of dietary protein in rats[36]. This method consists on the gain in body weight per gram of the animal according to the protein consumed. This assay requires that the protein in the diet represent the 10% of the macronutrients. The advantages are that PER does not need to do a nitrogen balance experiment and it is easy to carry on[36]. The disadvantages are that the weight gain is in function of the food consumption, it may not be necessary influenced by the dietary protein[36], and it does not make allowance for protein used for maintenance[35].

$$\text{PER} = \text{weight gain of animal (g)/protein consumed by animal (g).}$$

NPR: It was developed by Bender and Doell in 1957 to improve the PER, taking into account the requirement for the maintenance of the animal; as the PER, the protein represents the 10% of the macronutrients in the diet. This method includes a group with a protein-free diet[35,36].

$$\text{NPR} = \frac{\text{weight gain of test animal (g) + weight loss of non-protein group (g)}}{\text{Protein consumed by test animal (g)}}$$

NPU: Bender and Miller developed this method in 1953 to estimate the nitrogen retention in animals[36]. It represents the percentage of ingested nitrogen that is retained in the body and is determined by measuring digestive, metabolic (urinary) and miscellaneous nitrogen losses. NPU values are true or apparent depending on whether the loss of endogenous nitrogen is taken into account or not and this is critical to precisely determine the efficiency of dietary protein utilization and the quality of the different dietary protein sources[37].

$$\text{NPU} = \frac{\text{Ingested N-(Faecal N-Metabolic faecal N) – (Urine N- Metabolic urine N) x 100}}{\text{Ingested N}}$$

BV: K. Thomas Mitchell defined it in 1909 as the fraction of absorbed N retained in the body for maintenance and growth of the animal[36]. It was modified

by HH. Mitchell in 1924[37] and even though it does not take into account the digestibility, it has been widely used. This method as the NPU and NPR includes a protein-free diet group[35,38]. This method might underestimate the metabolic faeces N and urine N, as a free-protein diet is not a normal diet for the animal, and the body has mechanisms to save N.

$$BV = \frac{\text{Ingested N-(Faecal N-Metabolic faecal N)} - \text{(Urine N- Metabolic urine N) x 100}}{\text{Ingested N-(Faecal N-Metabolic faecal N)}}$$

In 1989 the joint FAO/WHO Expert Consultation on Protein Quality Evaluation recommended the use of the Protein Digestibility Corrected Amino Acid Score (PDCAAS) method for evaluating protein quality that included digestibility[39]. In calculating PDCAAS, the limiting AA score (i.e. the ratio of the first-limiting AA in a gram of target food protein to that in a reference protein or requirement value) is multiplied by protein digestibility with the intention of assessing how well dietary protein can match the demand for AA, and allowing the prediction of dietary protein utilisation. The PDCAAS method has now been in use for some 20 years and has proved to be of considerable value in practice. Nevertheless, limitations of PDCAAS have been recognised and debated, and new research findings have accumulated, whereby it has become timely to review the adequacy of PDCAAS and its application vis-à-vis other methods of estimating dietary protein quality.

It was in this context that an FAO Expert Consultation on Protein Quality Evaluation in Human Nutrition was held in Auckland, New Zealand, from March 31 to April 2, 2011[40]. As in previous reports, the primary task of this Consultation was to provide FAO with tools for addressing practical questions on matters such as the adequacy of food supplies, targets for food and nutrition policy and the norms to be applied in labelling and regulation of protein quality for normal populations; as well as providing a perspective on the potential role for protein with respect to health, well-being and clinical conditions at various stages of th e life course.

The key findings and most relevant conclusions of the report are:

- In dietary protein quality evaluation, dietary AA should be treated as individual nutrients and wherever possible data for digestible or bioavailable AA should be given in food tables on an individual AA basis.
- A new protein quality measure (digestible indispensable AA score; DIAAS) is recommended to replace PDCAAS. DIAAS is defined as:
- DIAAS % = 100 x [(mg of digestible dietary indispensable AA in 1 g of the dietary protein) / (mg of the same dietary indispensable AA in 1g of the reference protein)].
- Both ileal and faecal AA digestibility approaches can be subject to important limitations, but it is concluded that on balance ileal protein or AA digestibility, i.e. determined at the terminal ileum at the end of the small intestine, is considered to better reflect the amounts of AA absorbed and should be used in calculating DIAAS. Digestibility should be based on the true ileal digestibility of each AA preferably determined in humans, but if this is not possible, in growing pigs or in growing rats in that order.
- It is recommended that for foods susceptible to damage from processing, 'reactive' rather than 'total' lysine contents and the true ileal digestibility of reactive lysine (lysine availability) rather than of total lysine, be determined and used in the calculation of DIAAS.
- Recommended AA scoring patterns (i.e. AA pattern of the reference protein) to be used for calculating DIAAS are as follows: a) Infants (birth to 6 months), pattern of breast milk; b) Young children (6 months to 3 y), pattern for the 0.5 y old infant; c) Older children, adolescents and adults, pattern for the 3 to 10 y old child, can be found in different Tables of the FAO nº 92 Report[45]. For regulatory purposes two scoring patterns are recommended: the AA composition of human milk for infant formulas, and for all other foods and population groups the pattern for young children (6 months to 3 y)
- In calculating DIAAS the ratio should be calculated for each dietary indispensable AA and the lowest value designated as the DIAAS. DIAAS can have values below or in some circumstances above 100%. Values above 100% should not be truncated except where calculating DIAAS for protein or AA intakes for mixed diets or sole source foods.
- After assessment of the ileal AA digestibility dataset it was concluded that currently, available data are insufficient to support the application in practice (though its use in principle is supported) of true ileal AA digestibility in the calculation of DIAAS. More data on the true ileal AA digestibility of human foods are urgently needed, determined in humans and animal models. More inter-species (human, pig, rat) true ileal AA digestibility comparisons are needed. The report makes recommendations for further research in the area.

Carbohydrates and diet quality

WHO/FAO Expert Consultation[1,41] recommended that total carbohydrate in diet should provide 55–75 % of total energy. In a later update in 2006[42], WHO/FAO Experts recommended the revision of the lower limit suggesting 50 % total energy. In Europe, the European Food Safety Authority[43] proposes a dietary reference

values for total carbohydrates of 45-60 % total energy and in Spain the Spanish Society of Community Nutrition (SENC) recommend 50-60 % total energy[44].

The dietary carbohydrates are a diverse group of substances with a range of chemical, physical and physiological properties. These properties have implications for our overall health; contributing particularly to the control of body weight, diabetes, cardiovascular disease, large bowel cancer, constipation and resistance to gut infection, caries and low micronutrients density. However, the classification of carbohydrates is very complex and need to be discussed. A chemical approach divides carbohydrates into three main groups, sugars (monosaccharides, disaccharides and sugar alcohol), oligosaccharides (malto-oligosaccharides, etc.) and polysaccharides (starch and non-starch). According to a functional approach, carbohydrates can be classified based in physiological or nutritional properties like resistant starch, prebiotics, sugars or dietary fibre. Regarding dietary fibre, now there is a consensus in its definition that must be limited to polysaccharides that are intrinsic to the plant cell wall and not the indigestibility in the small intestine.

To judge the quality of the diet in relation to the content of carbohydrates, it is of vital importance to distinguish between the different types, mainly according to the content of sugars (natural or added) and fibre; glycaemic index and load (GI, GL); refined *vs*. whole grains; fruits and vegetables; and liquids vs. solids carbohydrates. Assessment of carbohydrate quality would have been helpful in drawing meaningful conclusions about the relationship between dietary carbohydrates and health and disease.[45].

Evidence of associations between carbohydrates and diseases comes from epidemiological and clinical studies. Carbohydrates are among the macronutrients that provide energy and can thus contribute to weight gain, overweight and obesity when consumed in excess of energy requirements. On the other hand, a diet with a high content of dietary fibre is associated with relatively low energy density, promotion of satiety and, in observational studies with lesser degree of weight gain than those with lower intakes. There are also evidences about the relationship between dietary carbohydrate and CVD, metabolic syndrome and cancer [46, 47]. Whole-grain cereals, vegetables, legumes and fruits are the most appropriate sources of dietary carbohydrate because they have a high content in dietary fibre and less content in calories.

Recent scientific publications have defined a quality index based on carbohydrates for diet[53,54]. The authors define de Carbohydrate Quality Index (CQI) using the following criteria: Intake of dietary fibre in g/d, glycaemic index, whole grains to total grains ratio and solids carbohydrates to total carbohydrates ratio. Each of the criteria was scored between 1 and 5 according to the quintile categorization. The CQI result from the sum of the four values (ranging between 4 and 20) and categorized in quintiles.

Using this CQI in the SUN cohort[48] the incidence of overweight and obesity showed an inverse association with CQI. These results highlight the importance of the quality and not only de quantity or the percentage of total energy of dietary carbohydrates in the maintenance of body weight. In another study in the same cohort, Zazpe et al. (2014)[49] observed that there is a strong relationship between the CQI and the intake of nineteen micronutrients with relevance in public health. The better micronutrient intake adequacy was observed in the individuals with higher CQI[49].

Other nutrients

At present, many developed and affluent countries consume excessive amounts of sodium and insufficient amounts of potassium. The health consequences of excessive sodium and insufficient potassium are substantial and include increased levels of blood pressure and its consequences (heart disease and stroke). In 2005, the DGAC of the USDA (2010) recommended a daily sodium intake of less than 2300 milligrams for the general adult population and stated that hypertensive individuals[3]. Several specific populations e.g. middle-aged and older adults would benefit from reducing their sodium intake even further to 1500 milligrams per day. Hence, some DQIs have include sodium in their composite score e.g. HEI and DQI

Other minerals like calcium and iron have been considered in some DQIs. Although trace elements and vitamins play essential roles in health, any of the current DQIs have included these substances in their composition. However, it is assumed that consumption of a variety of food groups would results into acceptable intake of these essential compounds

Conclusions and future trends

DQIs are important tools to evaluate the quality of the diet for specific populations not only in terms of intake of nutrients but also in terms of food diversity and moderation. The FINUT pyramid of healthy lifestyles has been recently designed as a new strategy for promoting adequate nutrition and active healthy lifestyles in a sustainable way. Indeed, based on the FINUT pyramid, a global HLI should consider, beyond food groups and nutrients, selected items on food safety e.g. consumption rate of proceed foods, food handling, preparation and storage and access to drinking water, selected food habits, including alcoholic beverage and salt consumption patterns, purchase of seasonal and local foods, home cooking, and conviviality, physical activity, sedentary and rest habits and some selected sociocultural habits, particularly those related to food selection, religious beliefs and socializing with friends, should be included. Figure 2 depicts the items included in this global HLI.

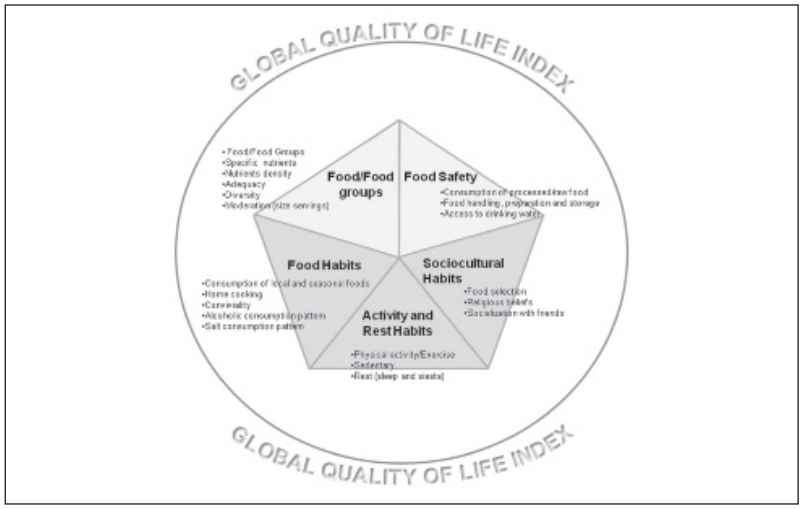


Fig. 2.—Global quality of life index.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

We acknowledge the support of the Instituto de Salud Carlos III del Ministerio de Ciencia e Innovación. Red SAMID RETIC no. RD08/0072.

References

1. World Health Organization. Diet, nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series no. 916, WHO, Geneva, 2013.
2. Lucini D, Zanuso S, Blair S, Pagani M. A simple healthy lifestyle index as a proxy of wellness: a proof of concept. *Acta Diabetol* 2014 Jun 11. [Epub ahead of print].
3. USDA. USDA report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans 2010 [cited 2015 Jan 5]. Available from: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.
4. Gil A, Ruiz-Lopez MD, Fernandez-Gonzalez M, et al. The FINUT healthy lifestyles guide: Beyond the food pyramid. *Adv Nutr* 2014; 5: 358S-67S.
5. Bach-Faig A, Berry EM, Lairon D, et al. Mediterranean Diet Foundation Expert Group. Mediterranean diet pyramid today: science and cultural updates. *Public Health Nutr* 2011; 14: 2274–84.
6. Wengreen H, Munger RG, Cutler A, et al. Prospective study of Dietary Approaches to Stop Hypertension- and Mediterranean-style dietary patterns and age-related cognitive change: the Cache County Study on Memory, Health and Aging. *Am J Clin Nutr* 2013; 98: 1263-71.
7. Fransen HP, Ocké MC. Indices of diet quality. *Curr Opin Clin Nutr Metab Care* 2008; 11: 559-65.
8. Kant AK. Indexes of overall diet quality: a review. *J Am Diet Assoc* 1996; 96: 785-91.
9. Kant AK. Dietary patterns and health outcomes. *J Am Diet Assoc* 2004; 104: 615–35.
10. Waijers PM1, Feskens EJ, Ocké MC. A critical review of predefined diet quality scores. *Br J Nutr* 2007; 97: 219-31.
11. Arvaniti F, Panagiotakos DB. Healthy indexes in public health practice and research: a review. *Crit Rev Food Sci Nutr* 2008; 48: 317–27.
12. Alkerwi A. Diet quality concept. *Nutrition* 2014; 30: 613-8.
13. Kennedy ET, Ohls J, Carlson S, et al. The Healthy Eating Index: design and applications. *J Am Diet Assoc* 1995; 95: 1103-8.
14. Patterson RE, Haines PS, Popkin BM. Diet quality index: capturing a multidimensional behavior. *J Am Diet Assoc* 1994; 94: 57–64.
15. Huijbregts P, Feskens E, Rasanen L, et al. Dietary pattern and 20 year mortality in elderly men in Finland, Italy, and The Netherlands: longitudinal cohort study. *BMJ* 1997; 315: 13–7.
16. Trichopoulou A, Kouris-Blazos A, Wahlqvist ML, et al. Diet and overall survival in elderly people. *BMJ* 1995; 311: 1457-60.
17. Kennedy E. Dietary diversity, diet quality, and body weight regulation. *Nutr Rev* 2004; 62: S78-81.
18. McCullough ML, Feskanich D, Stampfer MJ, et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *Am J Clin Nutr* 2002; 76:1261-71.
19. Fung TT, McCullough ML, Newby PK, et al. Diet quality scores and plasma concentrations of markers of inflammation and endothelial dysfunction. *Am J Clin Nutr* 2005; 82: 163–73.
20. Haines PS, Siega-Riz AM, Popkin BM. The Diet Quality Index revised: a measurement instrument for populations. *J Am Diet Assoc* 1999; 99: 697-704.
21. Gerber M. Qualitative methods to evaluate Mediterranean diet in adults. *Public Health Nutr* 2006; 9: 147-51.
22. Trichopoulou A, Costacou T, Bamia C, et al. Adherence to a Mediterranean Diet and Survival in a Greek Population. *N Eng J Med* 2003; 348: 2599-608.
23. Schröder H, Fitó M, Estruch R, et al. A short screener is valid for assessing Mediterranean diet adherence among older Spanish men and women. *J Nutr* 2011; 141: 1140–5.
24. Estruch R, Ros E, Salas-Salvadó J, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. *N Engl J Med* 2013; 368: 1279-90
25. Sotos-Prieto M, Moreno-Franco B, Ordovás JM, et al. Design and development of an instrument to measure overall lifestyle habits for epidemiological research: the Mediterranean Lifestyle (MEDLIFE) index. *Public Health Nutr* 2014; 15: 1-9
26. Drewnowski A, Fulgoni VL. Nutrient density: principles and evaluation tools. *Am J Clin Nutr* 2014; 99 (Suppl 5): 1223S-8S.
27. Fulgoni VL, Keast DR, Drewnowski A. Development and Validation of the Nutrient-Rich Foods Index: A Tool to Measure Nutritional Quality of Foods. *J Nutr* 2009; 139: 1549–54.
28. Food and Agriculture Organization of the United Nations (FAO). Fat and fatty acids in human nutrition. Report of an Expert Consultation. Food and Nutrition Paper nº.91, Rome, 2010.
29. Fehily AM, Pickering JE, Yarnell JW, et al. Dietary indices of atherogenicity and thrombogenicity and ischaemic heart disea-

se risk: the Caerphilly Prospective Study. *Br J Nutr* 1994; 71: 249-57.
30. Ulbricht LV, Southgate DAT. Coronary heart disease: seven dietary factors. *Lancet* 1991; 338: 985-92
31. Boye J, Wijesinha-Bettoni R, Burlingame B. Protein quality evaluation twenty years after the introduction of the protein digestibility corrected amino acid score method. *Br J Nutr* 2012; 108 (Suppl 2): S183-211.
32. Institute of Medicine (IOM). Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). National Academy Press. 589-611, Washington, 2005.
33. FAO/WHO-UNU. Energy and Protein Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation, WHO Technical Report Series no.724, Geneva: WHO, 1985.
34. Otter DE. Standardised methods for amino acid analysis of food. *Br J Nutr* 2012; 108 Suppl 2: S230-37.
35. AOAC Official Methods of Analysis of the Association of Official Analytical Chemists International 17th edition. Section 45.3.04 (AOAC Official Method 960.48, Protein Efficiency Ratio), section 45.3.05 (AOAC Official Method 982.30, protein Efficiency Ratio, Calculation Method) section 45.3.06 (AOAC Official Method 991.29; True Protein Digestibility of Foods and Food Ingredients, Rat Bioassay), section 45.4.04 (AOAC Official Method 988.15, Tryptophan in Foods and Food and Feed Ingredients), section 45.4.05 (AOAC Official Method 985.28, Sulfur Amino Acids in Food and Feed Ingredients, Ion-Exchange Chromatographic method: Extension to Processed Foods). Gaithersburg, Maryland: Association of Official Analytical Chemists International, 2000
36. Wu, G. Amino acids: biochemistry and nutrition. Taylor & Francis Group. Pp. 452-454, Boca Raton, Fl, 2013.
37. Tome D. Criteria and markers for protein quality assessment - a review. *Br J Nutr* 2012; 108 (Suppl 2): S222-9.
38. Bender, David A. Amino Acid Metabolism. Third edition. John Wiley and Sons Ltd. pp.417, Hoboken, NJ, 2012.
39. FAO/WHO Protein Quality Evaluation: Report of the Joint FAO/WHO Expert Consultation, FAO Food and Nutrition Paper 51. Rome: FAO, 1991.
40. Food and Agriculture Organization of the United Nations (FAO). Dietary protein quality evaluation in human nutrition. Report of an Expert Consultation Series nº 92. FAO, Rome, 2013
41. Food and Agriculture Organization of the United Nations (FAO). Carbohydrates in Human Nutrition. Report of a Joint FAO/WHO Expert Consultation. (FAO Food and Nutrition Paper – 66). Rome, 1988.
42. Mann J, Cummings JH, Englyst HN, et al. FAO/WHO scientific update on carbohydrates in human nutrition: conclusions. *Eur J Clin Nutr* 2007; 61 Suppl 1: S132-7.
43. European Food and Safety Authority (EFSA). Panel on Dietetic Products, Nutrition, and Allergies (NDA); Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. EFSA Journal 2010; 8:1462 [77 pp.].
44. SENC. Objetivos nutricionales para la población española. Consenso de la Sociedad Española de Nutrición Comunitaria 2011. *Rev Esp Nutr Com* 2011; 17: 178-9.
45. Roberts CK, Liu S. Carbohydrate intake and obesity: an association that needs "refining". *J Am Diet Assoc* 2009; 109: 1163-4.
46. Schulze MB, Hu FB. Dietary Approaches to Prevent the Metabolic Syndrome. *Diabetes Care* 2004; 27: 613–4.
47. Gaesser, GA. Carbohydrate quantity and quality in relation to body mass index. *J Am Diet Assoc* 2007; 107: 1768–80.
48. Santiago S, Zazpe I, Bes-Rastrollo M, et al. Carbohydrate quality, weight change and incident obesity in a Mediterranean cohort: the SUN Project. *Eur J Clin Nutr* 2014; doi: 10.1038/ejcn.2014.187
49. Zazpe I, Sánchez-Taínta A, Santiago S, et al. Association between dietary carbohydrate intake quality and micronutrient intake adequacy in a Mediterranean cohort: the SUN (Seguimiento Universidad de Navarra) Project. *Br J Nutr* 2014; 111: 2000–9.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):145-154
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Immunonutrition: methodology and applications

Belén Zapatera, Andreu Prados, Sonia Gómez-Martínez and Ascensión Marcos

Immunonutrition Research Group. Department of Metabolism and Nutrition, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), Madrid. Spain.

Resumen

La Inmunonutrición es una materia emergente e interdisciplinar, ya que abarca distintos aspectos relacionados con la Nutrición, la Inmunidad, la Infección, la Inflamación y la Injuria o daño tisular, lo que se ha denominado como la Nutrición y las 4 "Ies". En estas interacciones se encuentran implicados los sistemas endocrino, nervioso e inmune, formando parte la microbiota de este último. Actualmente la microbiota intestinal tiene un papel fundamental no solo a nivel del tracto gastrointestinal sino que presenta además un eje de conexión bilateral con el sistema nervioso

Para el estudio de la Inmunonutrición existen diferentes biomarcadores del sistema inmune que proporcionan información acerca del estado nutricional del individuo. Sin embargo, se debe tener en cuenta que no existe un solo parámetro para evaluar la relación causa-efecto de la nutrición sobre el sistema inmunitario, sino que es un conjunto de biomarcadores a tener en cuenta dependiendo de los distintas situaciones nutricionales.

Si bien está claro que se trata de una materia multidisciplinar, no solo se deben focalizar los estudios sobre las interacciones entre la nutrición y el sistema inmune de manera aislada, sino sobre otros sistemas del organismo teniendo en cuenta un gran abanico de factores de confusión y determinantes derivados de las condiciones idiosincrásicas de cada individuo, su genética y su estilo de vida.

Por todo ello, la Inmunonutrición permite llevar a cabo una serie de estudios basados fundamentalmente en cuatro líneas de investigación: 1) Evaluación de poblaciones supuestamente sanas pero con riesgo de malnutrición (niños, adolescentes, adultos, gestantes, lactantes, personas mayores y deportistas), 2) Estudio de la evolución de pacientes con enfermedades relacionadas con la nutrición y el sistema inmunitario, 3) Estudio de los efectos de nutrientes, compuestos bioactivos y alimentos convencionales y funcionales sobre el sistema inmunitario; 4) Estudio del impacto del estilo de vida sobre el comportamiento del sistema inmunitario, teniendo como determinantes principales la dieta, el comportamiento alimentario, la actividad física, el sedentarismo, la calidad y cantidad de sueño, y como factor clave, el estrés.

(*Nutr Hosp* 2015;31(Supl. 3):145-154)

DOI:10.3305/nh.2015.31.sup3.8762

Key words: *Diet. Food. Food habits. Health. Lifestyles. Nutrients.*

Correspondence: Ascensión Marcos.
Immunonutrition Research Group. Department of Metabolism and Nutrition, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC).
José Antonio Novais Street 10, 28040 Madrid, Spain.
E-mail: amarcos@ictan.csic.es

INMUNONUTRICIÓN: METODOLOGÍA Y APLICACIONES

Abstract

Immunonutrition is an emergent and interdisciplinary subject, since it comprises several aspects related to Nutrition, Immunity, Infection, Inflammation, and Injury or tissue damage, what is known as Nutrition and 4 "Is". Within these interactions the endocrine, nervous and immune systems are involved, microbiota being a part of the last one. Nowadays, gut microbiota has been shown to play an essential role, not only in the gastrointestinal tract but also into the nervous system, because of its bilateral connection.

There are several methods to study Immunonutrition, which allow measuring different immunological biomarkers to provide information about the nutritional status. However, it should be taken into account that there is not a single gold standard parameter to evaluate the cause-effect relationship between nutrition and the immune system. On the contrary, a combination of biomarkers have to be assessed depending on the different nutritional situations.

Since Immunonutrition is a multidisciplinary matter as mentioned above, the study on the interactions between nutrition and the immune system has not been exclusively focused as such, but bearing in mind other systems of the organisms as well as a wide range of confounding factors and determinants coming from idiosyncratic features, genes and lifestyle of each individual.

Therefore, Immunonutrition allows to study the following research fields: 1) Evaluation of nutritional status in presumably healthy people with risk of malnutrition (children, adolescents, adults, pregnant women, elderly, and sportspeople); 2) Assessment of the evolution and progress of patients with nutrition and immune-related diseases, such as food allergies, eating and metabolic disorders; 3) Evaluation of the effects of nutrients, bioactive compounds and both conventional and functional foods on the immune system; 4) Evaluation of impact of lifestyle determinants on the immune system, such as diet, food behaviour, physical activity, sedentariness, sleep quality and quantity, and as a key factor, stress.

(*Nutr Hosp* 2015;31(Supl. 3):145-154)

DOI:10.3305/nh.2015.31.sup3.8762

Palabras clave: *Immunonutrition. Biomarkers. Microbiota. Lifestyle. Malnutrition.*

Abbreviations

ICTAN: Institute of Food Science, Technology and Nutrition.
CSIC: Spanish National Research Council.
NK cells: natural killer cells.
Th: T helper.
PEM: protein-energy malnutrition.
DHST: delayed hypersensitivity skin test.
Ig: immunoglobulins.
LPS: lipopolysaccharide.
CRP: C-reactive protein.
hs-CRP: highly sensitive C-reactive protein.
PBMCs: peripheral blood mononuclear cells.
MALT: mucosa-associated lymphoid tissue.
GALT: gut-associated lymphoid tissue.
BALT: bronchial-associated lymphoid tissue.
NALT: nasopharynx-associated lymphoid tissue.
VALT: vulvovaginal-associated lymphoid tissue.
LDALT: lacrimal drainage-associated lymphoid tissue.
EVASYON: Development, implementation and evaluation of the efficacy of a therapeutic programme for overweight/obese adolescents.
BMI: Body Mass Index.
TL: telomeres.
CVDs: cardiovascular diseases.

State of the art: nutrition and immunity

The Immune System

The immune system is a complex defence network that protects body against potentially harmful agents and has the capacity to respond to millions of antigens. Through orchestrated reactions, that is, the immune response, the immune system can recognize and remove pathogens[1]. It serves to distinguish "non-self" from "self" and acts to ensure tolerance of "self", food and other environment components and commensal bacteria inherent in the body. However, any mistake or alteration in tolerance pathways may lead to an immunological disordered process. Although there are plenty of factors involved in the aetiology of disease, most conditions are related to the immune system, they frequently being infectious, inflammatory, or autoimmune processes[1]. In the last few years, research keeps confirming how an inappropriate inflammatory response actually plays a crucial role in the onset, progression and severity of many chronic conditions such as Alzheimer's disease, heart attacks, obesity, cancers or autoimmune pathologies (different types of allergies, psoriasis, systemic lupus erythematosus, Crohn's disease, celiac disease, multiple sclerosis, or rheumatoid arthritis)[1,2].

Briefly, the immune system comprises three levels of defence: anatomical and physiological barriers, the innate or unspecific immunity and the adaptive or specific immunity (also termed acquired)[1,3,4]. Physicochemical barriers include intact skin, ciliary clearance in respiratory tract, mucosal membranes, lysozyme in tears and saliva, stomach acid, and commensal microbiota in skin, mouth, gastrointestinal tract and genitourinary tract[4]. After infectious agents and other noxious insults have crossed this first line of defence, the immune system establishes active defence mechanisms which could be divided into two categories: the innate and the adaptive immune responses. Both immune responses include several blood-borne factors or soluble components and cells (Table I). The innate immune response represents the first defensive system in the organism, and it is particularly important for preventing the entry of infectious agents into the body and, if they enter, eliminating them rapidly[3,4]. The innate immune system includes cells (granulocytes -neutrophils, basophils, and eosinophils-, monocytes/macrophages, and natural killer -NK- cells), and soluble factors[1,3,4] (Table I). Innate immunity has no memory and is therefore not influenced by prior exposure to an organism[4]. This response is activated by any strange substance penetrating the organism, which will be eliminated by mechanisms of phagocytosis and cytotoxicity[1]. Although this first barrier represents a good defensive system, it is sometimes not sufficient to protect the organism, and thus the adaptive immune response is required. This response is more complex and sophisticated and its key feature is to be specifically effective for those antigens that triggered the response[4]. The adaptive response beco-

Table I
Components of the innate and adaptive immune system

	Innate immunity	*Adaptive immunity*
Cellular components	Granulocytes: neutrophils, basophils and eosinophils Monocytes/macrophages Mast cells Natural killer cells	B lymphocytes (B cells) T lymphocytes (T cells): T cytotoxic, T helper (T_h1, T_h2) cells
Soluble components	Complement factors Acute phase proteins Macrophage-derived cytokines	Antibodies Lymphocyte-derived cytokines

mes effective over several days after the initial activation, but it also persists for some time after the removal of the initiating antigen[4]. This persistence gives rise to immunological memory, which is the basis for a stronger, more effective immune response on reexposure to an antigen[4]. The adaptive response is mainly mediated by lymphocytes and classified into two types: humoral and cellular (Fig. 1). In general terms, the humoral response involves mainly B lymphocytes while T cells are in charge of the cell-mediated immune response[3,4]. Humoral immunity deals with extracellular pathogens, whereas cell-mediated immunity is directed towards intracellular pathogens -viruses and some bacteria-, which escape humoral immunity[4]. Both responses are linked and together result in a highly effective antigen-driven specific immune response. T helper (Th lymphocytes are characterized by their capacity to produce cytokines and participate in the initiation and development of the immune response. Th1 cells promote the cell-mediated immune response while Th2 stimulate the humoral response[1,3]. The innate and adaptive systems are communicated by direct cell-to-cell contact involving cell surface proteins (e.g., adhesion molecules) and by the production of chemical messengers such as cytokines[3]. On the other hand, gut microbiota do not only have a role as a physical barrier, but also interacts dynamically with both the intestinal innate and adaptive immune system, affecting various aspects of its development and function and therefore microbiota is a part of the immune system that should be taken into account to evaluate the nutritional status[5]. (Table I and Fig. 1).

Interest of immunonutrition

Relationships between nutrition and immunity

It is well-known that adequate nutrition is an important factor allowing the normal development of the immune system as well as its correct function throughout life, although the study of the relationship between nutrition and immune function is relatively recent. Immunonutrition is the science that studies interactions between nutrition and Immune system, Infection, Inflammation and Injury or tissue damage. Thus, Immunonutrition is also known as Nutrition and 4 "Is". Malnutrition is a condition that occurs when a person's diet does not contain the right amount of nutrients and can refer to both undernutrition and overnutrition. Traditionally, the study of the interaction between nutrition and infection (as *"the first I"*) has included the role of infection in defining nutritional status and the role of nutrition in determining host defence mechanisms[6]. The 1968 *World Health Organization* monograph about "Interactions between Nutrition and Infection" presented the mechanisms linking infection and poor nutritional status. Following the development of immunology as a science, increasing evidence was obtained as well to show how undernutrition may impaire resistance to infections and the immune response[7].

In fact, nutrients play an important role in the development and functionality of the immune system and any deficiency, either single or multiple, is often the cause of a compromised immunity. The understanding that protein-energy malnutrition (PEM) is not only

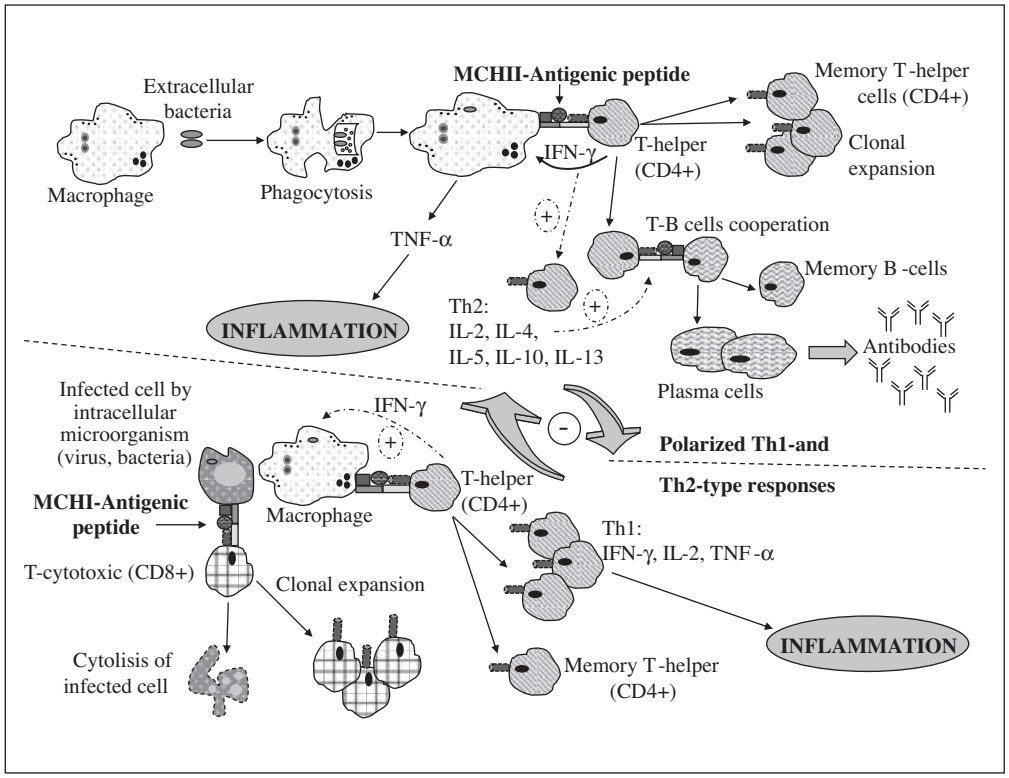


Fig. 1.—Schematic view of the adaptive immune response. Adapted from Marcos A, Nova E, Perdigón G, de Moreno A. Nutrición e Inmunidad. En: Nutrición y Salud Pública. Métodos, Bases Científicas y Aplicaciones. 2ª ed. Serra Ll, Aranceta J, Mataix J, eds. Barcelona: Masson; 2006. p.482-90.

protein and energy but also involves insufficiencies in the cellular supply of multiple micronutrients, serves to highlight the importance of specific micronutrients (vitamin A, Fe, Zn, and Cu) and their respective carrier proteins on specific and non-specific components of the immune response[6]. This knowledge led to the need to include immunity as the link within the relationship between nutrition and infection (*"the second I"*)[6]. Afterwards, the discovery that several nutrients, such as tocopherol, retinol, zinc and essential fatty acids, could modulate the intensity of the responses that define inflammatory process opened a field on the potential influence of nutrition on inflammatory processes[6]. The potential health gains from modulating the balance between n-3 and n-6 fatty acid intake paved the way for the inclusion of inflammation as *"the third I"* in the relationship between nutrition and infection[6]. Finally, the consideration that nutrients also modulate injury as an end point of hypoxic or toxin mediated cell damage led to include injury as *"the fourth I"*[6].

Controversies and limitations

As was mentioned before, study of immunological parameters allow helping to know the nutritional status of apparently healthy people. These parameters are not usually used in epidemiological studies, and their use is commonly limited by the necessity of experts on immunology who can correctly interpret the results, also of specialized laboratories and techniques, and the high costs of immunological tests[8]. In addition, it is important to highlight that no single biomarker is capable to predict malnutrition status and therefore it should be necessary to assess several biomarkers and their relationship with the nutritional status[9]. In this context, techniques should be standardized and based on updated laboratory protocols. It is also necessary to kick-off all the instruments.

There are several *In vivo* studies that are not possible to being performed in alive subjects because they use aggressive challenges. However, the evaluation of *in vivo* immune function can be determined through animal models or even by using analysis such as vaccines or delayed hypersensitivity skin tests (DHST)[9].

The immune system is affected by a variety of subject-specific and technical factors, which should be strictly controlled in order to reduce the variation in the outcome of immunological measurements (Table II). Furthermore, genetic polymorphisms, early life events, hormone status, and gut microbiota may be additional factors contributing to such variation. In addition, ethical constraints may restrict the use of specific markers in certain populations[9] (Table II).

With the aim to evaluate nutritional status through immunological parameters in human studies it is important to consider several aspects. First of all, the number of subjects should be sufficient in order to have strong statistical power and to extrapolate the outcomes to the general population[6]. In human nutritional studies there are several confounding factor that should be considered and they are: stress, physical activity/exercise, sleep time (quality/quantity), and food behaviour[9]. Besides, human studies are often limited by the ability to take samples, usually blood and external secretions such as saliva, tears or urine. In addition, normal ranges and reference values for immune cell number and function in specific populations (children, pregnant women, elderly, sports people, etc.) are not still well defined[3] (Fig. 2).

Moreover, studies should allow identifying changes in the prevalence of side effects. In addition, the design of the study should be randomized, double-blind, cross-over or parallel with adequate inclusion and exclusion criteria[6]. The final objective of the study should consider other aspects apart from adequate nutrition, in order to have an impact on overall health, reduction of both comorbidities and risk of mortality, and socio-economic determinants of life quality.

Table II
Confounding subject-specific and technical factors modulating immune function in human studies[10]

Subject-specific factors	*Technical factors*
Age	Selection of the population and appropriate controls to be evaluated and compared with
Sex (hormones, menstrual cycle)	Time of sample collection (circadian rhythm)
BMI	Seasonality
Background diet and nutrient supplementation before and during intervention	Time since last meal (fasting period)
Physical activity and exercise	Use of washout periods
Smoking	Length of intervention period
Hydration status	Appropriate selection of immunological biomarkers
Genetics (low/high responder)	Correct interpretation of the outcome by experts on Immunonutrition
Presence of infections or other diseases	
Psychological stress	
Sleep deprivation	
Alcohol, drug and medications	
Vaccination and infection history	

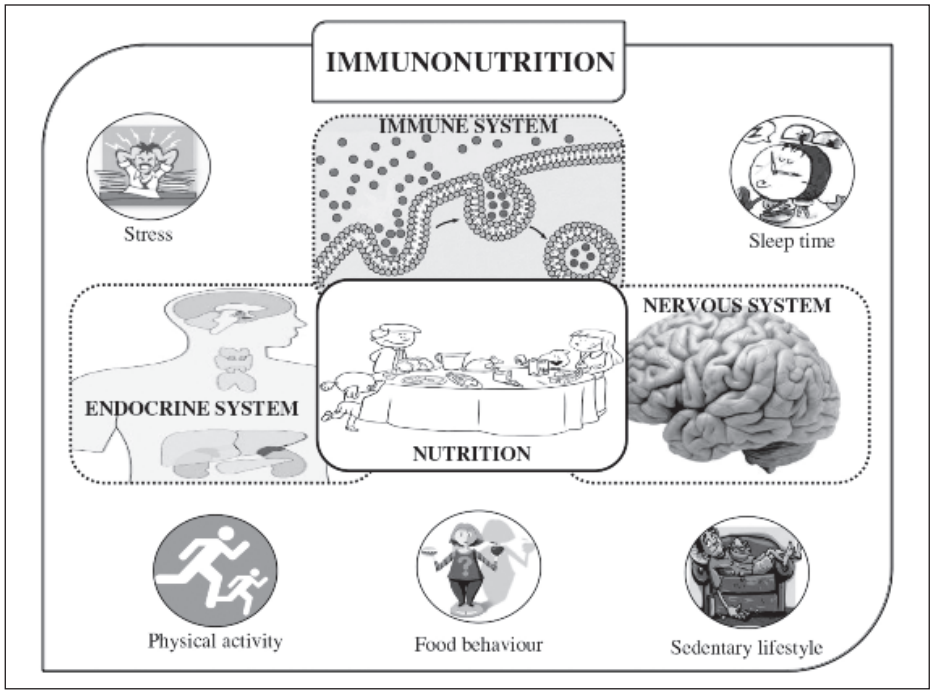


Fig. 2.— Confounding factors that should be taken into account in immunonutrition studies.

Current status and perspectives

The assessment of immunological parameters can point towards a subclinical malnutrition status and therefore acquires great interest as a useful tool to evaluate the nutritional status. When analysing immune parameters, it is necessary to bear in mind the complex interactions and reciprocal control among the immune system, the endocrine system and the central nervous system, as already cited above[10].

Tissues and organs

Malnutrition may lead to decreased cellular proliferation, decreased of protein synthesis, and deficiency of nutrients involved in metabolic pathways. These alterations can modify the immune response by affecting lymphoid tissues and immune cell number and function[11]. Specifically, protein-energy malnutrition (PEM) produces generalized atrophy of lymphoid tissues. In these situations, thymus, spleen, tonsils, Peyer's patches, and lymphatic nodes are seriously affected, with histological evidence of significant specific atrophy in T lymphocyte areas affecting mainly the adaptive immune system[12].

Circulating factors

Molecules

Immunoglobulins (Ig)

Immunoglobulins are proteins found in different fluids in the organism including blood and secretions such as saliva, tears, and breast milk. They are produced by plasma cells and their main function is to recognize the antigens or strange substances in order to neutralize them. Immunoglobulins (Ig) are also known as antibodies and there are five primary types of them (IgG, IgA, IgM, IgD and IgE) and each type has different isotypes (IgG1, IgG4…). Their determination could be possible through different immunoassays (ELISA, ELISPOT, standard analysis by nephelometry). Concentration of these antibodies in blood allows analysing basal status of any subject. However, the study of Ig concentrations after stimulation (in *ex vivo* cultures induced by a mitogene such as lipopolysaccharide (LPS) or *in vivo* with a specific antigen) allows getting more information about the response capacity of B cells.

Acute-phase proteins: C-reactive protein, complement factors C3 and C4 and ceruloplasmin

C-reactive protein (CRP) is a very sensitive marker of inflammation, and its concentration increases rapidly in response to a wide range of stimuli. Belonging to the innate immune response, high CRP levels have no specificity in differentiating disease entities from one another, but despite its lack of specificity, CRP has now emerged as one of the most powerful predictors of cardiovascular risk. Indeed, CRP is usually increased in overweight/obese people, as obesity involves a low-grade chronic inflammation state not only in adults, but also in children[13].

Regarding complement factors C3 and C4 and ceruloplasmin, these are proteins that strongly predict cardiovascular events in adults. Complement factors C3 and C4 are part of the innate immune system and

stimulate phagocytosis of foreign components and active some inflammatory processes in the organism. On the other hand, ceruloplasmin is another protein produced in the liver during the acute phase response. It is a major plasma protein and functions as a copper transporter. However, its high levels are associated with atherosclerosis. C3, C4, highly sensitive CRP (hs-CRP), and ceruloplasmin are measured in serum by using immunoturbidimetry[13].

In a representative sample of Spanish adolescents aged 13-18.5 years from the AVENA study, CRP, C3, and C4 levels were correlated with central obesity. Particularly, we found that central obesity is independently associated with C3 concentrations[13].

Concentrations of cytokines or of soluble cytokine receptors

Cytokines can be affected by malnutrition, both undernutrition and overnutrition. They can be classified as pro-inflammatory (IL-1, IL-6, TNF-a) and anti-inflammatory (IL-2, IL-4, IL-10). An excess of body fat have not an observed effect on the capacity of leukocytes for *in vitro* production of IL-6 and TNF-a in a sample of Spanish adolescents in the AVENA Study[13]. Conversely, in anorexia nervosa patients, the production of TNF-a and IL-6 was lower while the secretion of IL-1b was higher than in the control group when these levels were compared before and one month after admission to the hospital. This outcome could suggest that the immune function in anorexic patients could be preserved despite their severely malnourished condition[14]. In our group, he have found that excess weight and inadequate sleep duration are independently associated with the incidence of allergy symptoms in adolescents. Adequate sleep duration and weight during adolescence might be relevant for a decreased risk of suffering allergy symptoms[15].

The production of cytokines by lymphocytes and monocytes usually requires these immunocompetent cells to be stimulated by a mitogen such as phytohemagglutinin or bacterial lipopolysaccharide. Moreover, the spontaneous production of cytokines can also be measured by peripheral blood mononuclear cells (PBMCs). Cytokine protein concentrations in the cell culture medium are measured by ELISA or flow cytometry.

Actually, it is very useful the determination the soluble cytokine receptors in biological samples through immunoassays.

Immunocompetent cells

Neutrophils and monocytes counts and functionality

Neutrophils and monocytes are the main phagocytic cells and their counts help understand how is the immune system response to an infection. In order to complete the study, it is necessary to know not only their counts, but also their functionality. Only in extreme cases, such as severe denutrition, leukocyte counts themselves are physiological relevant. Thus, it is important to be familiarized with the significance of their normal reference values.

Total lymphocyte counts

Total lymphocyte count is a measure of nutritional status. Total lymphocyte normal range is over 2.000 cells/mm^3. When it is between 1.200 and 2.000 cells/mm^3 indicates mild denutrition; 800-1.200 cells/mm^3 reflects moderate denutrition and counts under 800 cells/mm^3 represents severe denutrition[16].

Lymphocyte subsets counts

Phenotypic analysis by flow cytometry allows define different types of lymphocytes. Furthermore, it gives information about redistribution of immunocompetent cells caused by several factors such as fasting and refeeding[15]. Study of lymphocyte subsets include: mature T-cells (CD3+), helper T-cells (CD4+), cytotoxic or suppressor (CD8+), natural killer (NK) cells (CD3-CD16+ CD56+), B-cells (CD19+), naïve and memory cells (CD45RA+ and CD45RO+, respectively). This analysis allows distinguish between active subsets using different markers such as CD69+, in order to be used in the functionality of the immune system. The ratio CD4+/CD8+is an index of nutritional status that reflects immunodeficiency secondary to malnutrition states[17,18]. A sleep duration of 8-8.9 h/night was associated with a healthier immune profile in European adolescents[19].

Immune system functionality

In vivo measures

Vaccines

Vaccination responses are widely used in immunonutrition studies in the human population and allow high quality information about their immunomodulatory effects on the immune response. Vaccination responses may be influenced by a variety of factors other than environmental ones and they include psychological stress, nutrition, and (infectious) diseases, and lifestyle determinants (e.g., smoking)[20].

Delayed hypersensitivity skin test (DHST)

DHST is based on the reaction that occurs in response to the intradermal injection of an antigen (e.g., tuberculin). The histologic findings and immunologic mechanisms characterizing this form of immunologic response are based on mobilization of macrophages and other phagocyte cells causing an increased lymphocyte response. This measurement is useful because it represents a coordinated, integrated cell-mediated immune response to a relevant challenge. However, the test cannot be

repeated on the same are of skin, and recent vaccination may interfere with the outcome[3].

Ex vivo measures

Ex vivo measures allow the functional responses of specific immune cell types to be determined[3].

Phagocytosis by neutrophils and monocytes

Substrates for phagocytosis can be studied in the opsonized (i.e., complement- or antibody-coated) and unopsonized states. Some techniques (e.g., flow cytometry) allow identification of both the number of cells participating in phagocytosis and the phagocytic activity per cell[3]. Measures of phagocytosis can be coupled to measures of oxidative burst.

Oxidative (respiratory) burst (superoxide generation) by neutrophils and monocytes

Oxidative burst studies the percentage and activity of phagocytic cells (neutrophils and monocytes). Reactive oxygen species such as hydrogen peroxide are measured. This technique can oriented research on innate immune mechanisms and inflammation[3].

Chemotactic response of neutrophils or monocytes

This is the movement of these cells toward particular stimuli; stimuli used include leukotriene B4, and bacterial cell wall peptides[3].

Natural killer cell activity

NK cells induce direct cytotoxicity or secretion of cytokine/chemokine without recognizing a specific antigen as B and T cells. NK cytotoxicity acts against virus-infected cells and tumour cells[22].

NK cells activity is one of the most sensitive functions affected by diet. It can be due to the fact that NK cells are high dependent on cytokines. Killing can be expressed in various ways, such as percentage target cells killed or "lytic ratio", which is the ratio of killer to target cells required to kill a particular percentage of target cells[3].

Lymphocyte proliferation

This is the increase in number of lymphocyte in response to a stimulus. Most often this is measured as the incorporation of radioactively labelled thymidine into the DNA of the dividing lymphocytes, although a number of other measures, not involving the use of radioactivity, are available[3].

Measures of mucosal immune responses

The collectively called mucosa-associated lymphoid tissue (MALT) is found along mucosal linings in the human body and constitutes the most extensive component of human lymphoid tissue. These surfaces protect the body from an enormous quantity and variety of antigens. MALT includes gut-associated lymphoid tissue (GALT), bronchial-associated lymphoid tissue (BALT), nasopharynx-associated lymphoid tissue (NALT), vulvovaginal-associated lymphoid tissue (VALT), and lacrimal drainage-associated lymphoid tissue (LDALT)[23]. The basic architecture of MALT includes discrete areas where B lymphocytes are localized next to areas in which T lymphocytes predominate. Lymphoid tissues of MALT have the ability to concentrate and respond to local antigens. Concentration of total and antigen-specific secretory IgA is a useful measure of mucosal immune responses[3].

GALT accounts for up to 80% of the mucosal immune system and is distributed along the intestine in two forms: as organized GALT, which includes Peyer's patches, isolated follicles and mesenteric lymph nodes, and as diffuse GALT, consisting of lymphocytes scattered in the epithelium and the lamina propria. Both compartments are part of a regulatory system with specific roles; organized GALT is the inductor site of the immune response and diffuse GALT is the effector site. GALT has a role in both innate and acquired immune responses. Another component of the mucosal immune system consists of regulatory T-cells, which mediate peripheral T-cell tolerance to antigens derived from the dietary origin or from the commensal microbiota. Systemic immune system biomarkers can be found in lamina propria and they can be studied by the same methods mentioned before [23].

Microbiota

A healthy gut microbiota may be viewed as a positive attribute, while dysbiosis (gut microbiota alteration) is associated with altered health states. The current understanding of the gut microbiota provides information essential for efficiently dealing with well-being and diseases such as obesity, the metabolic syndrome, food intolerance, inflammatory bowel disease and irritable bowel syndrome. Furthermore, the central nervous system is also affected through gut-brain communication pathways[24] (Fig. 3).

In human studies, gut microbiota could act as a biomarker to assess dietary and lifestyle interventions. In the comprehensive programme EVASYON (Development, implementation and evaluation of the efficacy of a therapeutic programme for overweight/obese adolescents), which includes diet, physical activity and psychology interventions in 13-16 years old overweight adolescents after intervention there were two groups: low weight-loss (< 2 kg) and high weight-loss (> 4 kg) group. We observed that intervention were only successful in the high weight-loss group, maybe due to a different microbiota between both groups. Therefore, individual's gut microbiota

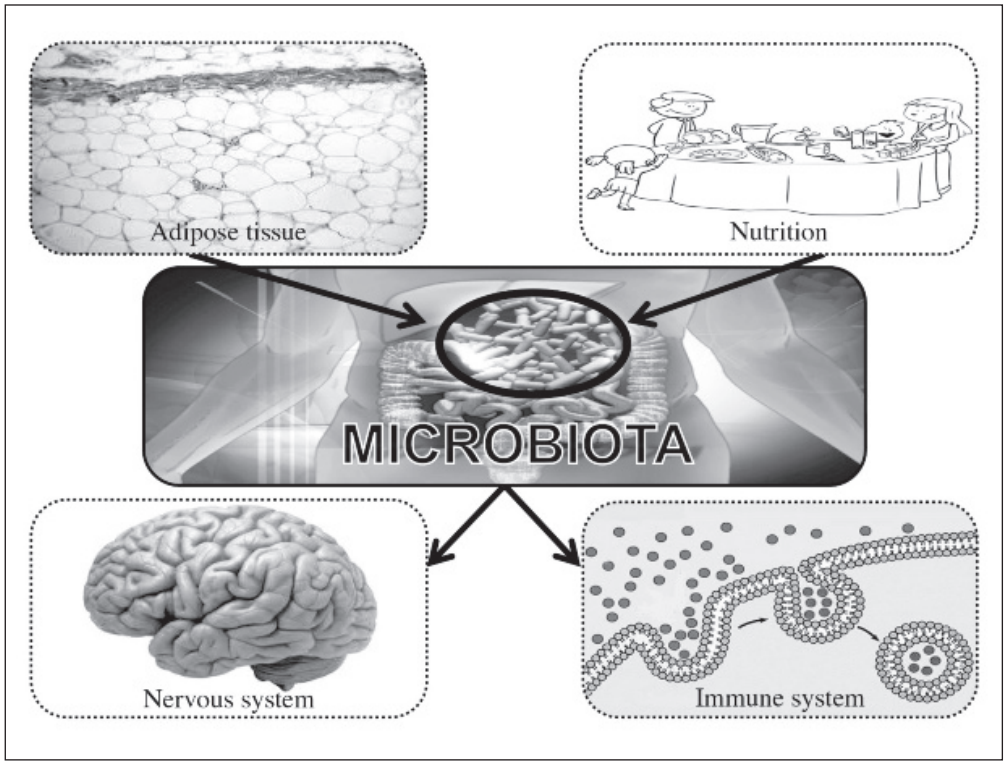


Fig. 3.— Interrelationships between confounding factors and microbiota.

composition is more important to achieve weight loss than expected[25]. On the other hand, childhood microbial colonization patterns are different depending on maternal Body Mass Index (BMI). This evidence suggests that microbiota may act as a marker to predict the possible risk of obesity[26].

In addition, the interaction of gut microbiota with immune cells in the mucosal environment has a principal role in a number of processes directly dependent on the MALT, such as oral tolerance induction, the modulation of cytokine and chemokine release and, in general, the regulation of immune responses in the intestinal mucosa which are important in the pathogenesis of inflammatory bowel disease[27].

Genetics

Nutritional genomics has tremendous potential to change the future of dietary guidelines and personal recommendations. Nutritional genomics covers nutrigenomics, which explores the effects of nutrients on the genome, proteome and metabolome, and nutrigenetics, the major goal of which is to elucidate the effect of genetic variation on the interaction between diet and disease[28].

Epigenetics refers to the study of changes on heredity patterns of gene expression that occur without changes in the DNA sequence. In recent years, epigenetic markers emerged as a new tool to understand the influence of lifestyle factors on obesity phenotypes. Indeed, we have seen in EVASYON study that methylation changes may help to better understand the weight loss response in obese adolescents[29]. Secondly, telomeres (TL) are biomarkers of biological aging. Shorter telomeres have been associated with increased adiposity in adults but we found that a weight loss intervention is accompanied by a significant increase in TL in overweight/obese adolescents. Moreover, we suggest that initial longer TL could be a potential predictor for a better weight loss response[30].

Numerous gene variants that are associated with a greater or lesser risk of the different types of cardiovascular diseases (CVDs) and of intermediate phenotypes (i.e., hypercholesterolemia, hypertension, diabetes) have been successfully identified. However, despite the close link between aging and CVD, studies analyzing the genes related to human longevity have not obtained consistent results and there has been little coincidence in the genes identified in both fields. The APOE gene stands out as an exception, given that it has been identified as being relevant in CVD and longevity[30].

Immunonutrition applications

Immunonutrition is an emergent subject that carries out studies based mainly on four investigation lines:

Evaluation of nutritional status through immunological biomarkers in presumably healthy people with risk of malnutrition (children, adolescents, adults, pregnant women, elderly, and athletes).

Different immunological and stress biomarkers can be studied in serum and plasma samples of subjects

in different life stages in order to detect the risk of potential malnutrition states, both by defect and excess. Immune system development begins in the utero environment, depending on lifestyle and nutrition of mother, and continues with lactation. After, childhood and adolescence are critical periods in which healthy habits should be instaured and will have an impact on adult age. Finally, immunosenescence is linked to subclinical deficiencies and effects on immune system and cognitive functions are the major outcomes.

Study evolution of patients with diet and immune-related diseases, such as food allergies and other atopies, eating disorders, obesity, metabolic syndrome, diabetes, cardiovascular disease (CVD), different types of cancer, and autoimmune diseases including fibromyalgia, multiple sclerosis and Alzheimer's disease, among others.

Study of nutrients' effects, bioactive compounds and both conventional and functional foods on the immune system.

Assess the impact of lifestyle determinants, such as physical activity, exercise, sedentariness, food behaviour, sleep time and stress, on the immune response. Short sleep duration during adolescence might play an important and independent role in cardiovascular and metabolic diseases through C-reactive protein (CRP).

Recommendations and final remarks

The use of immunological parameters to assess nutritional status should be considered both an individual level and epidemiological studies. This subject offers a sensitive and useful tool for detect nutritional imbalances at a subclinical level, caused both by undernutrition or overnutrition.

References

1. Romeo J, Pérez de Heredia F, Gómez-Martínez S, Díaz LE, Pozo-Rubio T, Marcos A. Food Supplements and Immune Function in Humans. In: Bioactive Food as Dietary Interventions for Arthritis and Related Inflammatory Diseases. Watson R, Preedy V, eds. San Diego, CA, USA: *Academic Press* 2013. p.145-156.
2. Pérez de Heredia F, Gómez-Martínez S, Marcos A. Obesity, inflammation and the immune system. *Proc Nutr Soc* 2012; 71(2):332-338.
3. Calder PC. Immunological parameters: what do they mean? *J Nutr* 2007; 137(3 suppl 2):773S-780S.
4. Delves PJ, Seamus JM, Burton DR, Roitt IM. Essential Immunology. 12th ed. Oxford: Wiley-Blackwell; 2011.
5. Purchiaroni F, Tortora A, Gabrielli M, Bertucci F, Gigante G, Ianiro G, et al. The role of intestinal microbiota and the immune system. *Eur Rev Med Pharmacol Sci* 2013; 17(3):323-333.
6. Uauy R. Academic-industry partnerships in addressing nutrition-[infection-immunity-inflammation] interactions. *Br J Nutr* 2007; 98 Suppl 1:S17-23.
7. Scrimshaw, N. S., Taylor, C. E. & Gordon, J. E. (1968) Interactions of nutrition and infection. Monogr. Ser. World Health Organ. 57: 3–329.
8. Wärnberg J, Ruiz JR, Ortega FB, Romeo J, González-Gross M, Moreno LA, et al. On behalf on AVENA group. AVENA study. Food and Nutritional Evaluation in Adolescents. Results obtained 2003-2006. *Pediatr Integral* 2006; Supl (1): 50-55.
9. Albers R, Antoine JM, Bourdet-Sicard R, Calder PC, Gleeson M, Lesourd B, et al. Markers to measure immunomodulation in human nutrition intervention studies. *Br J Nutr* 2005; 94(3):452-481.
10. Marcos A. Eating disorders: a situation of malnutrition with peculiar changes in the immune system. *Eur J Clin Nutr* 2000; 54 Suppl 1:S61-64.
11. Marcos A. The immune system in eating disorders: an overview. *Nutrition* 1997; 13:853-862.
12. Savino W, Dardenne M. Nutritional imbalances and infections affect the thymus: consequences on T-cell-mediated immune responses. *Proc Nutr Soc* 2010; 69(4):636-643.
13. Wärnberg J. Inflammatory status in adolescents; the impact of health determinants such as overweight and fitness. Thesis for doctoral degree, 2006. Stockholm: Karolinska University Press; 2006.
14. Nova E, Gómez-Martínez S, Morandé G, Marcos A. Cytokine production by blood mononuclear cells from inpatients with anorexia nervosa. *Br J Nutr* 2002; 88(2):183-188.
15. Nova E, Martínez-Gómez D, Gómez-Martínez S, Veses AM, Calle ME, Veiga OL, Marcos A. Influence of health behaviours on the incidence of infection and allergy in adolescents: the AFINOS cross-sectional study. *BMC Public Health* 2014;14:19.
16. Codificación de la Desnutrición Hospitalaria. En: Codificación Clínica con la CIE-9-MC. Unidad Técnica de la CIE-9-MC para el Sistema Nacional de Salud. Ministerio de Sanidad y Política Social. Madrid: 2008.
17. Walrand S, Moreau K, Caldefie F, Tridon A, Chassagne J, Portefaix G, CynoberL, Beaufrère B, Vasson MP, Boirie Y. Specific and nonspecific immune responses to fasting and refeeding differ in healthy young adult and elderly persons. *Am J Clin Nutr* 2001; 74(5):670-8.
18. Marcos A, Nova E, Montero A. Changes in the immune system are conditioned by nutrition. *Eur J Clin Nutr* 2003 Sep;57 Suppl 1:S66-9.
19. Pérez de Heredia F, Garaulet M, Gómez-Martínez S, Díaz LE, Wärnberg J, Androutsos O, Michels N, Breidenassel C, Cuenca-García M, Huybrechts I, Gottrand F, Ferrari M, Santaliestra-Pasías AM, Kafatos A, Molnár D, Sjöstrom M, Widhalm K, Moreno LA, Marcos A; HELENA Study Group. Self-reported sleep duration, white blood cell counts and cytokine profiles in European adolescents: the HELENA study. *Sleep Med* 2014 Oct;15(10):1251-8.
20. Van Loveren H, Van Amsterdam JG, Vandebriel RJ, Kimman TG, Rümke HC, Steerenberg PS, Vos JG. Vaccine-induced antibody responses as parameters of the influence of endogenous and environmental factors. *Environ Health Perspect* 2001;109(8):757-64.
21. Park KH, Park H, Kim M, Kim Y, Han K, Oh EJ. Evaluation of NK cell function by flowcytometric measurement and impedance based assay using real-time cell electronic sensing system. *Biomed Res Int* 2013:210726.
22. Brandtzaeg P. Function of mucosa-associated lymphoid tissue in antibody formation. *Immunol Invest* 2010; 39(4-5):303-355.
23. Granger N, Kevil CG & Grisham MB (2006) Recruitment of inflammatory and immune cells in the gut: physiology and pathophysiology. In Physiology of the gastrointestinal tract, pp. 1137–1162 [LR Johnson, KE Barrett, JL Merchant, FK Ghishan, HM Said and JD Wood, editors]. Amsterdam: Elsevier Academic Press.
24. Doré J, Simrén M, Buttle L, Guarner F. Hot topics in gut microbiota. *United European Gastroenterol J* 2013; 1(5):311-318.
25. Santacruz A, Marcos A, Wärnberg J, Martí A, Martin-Matillas M, Campoy C, et al. Interplay between weight loss and gut microbiota composition in overweight adolescents. *Obesity (Silver Spring)* 2009; 17(10):1906-1915.
26. Sanz Y, Moya-Pérez A. Microbiota, inflammation and obesity. *Adv Exp Med Biol* 2014; 817:291-317.

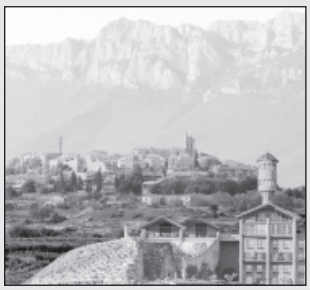
27. Nova E, Wärnberg J, Gómez-Martínez S, Díaz LE, Romeo J, Marcos A. Immunomodulatory effects of probiotics in different stages of life. *Br J Nutr* 2007; 98 Suppl 1:S90-95.
28. Corella D, Ordovás JM. Aging and cardiovascular diseases: The role of gene-diet interactions. *Ageing Res Rev* 2014 Aug 24;18C:53-73.
29. Moleres A, Campión J, Milagro FI, Marcos A, Campoy C, Garagorri JM, Gómez-Martínez S, Martínez JA, Azcona-Sanjulián MC, Martí A; EVASYON Study Group. Differential DNA methylation patterns between high and low responders to a weight loss intervention in overweight or obese adolescents: the EVASYON study. *FASEB J* 2013;27(6):2504-12.
30. García-Calzón S, Moleres A, Marcos A, Campoy C, Moreno LA, Azcona-Sanjulián MC, Martínez-González MA, Martínez JA, Zalba G, Marti A; EVASYON Study Group. Telomere length as a biomarker for adiposity changes after a multidisciplinary intervention in overweight/obese adolescents: the EVASYON study. PLoS One. 2014; 9(2):e89828.

ESTIMATE OF ENERGY AND NUTRIENT INTAKE, BIOMARKERS AND VALUES OF REFERENCE

ESTIMACIÓN DE LA INGESTA DE ENERGÍA Y NUTRIENTES, BIOMARCADORES Y VALORES DE REFERENCIA

"Consensus Meeting on the Methodology of Dietary Surveys, Classification of Physical Activity and Healthy Lifestyles"

"Reunión de Consenso sobre la Metodología de las Encuestas Alimentarias, Tipificación de la Actividad Física y Estilos de Vida Saludables"



Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):157-167
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Dietary intake and anthropometric reference values in population studies

Victoria Arija[1], Carmen Pérez Rodrigo[2], Emilio Martínez de Vitoria[3], Rosa M. Ortega[4], Luis Serra-Majem[5,6,7], Lourdes Ribas[6] and Javier Aranceta[2,8]

[1]Unidad de Nutrición y Salud Pública, Facultad de Medicina y Ciencias de la Salud, Universidad Rovira i Virgili. Reus. [2]Fundation FIDEC, Bilbao. [3]Institute of Nutrition and Food Technology, Department of Physiology, University of Granada. Granada. [4]Departamento de Nutrición, Facultad de Farmacia, Universidad Complutense de Madrid. Madrid. [5]Instituto de Investigaciones Biomédicas y Sanitarias, Universidad de Las Palmas de Gran Canaria. Las Palmas de Gran Canaria. [6]CiberOBN, Instituto de Salud Carlos III. Madrid. [7]Fundación para la Investigación Nutricional. Barcelona. [8]Department of Preventive Medicine and Public Health, University of Navarra. Pamplona. Spain.

Abstract

In nutritional epidemiology it is essential to have reference values for nutrition and anthropometry in order to compare individual and population data.

With respect to reference nutritional intake, the new concept of Dietary Reference Intakes is generated based more on the prevention of chronic diseases than on covering nutritional deficiencies, as would occur in the early Recommendations. As such, the more relevant international organizations incorporated new concepts in their tables, such as the Adequate Intake levels or the Tolerable Upper Intake levels. Currently, the EURRECA recommendations (EURopean micronutrient RECommendations Aligned) are generating reference values for Europe in a transparent, systematic and scientific manner. Using the DRI, health-care authorities formulated nutritional objectives for countries or territories and Dietary Guides to disseminate the dietary advice to the population.

Anthropometric assessment continues to be one of the most-used methods for evaluating and monitoring health status, nutritional state and growth in children, not only individuals but also communities. Different organizations have established anthropometric reference patterns of body mass index (BMI) with cut-off points to define overweight and obesity. In children, growth curves have been revised and adapted to the characteristics of healthy children in order to obtain anthropometric reference standards that better reflect optimum growth in children. The Growth Standards for children below 5 years of age of the WHO are a response to these principles, and are widely accepted and used worldwide.

(*Nutr Hosp* 2015;31(Supl. 3):157-167)

DOI:10.3305/nh.2015.31.sup3.8763

Key words: *Nutrition. Anthropometry. Population. "Dietary Reference Intakes". "Growth curves".*

Correspondence: Victoria Arija, MD.
Unidad de Nutrición y Salud Pública.
Facultad de Medicina y Ciencias de la Salud.
Universitat Rovira i Virgili.
C/ Sant Llorenç 21.
43201 Reus, Spain.
E-mail: victoria.arija@urv.cat

VALORES DE REFERENCIA DE INGESTA DIETÉTICA Y DE ANTROPOMETRÍA EN ESTUDIOS POBLACIONALES

Resumen

En epidemiologia nutricional son fundamentales las referencias nutricionales y antropométricas para comparar los datos de individuos o colectivos.

En relación a las ingestas nutricionales de referencia, el nuevo concepto de Ingestas Dietéticas de Referencia se realizó basándose más en la prevención de las enfermedades crónicas actuales, que en cubrir deficiencias nutricionales, como ocurría con las primeras Recomendaciones. Así, las Organizaciones Internacionales más relevantes han incorporado nuevos conceptos en sus tablas, como el de Ingestas Adecuadas o el Límite Superior de Ingesta Tolerable. Actualmente, la (EURopean micronutrien RE-Comendations Aligned) (EURRECA) está creando valores de referencia para Europa, de manera transparente, sistemática y científicaA partir de las IDR, las autoridades de salud formulan los objetivos nutricionales para un país o territorio y las Guías Alimentarias, que transmiten el consejo alimentario para la población

La valoración antropométrica sigue siendo uno de los métodos más utilizados para evaluar y vigilar el estado de salud, el estado nutricional y el crecimiento de los niños, tanto en los individuos, como en las comunidades. Diferentes organismos establecen los patrones de referencia antropométrica del IMC y definen los puntos de corte para definir sobrepeso y obesidad. En los niños, se han revisado las curvas de crecimiento adaptándolas a las características de niños sanos desarrollados en ambientes saludables para obtener estándares antropométricos de referencia que reflejen mejor el crecimiento óptimo de los niños. A estos principios responden los Estandares de Crecimiento para niños menores de cinco años de edad de la OMS, los cuales han sido ampliamente aceptados y utilizados a nivel mundial.

(*Nutr Hosp* 2015;31(Supl. 3):157-167)

DOI:10.3305/nh.2015.31.sup3.8763

Palabras clave: *Nutrición. Antropometría. Población."Ingestas Dietéticas de Referencia". "Curvas de crecimiento".*

Dietary reference Intakes for individuals and populations; concepts and definitions

The first Recommended Nutrient Intakes (RNIs) tables were collated in 1938 for the Canadian and United Kingdom populations (Daily Recommended Nutrient Intakes); in 1941 for the population of the USA (Recommended Dietary Allowances; RDAs); by the Institute of Medicine (*IOM*); and, in the 50s, for the world population under the auspices of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). The recommendations were originally defined to avoid nutritional deficiencies.

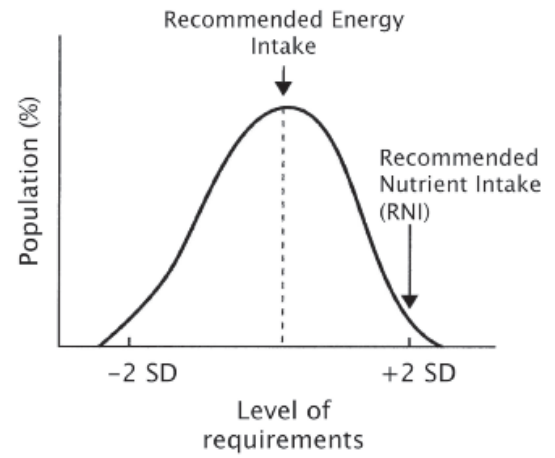
In 1994 the Food and Nutrition Board with the support of the government of the US and Canada initiated the revision of the RNIs and RDAs and generating, with the use of new scientific knowledge and statistics, the Dietary Reference Intakes (DRIs). The difference from the original tables was that each nutrient was given several values for different circumstances, as well as a unique reference value. This new concept is based, on the one hand, on the observation that, currently, the diseases to be prevented are, mostly, chronic i.e. they are more severe and more prevalent than deficiency diseases; the latter having been used in generating the original recommended intakes. In addition, advancing knowledge highlighted the convenience of incorporating new reference values such as that of certain food components (fat or fiber, among others) which, despite not being essential nutrients, their intake is also related to health status. Further, reference values for some nutrients can be used even when the information required to calculate the recommended intake is lacking or when the extremes of values of nutritional intake can cause adverse health effects.

Thus, the new tables of DRI include the following concepts[1,2,3,4,5] (Fig. 1).

The Estimated Average Requirement (*EAR*) is the average daily nutrient intake level that is estimated to meet the nutrient needs of half of the individuals in a life-stage or gender-group. In the case of energy, an Estimated Energy Requirement (*EER*) is provided.

Recommended Dietary Allowance (*RDA*) is the average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97-98 percent) healthy individuals in a particular life-stage and gender-group. *RDA*s are established for each age group and gender, or physiological status (pregnancy and lactation). For nutrients with a statistically normal requirement distribution, these are calculated from the EAR of each nutrient + 2 standard deviations of its distribution. The standard deviation is estimated from the coefficient of variation of the nutrient in the population (for those nutrients with an estimation of the coefficient of variation) (Fig. 2).

The Acceptable Range of Intake (*ARI*) or Acceptable Intake (*AI*) is the amount of nutrient intake that is recommended when there are not enough data to estimate the (EAR) due, mainly, to lack of awareness of the variability of requirements and, therefore, the impossibility of calculating its standard deviation. These values should be considered a provisional value, prior to RDA.



The recommended amounts for the majority of the nutrients are located two standard deviations (SD) above the mean value of the estimated nutrient needs in this population group. The amount of energy recommended for a population group is the one placed on the average level of the needs estimated for this population.

Fig. 1.—Recommended Energy and Nutrient Intakes.

The Tolerable Upper Intake Level (*UL*) of intake is the maximum amount of a nutrient that individuals can ingest daily without any health risk. This new value is gaining interest, given the increasingly frequent use of nutrient concentrates, fortified foods, and functional foods, all of which can lead to an excessive intake.

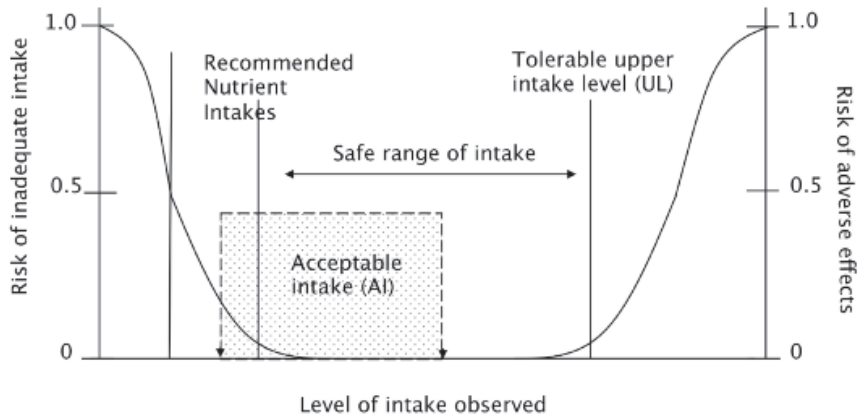
The Lowest Threshold Intake (*LTI*) is the value below which a nutritional deficiency would emerge in most of the population group. It is the mean of Nutritional Requeriments minus 2 standard deviations.

The Acceptable Macronutrient Distribution Range (*AMDR*) is the range of intake for a particular nutritional source that is associated with a reduced risk of chronic disease, while providing intakes of essential nutrients. If an individual consumes in excess of the AMDR, there is a potential for increasing the risk of chronic diseases and/or insufficient intakes of essential nutrients.

Recommended Safe Intake (*RSI*) is set to prevent possible clinical signs of deficiency, and to allow normal growth. It is not suitable for prolonged periods of infections or stress.

Protective Nutrient Intake (*PNI*) has been introduced in some cases to refer to an amount that is greater than the recommended intake but which may be protective against a specified health or nutritional risk relevant to public-health (folic acid to lower the risk of fetal neural tube defects, for example).

In addition, another term that should not be confused with the *DRI*, is the concept of Reference Labelling Values (*RLV*). This concept is used to describe the



Dietary reference intakes include four distinct concepts: a) the average of the nutritional needs of the population group, b) nutritional recommendations located two standard deviations of the average needs, except the recommendations of energy, c) the acceptable nutrient intake when there is insufficient data to estimate the recommendations but adequate information to make this dietary advice is available, and d) the tolerable upper intake levels, above which there can exist a health risk.

Fig. 2.— Dietary reference intakes.

Table I.I
Recommended Allowances and Adequate Intakes (*) for the US population

Category	*Age years*	*Water L*	*Energy kcal*	*kJ*	*Pr g*	*CH g*	*Fiber g*	*Lipids g*	*LFA G*	*LnFA G*	*Ca Mg*	*Fe mg*	*Zn mg*	*Se µg*	*Fl mg*	*I mg*	*Mg mg*
Infants	0.0-0.5	0.7*	650	2,720	9.1*	60*	ND	31	4.4*	0.5*	210*	0.27*	2*	15*	0.01*	110*	30*
	0.5-1.0	0.8*	850	3,556	11	95*	ND	30	4.6*	0.5*	260*	11	3	20*	0.5*0	130*	75*
Boys/ Girls	1-3	1.3*	1,300	5,439	13	130	19*	ND	7*	0.7*	700	7	3	20	0.7*	90	80
	4-8	1.7*	1,800	7,531	19	130	25*	ND	10*	0.9*	1,000	10	5	30	1*	90	130
Males	9-13	2.4*	2,500	10,460	34	130	31*	ND	12*	1.2*	1,300	8	8	40	2*	120	240
	14-18	3.5*	3,000	12,500	52	130	38*	ND	16*	1.6*	1,300	11	11	55	3*	150	410
	19-30	3.7*	2,900	12,133	56	130	38*	ND	17*	1.6*	1,000	8	11	55	4*	150	400
	31-50	3.7*	2,900	12,133	56	130	38*	ND	17*	1.6*	1,000	8	11	55	4*	150	420
	51-70	3.7*	2,300	9,623	56	130	30*	ND	14*	1.6*	1,000	8	11	55	4*	150	420
	>70	3.7*	2,300	9,623	56	130	30*	ND	14*	1.6*	1,200	8	11	55	4*	150	420
Females	9-13	2.1*	2,200	9,200	34	130	26*	ND	10*	1.0*	1,300	8	8	40	2*	120	240
	14-18	2.3*	2,200	9,200	46	130	26*	ND	11*	1.1*	1,300	15	9	55	3*	150	360
	19-30	2.7*	2,200	9,200	46	130	25*	ND	12*	1.1*	1,000	18	8	55	3*	150	310
	31-50	2.7*	2,200	9,200	46	130	25*	ND	12*	1.1*	1,000	18	8	55	3*	150	320
	51-70	2.7*	1,900	7,450	46	130	21*	ND	11*	1.1*	1,200	8	8	55	3*	150	320
	>70	2.7*	1,900	7,450	46	130	21*	ND	11*	1.1*	1,200	8	8	55	3*	150	320
Gestating	14-18	3.0*	+300	+1,250	71	175	28*	ND	13*	1.4*	1,300	27	12	60	3*	220	400
	19-30	3.0*	+300	+1,250	71	175	28*	ND	13*	1.4*	1,000	27	11	60	3*	220	350
	31-50	3.0*	+300	+1,250	71	175	28*	ND	13*	1.4*	1,000	27	11	60	3*	220	360
Lactating	14-18	3.8*	+500	+2,100	71	210	29*	ND	13*	1.3*	1,300	10	13	70	3*	290	360
	19-30	3.8*	+500	+2,100	71	210	29*	ND	13*	1.3*	1,000	9	12	70	3*	290	310
	31-50	3.8*	+500	+2,100	71	210	29*	ND	13*	1.3*	1,000	9	12	70	3*	290	320

Table I.II
Recommended Allowances and Adequate Intakes (*) for the US population

Infants	*Age years*	*Vit. A µg ER*[1]	*Vit. D µg Cole*[2]	*Vit. C mg*	*Vit. E mg ET*[3]	*Vit. K µg*	*Vit. B1 mg*	*Vit. B2 mg*	*Niacin mg NE*[4]	*Vit. B6 mg*	*Folate µg DFE*[5]	*Vit. B12 mg*
Infants	0.0-0.5	400*	10*	40*	4*	2*	0.2*	0.3*	2*	0.1*	65*	0.4*
	0.5-1.0	500*	10*	50*	5*	2,5*	0.3*	0.4*	4*	0.3*	80*	0.5*
Boys / Girls	1-3	300	15*	15	6	30*	0.5	0.5	6	0.5	150	0.9
	4-8	400	15*	25	7	55*	0.6	0.6	8	0.6	200	1.2
Males	9-13	600	15*	45	11	60*	0.9	0.9	12	1.0	300	1.8
	14-18	900	15*	75	15	75*	1.2	1.3	16	1.3	400	2.4
	19-30	900	15*	90	15	120*	1.2	1.3	16	1.3	400	2.4
	31-50	900	15*	90	15	120*	1.2	1.3	16	1.3	400	2.4
	51-70	900	15*	90	15	120*	1.2	1.3	16	1.7	400	2.4
	>70	900	20*	90	15	120*	1.2	1.3	16	1.7	400	2.4
Females	9-13	600	15*	45	11	60*	0.9	0.9	12	1.0	300	1.8
	14-18	700	15*	65	15	75*	1.0	1.0	14	1.2	400	2.4
	19-30	700	15*	75	15	90*	1.1	1.1	14	1.3	400	2.4
	31-50	700	15*	75	15	90*	1.1	1.1	14	1.3	400	2.4
	51-70	700	10*	75	15	90*	1.1	1.1	14	1.5	400	2.4
	>70	700	20*	75	15	90*	1.1	1.1	14	1.5	400	2.4
Gestating	≥18	750	15*	80	15	75*	1.4	1.4	18	1.9	600	2.6
	19-30	770	15*	85	15	90*	1.4	1.4	18	1.9	600	2.6
	31-50	770	15*	85	15	90*	1.4	1.4	18	1.9	600	2.6
Lactating	≥18	1,200	15*	115	19	75*	1.4	1.6	17	2.0	500	2.8
	19-30	1,300	15*	120	19	90*	1.4	1.6	17	2.0	500	2.8
	31-50	1,300	15*	120	19	90*	1.4	1.6	17	2.0	500	2.8

Pr: Proteins; CH: Carbohydrates; LFA: Linoleic Fatty Acid; LnFA: Linolenic Fatty Acid; ND: Not Determined; (*) The indicated value is the Adequate Intake (AI). For healthy children breastfed the AI concern the mean intakes. [1] RE= Retinol Equivalents; [2] Cole: Cholecalciferol, in the absence of adequate sunlight exposure, 1 µg of cholecalciferol = 40 IU of Vit D; [3] TE=Tocopherol Equivalents; [4] RE= Retinol Equivalents; NE = Niacin Equivalents; [5] DFE = Dietary Folate Equivalent
Sources: Food and Nutrition Board. Institute of Medicine. National Research Council (FNB/IOM/NRC). Dietary Reference Intakes (DRI): for Thiamine, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic acid, Biotin, and Choline. Washington DC: National Academy Press, 2000. FNB/IOM/NRC. DRI: for Vitamin C, Vitamin E, Selenium and Carotenoids. Washington DC: National Academy Press, 2000.FNB/IOM/NRC. DRI: A risk assessment models for establishing Upper Intake Levels for Nutrients. Washington DC: National Academy Press, 2000. FNB/IOM/NRC. DRI: for Calcium and Vitamin D. Washington DC National Academy Press, 2001. FNB/IOM/NRC. DRI: for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington DC: National Academy Press, 2001. FNB/IOM/NRC. DRI: for Energy, Carbohydrate, Fibre, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington DC: National Academy Press, 2002. FNB/IOM/NRC. DRI: for Water, Potassium, Sodium, Chloride, and Sulphate. Washington DC: National Academy Press, 2005

nutrient content of a food product. It can be expressed as a percentage of the DRI in adults. This information allows comparison of the nutritional values of food products.

The most relevant international organizations incorporate some of these new concepts into their tables. In the USA, the Food and Nutrition Board (FNB) of the National Research Council includes the values of AI, UL, and AMDR in various publications[3,4,5] (Table I). In 2002, the Committee of Experts of FAO-WHO incorporated the values of *AI, UL, RSI* and *PNI*[6]. At the European level, the Scientific Committee on Food (SCF) included, in 1993, the valu es of ARI, LTI[7]. However, most countries have developed their recommendations based on the specific characteristics of their population. In Europe there are recommendations in the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden), in the Germanic countries (Germany, Austria and Switzerland) while the United Kingdom, Ireland, France, Belgium, Italy and in Spain have their own recommendations[8].

The European Commission recognized the need to align the procedures used to obtain European micro-

nutrient recommendations within a globalized society. In 2007 the Commission funded the EURRECA (EURopean micronutrient REComendations Aligned) Network of Excellence coordinated by International Life Sciences Institute (ILSI) of Europe. The aim was to create a standard process for collecting and using the dietary reference values for micronutrients in a transparent, systematic and scientific manner. Their goals focus on the specific needs of vulnerable groups such as infants, children and adolescents, adults, pregnant and lactating women, the elderly, low-income individuals and immigrants, and to evaluate the impact on intake of various related situations such as socioeconomic status, ethnicity, inter-individual variability and vulnerability due to genetics, environmental factors and epigenetic phenomena[9].

Uses, applications and expression of the nutritional intake of populations in relation to the DRI

Among its many uses, the *DRI* helps in planning menus and diets, developing new dietary products by the food industry, labelling of foodstuffs, designing programs of nutritional education, or for estimating nutritional adequacy.

Nutritional adequacy assesses intake in relation to the recommended intakes. It is useful both collectively and individually. For example, at a collective level, reports evaluate the percentage of subjects below the *EAR* (only for those nutrients that comply with certain conditions). Since the *DRI* is presented as 97.5 percentile, when an individual or group of individuals have an intake below the recommended amounts, this does not indicate real deficiencies but, rather, a risk of deficit since it may be less than the amounts recommended but not lower than the individual's needs.

AI cannot be used to assess the prevalence of inadequate intakes, while *UL* is useful in assessing the percentage within a group who are at risk of adverse effects.

Nutrient intake adequacy at the individual level

If we have the real nutrient requirement of an individual and his/her true intake, we can compare those values: when the intake is equal to or above the requirement the intake is adequate, and when a given intake is below the requirement, it is considered as inadequate. Although neither the individual's requirements nor the true intakes are known with certainty, a qualitative or a quantitative evaluation can be made. The qualitative evaluation compares the individual's usual intake with the RDA; if it is above or equal to the RDA, there is a low probability that such an intake is inadequate. If the individual's usual intake is between the RDA and the EAR, there is considerable uncertainty whether the intake is adequate or not. There is a high probability of inadequacy when the nutrient intake is below the EAR. The quantitative approach calculates a confidence of adequacy based on the number of days that intake is measured, day-to-day variation in intake of the nutrient under study, variability of the requirement, and how far the intake value is above or below the ANR (EAR). The result of such an equation is a Z score from which a probability value is derived that reflects the degree of confidence that the individual's usual intake is adequate.

Nutrient intake adequacy at the group level

To calculate the proportion of the population with intakes that are below the requirements, a joint distribution of the nutrient requirement and the nutrient intake for each individual in the group would enable the calculation of the percentage of individuals with inadequate intakes. Unfortunately, the nutrient requirement for each individual in a group is not known, and no joint distribution can be calculated. In these circumstances, two approaches are used to calculate the prevalence of inadequate intakes: the probability approach or, when certain conditions are accomplished, a shortcut of that method i.e. the cut-off point method. Both methods are recommended for use only under the following conditions: the mean and the variance of the requirement distribution are known; intakes and requirements are not correlated; the form of the requirement distribution (normal or log-normal) must be known or must be assumed. To apply both methods, intake distributions need to be adjusted to remove the effect of day-to-day variation.

The probability approach is a statistical method that combines the distribution of the intakes and the risk-curve of the requirement distribution. Using the probability approach, the probability of inadequacy is assessed for each individual and the average probability is the group prevalence of inadequate intakes. The probability of inadequacy for each individual is defined by comparing the individual's intake with the requirement for that nutrient: if the intake is below that value, the individual's intake will be defined as inadequate.

The cut-off point method, proposed by Beaton[10], estimates the prevalence of inadequate intakes as the proportion of the population with usual intakes below the average requirement (EAR or ANR). The cut-off point method will be used when:

1. The requirement distribution is symmetrical.
2. The distribution of usual intakes is more variable than the distribution of requirements (the coefficient of variance for the distribution of requirements for most nutrients is set at 10%).

If these conditions are not met, then the probability approach will be used

For those nutrients with an AI value as requirement, it is not possible to determine the prevalence of ina-

dequate nutrient intakes in a group. The only assumptions that can be made are that if the mean intake of a group is at or above the AI, and the variance of intake is similar to the variance of intake from the population used to set the AI, then prevalence of inadequate intake for that population is likely to be low. Nothing can be concluded if the group median intake is below the AI.

From RDI to nutritional goals; Establishing concepts and comparison tables of nutritional goals in developed countries.

Promoting appropriate eating habits, which follow healthy dietary models, constitutes one of the most important components within health-promotion strategies. To achieve improvements in collective food intake, health authorities count on two tools of considerable value in public health: nutritional objectives and food guidelines[11,12].

Nutritional objectives are quantitative and qualitative, with nutritional recommendations based on scientific evidence and framed in the nutritional policy of the country. They are aimed at the general population in order to achieve an optimal health status, considering the specific characteristics and the mean intakes of the population for which they are intended while taking into account eating and nutritional behavior patterns, or the most frequent health problems[13].

Nutritional objectives for the Spanish population were developed based on a consensus meeting of the Spanish Society of Community Nutrition (*Sociedad Española de Nutrición Comunitaria; SNEC*) held in Bilbao in 2000 and sponsored by the WHO. Intermediate and final nutrition objectives were defined at this time[11,12], and have been modified by subsequent consensus meetings[13] (Table II). The table II summarizes the nutritional objectives established by various organizations, with special attention being paid to those issues having a high impact on health. These include aspects such as fat intake, which has been the subject of priority concern in most nutritional objectives because of its role in cardiovascular disease risk. Most populations in developed countries have an unbalanced energy profile, and concerns have been raised regarding reducing saturated fat while increasing PUFAs intake (where an insufficient contribution was most frequently noted and where the contribution of omega-3 fatty acids is particularly low). Results indicate that the quality of the fat needs to be improved and, in this respect, nutritional objectives can be used for guidance.

Dietary fiber intake in Spanish populations is quite far from the recommended nutrient intake goals. It is evident that a low consumption of vegetables and cereals (especially whole grains) contributes to this finding[12]. A study that evaluated the sodium intake in a representative sample of Spanish young and middle-aged adults aged 18–60 years highlighted, by measuring 24h urinary sodium excretion, that mean dietary salt intake (9.8 ± 4.6 g/day), exceeded the recommended intake of 5 g/day in 88.2% of the subjects studied. These results can be used as the baseline to design nutrition policies for reducing salt consumption[14].

Healthy weight maintenance is achieved by choosing a nutritious diet balanced by daily physical activity[15]. Almost half of European adults are overweight. For example, in representative samples of the Spanish population, 47.4% of adults and 30.8% of children were found to be overweight[16]. To maintain body weight in the population, recommendations for daily physical activity and BMI ranges should be included in the national nutritional goals and dietary guidelines. Moderate physical activity should be made an easy choice and part of everyday life[15] (Table II) (Fig. 3). Also, it is advisable to promote breast-feeding programs, not only among pregnant women, but also among pediatricians, obstetricians and maternity ward staff[13]. A moderate consumption of beverages with low alcoholic content (wine, beer, cider) is considered permissible, if limited to < 2 glasses/d if taken with meals. The consumption for women should be somewhat lower than for men[13] (Table II).

From nutrient intake goals to dietary guidelines; Establishing concepts and examples of dietary guidelines.

Part of an action policy to combat non-communicable diseases (NCD) and to meet nutritional goals should include the translation of the goals into food-based dietary guidelines (FBDG) at the national level[11,14].

Dietary guidelines are recommendations on food consumption to the population, in pursuit of the nutritional goals. The guidelines need to be relatively simple documents of nutritional health promotion addressed to the population, in order to promote nutritional well-being. The goals need to be easily achieved, written in appropriate language, using a positive approach. Designed by government agencies and/or scientific organizations, a system of food groups is used and includes advice on healthy lifestyles[17].

A survey conducted by the WHO[15] analyzed food-based dietary guidelines in member states of the European Union, illustrated important discrepancies between sub-regions and between countries in national food-based dietary guidelines. The Guide, distributed as a food guide by the Spanish Ministry of Health was shown as a prism, from which different graphics have been derived (pyramid, wheel, semicircle, etc.). Nevertheless, the pyramid proposed by the *SENC*, which was based on consensus documents, has become widespread as a guide for proper application in the Spanish population[11,13] (Fig. 3).

Food guidelines should be adapted to a country's specific needs to ensure that the nutrient needs of the population are covered, and which would contribute to

Table II
Nutritional objectives in developed countries

	FAO/WHO, 2003, 2008	*EFSA, 2010*	*SENC, 2011**	
			Intermediate objectives[a]	*Final objectives*[b]
Breast-feeding	Promotion of exclusive breast-feeding		4 months (exclusive breast- feeding)	≥6 months
Dietary fiber	High dietary intake of dietary fiber		>12 g/1000 kcal (> 22 g/day in women and 30 g/day in men)	>14 g/1000 kcal (> 25 g/day in women and 35 g/day in men)
Salt (g/day)	<5	<6	< 7	< 5
Physical activity[10]	Regular physical activity		PAL >1.60 (> 30 min/day)	PAL >1.75 (45-60 min/day)
BMI (kg/m^2)	21 – 23		21- 25	21 – 23 23-26 (>65 years)
Total fat (% of energy)	20-35%	20-35%	≤ 35%	30 – 35%
SFA (% of energy)	<10%	As low as possible	≤ 10%	7-8%
MUFA (% of energy)	By difference		20%	20%
PUFA (% of energy)	6-11%		4%	5%
n-6 (% of energy)	2.5-9%	4% (Linoleic FA)	2% (Linoleic FA)	3% (Linoleic FA)
n-3 (% of energy)	0.5-2%		1-2%	1-2%
Trans FA (% of energy)	<1%	As low as possible		<1%
Cholesterol	<300 mg/day	No reference value	<350 mg/day <110 mg/1000 kcal	<300 mg/day <100 mg/1000 kcal
Total carbohydrates (% of energy)	55-75%	50-55%	>50% Low glucemic index	50-55% Low glucemic index
Sweets	Sugar-free <10% of energy	Added sugars <10% of energy	<4 per day	<3 per day <6% of energy
Beverages with low alcoholic grade (wine/beer) (glasses/day)	Moderate alcohol		<2 (taken with meals)	<2 (taken with meals)

[a] Corresponds essentially to the 75th or 25th percentile, depending on the findings (favorable or unfavorable) of population-based nutrition studies carried out in Spain, or, when referring to micronutrients, to nutrient reference values. To be evaluated by the end of 2015. [b] Final nutrition objectives, in accordance with current scientific evidence and based on nutrient reference values. To be evaluated by the end of 2020. BMI: Body mass index, PAL: physical activity levels, SFA, saturated fatty acid, MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; FA: fatty acids

Sources: FAO-WHO. Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series No. 916 (TRS 916). World Health Organization: Geneva. 2003. http://www.fao.org/docrep/005/AC911E/AC911E00.htm. FAO-WHO. Fats and Fatty Acids in Human Nutrition. Rome: FAO Food and nutrition paper # 91. Report of an expert consultation. Geneva, November 10–14, 2008. EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA). Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol. The EFSA Journal 2010; 8, 1461. *Aranceta J, Serra Majem Ll, Grupo Colaborativo para la actualización de los Objetivos Nutricionales para la Población Española (2011). Nutritional objectives for the Spanish population. Consensus from the Spanish Society of Community Nutrition. Rev Esp Nutr Comunitaria 17: 178–99.

reducing the risk of NCD. In addition, they should be in accord with public policies on food safety and physical activity, while promoting a healthy environment and a local food economy[15]. Most food guidelines include similar information aimed at achieving healthy eating habits. These include:

-Eating a varied diet consisting mainly of food-items derived from plants

-Eating bread, grains, pasta, rice or potatoes several times a day

-Daily intake of fresh, local vegetables, legumes, and fruits (at least 400 g/d)

-Maintaining a healthy BMI by taking moderate levels of exercise, preferably daily

-Controlling fat intake (total and saturated)

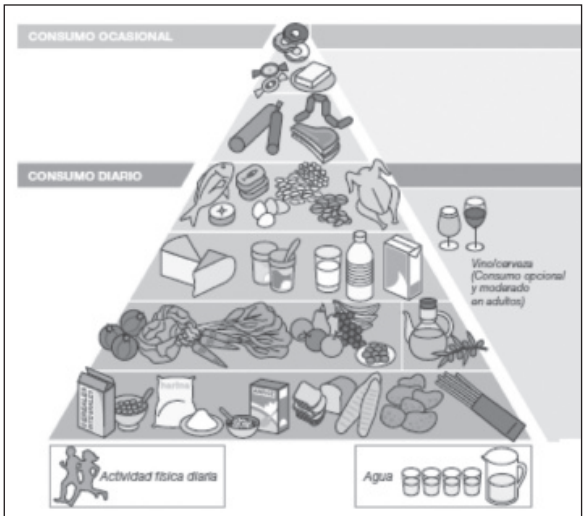
-Eating lean meat, poultry, fish

-Using low-fat milk and low-fat dairy products

-Low sugar intake

-Low salt intake

-If alcohol is consumed, the intake should be limited



Source: Aranceta J, Serra-Majem L; Working Party for the Development of Food-Based Dietary Guidelines for the Spanish Population. Dietary guidelines for the Spanish population. Public Health Nutr. 2001;4(6A):1403-8.

Fig. 3.—Food-Based Dietary Guidelines for the Spanish Population.

to no more than 1 drink for women and 2 drinks for men (each containing 10 g of alcohol) per day.

-Preparing food in a safe and hygienic manner

-Promoting breastfeeding exclusively for the first 6 months followed by the gradual introduction of safe and appropriate complementary foods. Supplementary breastfeeding can be continued over the first years of life.

Developing national dietary guidelines is an important part of generating nutrition policies, and disseminating consistent information on healthy diets and lifestyle. A set of consistent dietary guidelines should help the population and the health-care professionals achieve a better health status in the population[15].

National and international reference data on anthropometric indices

In practical terms, anthropometric indices are compared across populations in relation to an acceptable set of reference values. In population studies, anthropometric indices can be evaluated by comparison with the distribution of the reference data using Z-scores or percentiles[18].

Reference standards for the 'normality' of BMI have been defined to classify various degrees of overweight and obesity, but universal cut-off points have been challenged. There are a number of recent studies showing that the relationship between BMI and percentage body fat (BF%) is not only age and sex dependent, but also differs among ethnic groups. Similarly, low levels of BMI have been used to classify chronic energy deficiency.

Currently, there is no need for adult reference data for BMI, and interpretation should be based on pragmatic BMI cut-offs[19]; albeit international reference data from the WHO and the National Centre for Health Statistics are available[20].

The WHO BMI classifications of overweight and obesity are intended for international use. They reflect risk for type 2 diabetes and cardiovascular diseases, which are rapidly becoming major causes of death in adults in all populations, even in those that still have substantial malnutrition. The current WHO BMI cut-off points should be retained as international classification, but additional cut-off points need to be added for public health action. Wherever possible, countries should use all categories for reporting purposes, with a view to facilitating international comparisons (Table III). However, some authors maintain that universal BMI cut-off points for overweight and obesity are not appropriate due to important ethnic differences in distributions[21].

WHO has a global BMI database where BMI distributions in different countries can be consulted (http://apps.who.int/bmi/index.jsp)

The Spanish Society for the Study of Obesity (SEEDO) published a consensus document for the evaluation of overweight and obesity, and established BMI cut-off points for the classification of overweight and obesity in Spanish populations (Table III).

Where possible, in populations with a predisposition to central obesity and related increased risk of developing the metabolic syndrome, cardiovascular diseases and type 2 diabetes, waist circumference (WC) and waist-to-hip circumference ratio (WHtR) should also be used[22]. In a consensus of the International Diabetes Federation, country- and ethnic-specific values for waist circumference (as a measure of central obesity) have been published[23].

In Spain, the SEEDO published cut-off points for WC (>102 cm for males and >88 cm for females) (Table III). Other international organizations such as the WHO also have reference cut-off points than coincide with the values of SEEDO. The International Diabetes Federation has different cut-off points (>94 for males and >80 for females) [23]. Canadian Health surveys propose cut-off points for WC, BMI and WHR for each risk factor.

Reference standards of anthropometry during growth

Anthropometry remains one of the most-used methods for assessing and monitoring health status, nutritional status, as well as child growth in individuals and in communities.

Anthropometric measurements describe body size, proportions, and even composition. The most-used direct measurements are weight, linear growth (height or length), circumferences (head, mid-upper arm, waist,

Table III
Body Mass Index (BMI) cut-off points; Comparison of WHO and SEEDO data

Classification	*WHO BMI (kg/m²)*		*SEEDO BMI (kg/m²)*
	Principal cut-off points	Additional cut-off points	Cut-off points
Underweight	<18.50	<18.50	< 18.5
Severe thinness	<16.00	<16.00	-
Moderate thinness	16.00 - 16.99	16.00 - 16.99	-
Mild thinness	17.00 - 18.49	17.00 - 18.49	-
Normal range (normal weight)	18.50 - 24.99	18.50 - 22.99 23.00 - 24.99	18.5-24.9
Overweight	≥25.00	≥25.00	-
Pre-obese (Grade I overweight)	25.00 - 29.99	25.00 - 27.49	25.0-26.9
(Grade II overweight) (Pre-obese)		27.50 - 29.99	27.0-29.9
Obese	≥30.00	≥30.00	-
Obese class I	30.00 - 34.99	30.00 - 32.49 32.50 - 34.99	30.0-34.9
Obese class II	35.00 - 39.99	35.00 - 37.49 37.50 - 39.99	35.0-39.9
Obese class III (morbid obesity)	≥40.00	≥40.00	40.0-49.9
Obese class IV (extreme obesity)	-	-	≥ 50

Adapted from: WHO. Obesity: preventing and managing the global epidemic. Report of a WHO Consultation. WHO Technical Report Series 894. Geneva: World Health Organization, 2000. WHO expert consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. The Lancet, 2004; 157-163. Salas-Salvadó, J, Rubio MA, Barbany M, Moreno B and the Collaborative of SEEDO. SEEDO 2007 Consensus for the evaluation of overweight and obesity and the establishment of therapeutic intervention criteria. Med Clin (Barc) 2007;128(5):184-196.

hip...), skinfolds (triceps, biceps, suprailiac, subscapular...) or various body sizes. Its measurement is easy and inexpensive and applicable worldwide. However it should be performed with precise instruments and accepted methodological procedures[24].

Anthropometric indices are derived from relationships observed between some of the previously-direct measures (see above) or by a combination of an anthropometric measurement and age.

The anthropometric indices most commonly used in pediatrics are the ones related to age and those associated with weight and height. From a nutritional point of view each index describes a different body size and enables a type of deficit or excess to be characterized.

Weight-for-age and height-for-age reflect, respectively, body mass and linear growth relative to chronological age. They are sensitive parameters in detecting changes during monitoring of the child. For example, low weight-for-age may indicate overall under-nutrition, usually acute while low height-for-age estimates the degree of chronic or secular malnutrition. The weight/height index (the BMI) provides information on body proportionality. It is important that these indices, in children and adolescents, are described by age group. A low value on these indices reflects recent weight loss rather than chronic under-nutrition which would be reflected in both height and weight and would not affect the index. Conversely, a high value is indicative of overweight[24].

Anthropometric measurements, apart from being expressed in their units (g, cm, ...), can also be expressed in other units that provide insight into the anthropometric level relative to the whole population or relative to a benchmark. These include the percentage of adequacy, the percentile, or the Z score. The percentage of adequacy, with respect to the median of the reference population, is the individual value to reference value ratio, expressed as a percentage. The percentiles express the normal distribution of the frequencies from a given measure in the population. A value of 94% of a population comprises the values between the 3rd and 97th percentiles, which are considered as the limits of normality. The z score is the distance to the center of the normal distribution. It ranges from -6 to +6 and

represents the number of existing standard deviations between the measured value and the median. Of all measurements, the Z score is the most useful because it provides a greater amount of information, and can be used in more complete statistical analyses[24].

Knowledge of the dynamics of different anthropometric measures enables standards, norms, or benchmarks, of child growth to be constructed and expressed as graphs and tables segregated by age and gender. Reference standards of anthropometry have been published by various organizations as well as national and international institutions based on population samples that are local, national or international.

One of the most widely used references worldwide has been the percentiles for different anthropometric measurements (weight, length, head circumference and upper-arm circumference) that the National Center for Health Statistics (NCHS) of the United States published in 1977, based on data of child populations in different parts of the world[25]. These curves were adopted by the WHO for international use. Later, with the help of 100 experts from around the world, the WHO organized a comprehensive review of these patterns. An important conclusion was that the previous patterns did not represent the growth of early childhood, adequately. Hence, new growth curves were required[26].

More recently, the Centers for Disease Control and Prevention (CDC) in the United States published an improved version of the growth curves in 2000[27]. In these new standards, data were corrected to fit into the demographics, and other determinants, of child growth. Hence, very-low-birth-weight infants and recent data of children over 6 years of age were excluded so as to avoid including the increase in obesity seen in children in these years. The high numbers of children fed with infant formula that had been included previously, as well as some very local aspects, were corrected. Of note is that the curves for BMI for individuals up to 20 years of age were incorporated. However, despite these improvements, the references for growth data of the CDC were inappropriate in other population groups, particularly in developing countries.

In general, anthropometric reference values were developed on the basis of representative samples of one or more populations and, as such, the values obtained could not show optimal growth patterns.

Hence, the WHO Child Growth Standards for children under 5 years of age have been created recently with the aim of producing a standard generated with a selected sample of healthy children. Longitudinal data from birth to 24 months of age, and cross-sectional studies of children aged 18-71 months were combined. Children from diverse ethnic and cultural backgrounds participated (Brazil, Ghana, India, Norway, Oman and the United States) so as to be as representative as possible of children throughout the world. Various anthropometric measures were included: length/height-for-age, weight-for-age, weight-for-length, weight-for-height, BMI-for-age, head circumference-for-age, arm circumference-for-age, triceps skinfold-for-age and subscapular skinfold-for-age. Healthy children living in conditions favoring the development of their full genetic potential for growth, and born from mothers with healthy habits such as breastfeeding or not smoking, were represented. The growth patterns, as described by the WHO, detect both under-nutrition and obesity and are useful in developed as well as developing countries. The data introduce new reference concepts that focus on how children should grow, rather than merely describing how they grew in a specific time and place[28,29].

Five years after the introduction of the WHO Child Growth Standards, a survey was performed to assess their use and interpretation in national programs of 178 countries worldwide. The results showed that these growth charts have been used universally in pediatric care[30].

To correct for the gap that exists for children between the ages of 5 and 19 years, the WHO collated growth references for children of this age group based on international data from NCHS/WHO 1977[25]. Reference values for height-for-age, weight-for-age and BMI were generated and are considered appropriate (as provisional data) for this age group.

Some anthropometric references have focused on the detection of overweight and obesity, as is the case of the standards of the IOTF[31] created from representative national databases of children and adolescents aged 2 to 18 years from 6 countries (Brazil, Britain, Japan, Netherlands, Singapore, and the United States). Later, the reference values to define thinness were generated based on the same databases from these 6 nations.

The importance of early detection of growth deficit in early life is so that the adverse consequences, which can continue throughout life, can be addressed. These include cognitive or performance deficits in childhood or in adulthood. Also, excessive weight gain during infancy is associated with increased risk of chronic diseases in adulthood.

References

1. Serra-Majem L, Aranceta J. Requerimientos nutricionales e ingestas recomendadas: Ingestas Dietéticas de Referencia. In: Serra-Majem L, Aranceta J, eds. Nutrición y Salud Pública: Métodos, bases científicas y aplicaciones. 2º ed. Barcelona: Elsevier-Masson 2006: pp 20-30.
2. Otten JJ, Hellwig JP, Myers L. Institute of Medicine. Dietary Reference Intakes. The Essential Guide to Nutrient Requirements. Washington D.C: National Academy Press 2006: pp 1-543.
3. Food and Nutrition Board. Institute of Medicine. National Research Council. Dietary Reference Intakes: Risk assessment models for establishing Upper Intake Levels for Nutrients. Washington D.C: National Academy Press, 2000.
4. Food and Nutrition Board. Institute of Medicine. Dietary Reference Intake for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington DC: National Academy Press, 2002.

5. Food and Nutrition Board. Institute of Medicine. National Academies. Dietary Reference Intakes (DRIs). Washington DC: National Academy Press, 2004.
6. World Health Organization. Human vitamin and mineral requirements. Report for a Joint FAO/OMS Experts Consultation. Bangkok, Thailand, Roma: 2002.
7. Scientific Committee on Food. Nutrient and Energy Intakes for the European Community. Report Series nº31. Brussels: Commission of the European communities 1993.
8. Cuervo M, Corbalán M, Baladía E, Cabrerizo L, Formiguera X, Iglesias C, Lorenzo H, Polanco I, Quiles J, Romero de Ávila MD, Russolillo G, Villarino A, Martínez JA. Comparativa de las Ingestas Dietéticas de Referencia (IDR) de los diferentes países de la Unión Europea, de Estados Unidos (EEUU) y de la Organización Mundial de la Salud (OMS). *Nutr Hosp* 2009; 24: 384-414.
9. EURRECA: European Micronutrient Recommendations Aligned; Preparing the Way; a European Commission Network of Excellence. Hautvast J ed. Netherlands: Springer 2008.
10. Beaton GH. Approaches to analysis of dietary data: relationship between planned analyses and choice of methodology. *Am J Epidemiol* 1994; 59: 253S-261S.
11. Serra-Majem L, Aranceta J. SENC Working Group on Nutritional Objectives for the Spanish Population. Spanish Society of Community Nutrition. Nutritional objectives for the Spanish population. Consensus from the Spanish Society of Community Nutrition. *Public Health Nutr* 2001; 4(6A): 1409-1413..
12. Tur JA, Romaguera D, Pons A. Does the diet of the Balearic population, a Mediterranean-type diet, ensure compliance with nutritional objectives for the Spanish population? *Public Health Nutr* 2005; 8(3): 275-283.
13. Aranceta J, Serra Majem Ll. Grupo Colaborativo para la actualización de los objetivos nutricionales para la población Española. Nutritional objectives for the Spanish population. Consensus from the Spanish Society of Community Nutrition. *Rev Esp Nutr Comunitaria* 2011; 17: 178–199
14. Ortega RM, López-Sobaler AM, Ballesteros JM, Pérez-Farinós N, Rodríguez-Rodríguez E, Aparicio A, Perea JM, Andrés P. Estimation of salt intake by 24h urinary sodium excretion in a representative sample of Spanish adults. *Br J Nutr* 2011; 105(5): 787-794.
15. WHO/FAO. Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series No. 916 (TRS 916). Geneva: World Health Organization, 2003. http://www.fao.org/docrep/005/AC911E/AC911E00.htm
16. Ortega RM, López-Sobaler AM, Pérez Farinós N. Associated factors of obesity in Spanish representative samples. *Nutr Hosp* 2013b; 28(5): 56-62.
17. Aranceta J, Serra-Majem L. Working Party for the Development of food-based dietary guidelines for the Spanish population. Dietary guidelines for the Spanish population. *Public Health Nutr* 2001; 4(6A): 1403-1408.
18. Gibson RS. Principles of Nutritional Assessment. 2nd Edition. New York: Oxford University Press 2005.
19. De Onis M, Habicht JP. Anthropometric reference data for international use: recommendations from a World Health Organization Expert Committee. *Am J Clin Nutr* 1996; 64: 650-658.
20. Fryar CD, Gu Q, Ogden CL. Anthropometric reference data for children and adults: United States, 2007–2010. National Center for Health Statistics. *Vital Health Stat* 11 2012; 252: 1-48.
21. Deurenberg P. Universal cut-off BMI points for obesity are not appropriate. Invited commentary. *British Journal of Nutrition* 2001; 85: 135-136.
22. Dobbelsteyn CJ, Joffres MR, MacLean DR, Flowerdew G, The Canadian Heart Health Surveys Research Group. A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. *The Canadian Heart Health Surveys International Journal of Obesity* 2001; 25: 652-661.
23. Alberti KG, Zimmet P, Shaw J. International Diabetes Federation: a consensus on Type 2 diabetes prevention. *Diabet Med* 2007; 24: 451–463.
24. Leis R, Tojo R. Valoración del estado nutricional. In: Tratado de Pediatría, 19 ed. Kliegman RM, Behrman RE ed. Barcelona: Elsevier España 2012.
25. NCHS growth curves for children; birth-18 years, United States. Series 11, number 165. National Center for Health Statistics. Hyattsville: Md, 1977.
26. WHO. Physical status: the use and interpretation of anthropometry. Geneva: WHO-OMS 1995: pp 460-421.
27. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL. CDC growth charts: United States. Adv Data 2000; 8(314): 1-27.
28. WHO multicenter growth reference study group. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. Geneva: World Health Organization, 2006.
29. World Health Organization. WHO child growth standards: head circumference-for-age, arm circumference-for-age, triceps skinfold-for-age and subscapular skinfold-for-age: methods and development. Geneva: World Health Organization, 2007.
30. De Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. WHO Multicenter Growth Reference Study Group. Worldwide implementation of the WHO Child Growth Standards. *Public Health Nutr* 2012; 15(9): 1603-1610.
31. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; 320: 1240-1243.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):168-176
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Intake of energy and nutrients; harmonization of Food Composition Databases

Emilio Martinez-Victoria[1], Ignacio Martinez de Victoria[2] and M. Alba Martinez-Burgos[1]

[1]Department of Physiology, School of Pharmacy, Institute of Nutrition and Food Technology, Centre for Biomedical Research, University of Granada, Granada, Spain. [2]Computer Engineer and Master in Human Nutrition. BEDCA Asociation. Spain.

Abstract

Food composition databases (FCDBs) provide detailed information about the nutritional composition of foods. The conversion of food consumption into nutrient intake need a Food composition database (FCDB) which lists the mean nutritional values for a given food portion. The limitations of FCDBs are sometimes little known by the users. Multicentre studies have raised several methodology challenges which allow to standardize nutritional assessments in different populations and geographical areas for food composition and nutrient intake. Differences between FCDBs include those attributed to technical matters, such as description of foods, calculation of energy and definition of nutrients, analytical methods, and principles for recipe calculation. Such differences need to be identified and eliminated before comparing data from different studies, especially when dietary data is related to a health outcome. There are ongoing efforts since 1984 to standardize FCDBs over the world (INFOODS, EPIC, EuroFIR, etc.). Food composition data can be gathered from different sources like private company analysis, universities, government laboratories and food industry. They can also be borrowed from scientific literature or even from the food labelling. There are different proposals to evaluate the quality of food composition data. For the development of a FCDB it is fundamental document in the most detailed way, each of the data values of the different components and nutrients of a food. The objective of AECOSAN (Agencia Española de Consumo Seguridad Alimentaria y Nutrición) and BEDCA (Base de Datos Española de Composición de Alimentos) association was the development and support of a reference FCDB in Spain according to the standards to be defined in Europe. BEDCA is currently the only FCDB developed in Spain with compiled and documented data following EuroFIR standards.

(*Nutr Hosp* 2015;31(Supl. 3):168-176)

DOI:10.3305/nh.2015.31.sup3.8764

Key words: *Intake of energy. Intake of nutrients. Food Composition tables. Food composition databases. Harmonization. BEDCA.*

Correspondence: Emilio Martínez de Victoria.
Department of Physiology, School of Pharmacy.
Institute of Nutrition and Food Technology.
Centre for Biomedical Research, University of Granada.
Avda. del Conocimiento s/n.
18016 Armilla, Granada. Spain.
E-mail: emiliom@ugr.es

INGESTA DE ENERGÍA Y NUTRIENTES; ARMONIZACIÓN DE LAS BASES DE DATOS DE COMPOSICIÓN DE ALIMENTOS

Resumen

La conversión de consumo de alimentos a ingesta de nutrientes necesita una base de datos de composición de alimentos (FCDB) que recoge los valores nutricionales medios de una porción dada de alimento. Las limitaciones de las FCDBs son, en ocasiones, poco conocidas por los usuarios. Los estudios multicéntricos han planteados varios retos metodológicos que permitan estandarizar la composición de alimentos y la ingesta de nutrientes para la evaluación nutricional en diferentes poblaciones y áreas geográficas. Las diferencias entre FCDBs incluyen las atribuibles a aspectos técnicos, como la descripción de los alimentos, cálculo de energía y definición de los nutrientes, métodos analíticos y principios para el cálculo de recetas. Estas diferencias necesitan ser identificadas y eliminadas antes de comparar los datos obtenidos de diferentes estudios, especialmente cuando dichos datos dietéticos se relacionan con resultados de salud. Desde 1984 se han realizado diversas iniciativas para estandarizar los FCDBs en el mundo (INFOOD, EPIC, EUROFIR, etc.). Los datos de composición de alimentos pueden ser obtenidos de diferentes fuentes como análisis de empresas privadas, universidades, laboratorios gubernamentales e industria alimentaria. También pueden tomarse prestados de la literatura científica o incluso del etiquetado nutricional. Existen diferentes propuestas para evaluar la calidad de los datos de composición de alimentos. Para el desarrollo de una FCDB es fundamental documentar, lo más detallado posible, cada uno de los valores de los diferentes componentes y nutrientes de un alimento. El objetivo de la AECOSAN y la asociación BEDCA fue el desarrollo y mantenimiento en España de una FCDB de acuerdo con los estándares definidos para Europa. BEDCA es actualmente la única FCDB desarrollada en España con datos compilados y documentados siguiendo los estándares de EuroFIR.

(*Nutr Hosp* 2015;31(Supl. 3):168-176)

DOI:10.3305/nh.2015.31.sup3.8764

Palabras clave: *Ingesta de energia. Ingesta de nutrientes. Tablas de composición de alimentos. Bases de datos de composición de alimentos. Harmonización. BEDCA.*

Introduction

Food composition databases (FCDBs) provide detailed information about the nutritional composition of foods[1]. Food composition data may be available in different formats a) paper-based, often referred to as food composition tables (FCT), or b) electronic versions, known as nutrient databases or databanks[2].

Nutritional assessment by diet analysis is a process of two steps: the first step is the evaluation of food consumption, and the second the conversion of food into nutrient intake. To accomplish this, we need a FCDB which lists the mean nutritional values for a given food portion. We then multiply food intake by the mean nutrient content of that amount of food (obtained from the FCDB). As most professionals conducting nutritional assessments are primarily concerned with the evaluation of food intake, a large part of the literature on nutritional assessment focuses on minimizing errors at this step. However, errors and discrepancies may arise in nutrient estimation from the FCDB[3].

Apart from this important use, FCDBs o FCT, this tools are also needed for the development of nutritional guides about food information, consumer education, labelling, food legislation, marketing, development and reformulation of food products, medical practice, etc.[2, 4]. Information on food composition is of great importance for scientists and practitioners working in the fields of nutrition and public health. The most apparent role is to provide the basis for dietary assessment and the formulation of healthier diets. Nutrition, food-based dietary guidelines and health claims have to be supported by scientific evidence including data on food content in nutrients and energy. Today, the close relationship between nutrition and health requires additional information like the content of bioactive compounds, mainly in plant foods and also of potentially harmful compounds, the contaminants[1].

Limitations of Food Composition Databases (FCDBs)

The limitations of FCDBs are sometimes little known by the users. Food are based on the animal and vegetal kingdom. Are biologic products and due to that, they show changes in their composition. This variability lies in[1, 2, 5]:

a. Differences in the plant or animal species, and even intraspecies differences.
b. Environmental factors like the soil type or the climate. The presence of different amount of nutrients, especially minerals like iodine or selenium, can determine the mineral content in vegetables and also indirectly the compositional of animals that feed on them.
c. Differences in the agricultural and livestock practices and in the storage like the cultivation on irrigated or dry lands, in the case of vegetables. Regarding livestock, the type of feed and the composition of feed and pastures. The place and status of the storage (humidity, light, oxygen, etc.) can also modify the food composition.
d. The food processing and packaging. This technological and culinary processes (temperature, hydrogenation, light, pH, etc.) present in the industry and homes, have an important influence in the food composition as many of the nutrients and food compounds are affected by them.

Furthermore, not all the nutrients and food components are affected in a similar way. Macronutrient changes (carbohydrates and proteins) are less than micronutrients ones (minerals and vitamins). Regarding several nutrients like fats from macronutrients and Vitamin C and folates from micronutrients, the variance range is very wide[1, 2, 5].

There are also errors and discrepancies in the nutrient content of FCDBs foods which origin is the methods of analysis used for the estimation, sampling procedures and the date the food is gathered to be analysed[6].

Harmonization of food composition data

With the objective of establish and harmonize several actions in the nutrition and public health fields, it has been necessary to carry out multicentre studies. This kind of studies have raised several methodology challenges which allow to standardize nutritional assessments in different populations and geographical areas for food composition and nutrient intake[7]. FCDBs needed for the calculation of the nutrient intake from food consumption are a source of random and systematic errors in the determination of the intake composition.

National FCDBs and calculation procedures of nutrient intake differ between many countries in the world[8] or between different national FCDBs within the same country. The use of different countries FCDBs or different national databases are particularly prone to error when used to estimate nutrient intake[9]. To mitigate this scenario, there exists a strong need to harmonize and standardize existing data and collect new data on food composition[10].

Differences between FCDBs include those attributed to technical matters, such as description of foods, calculation of energy and definition of nutrients, analytical methods, and principles for recipe calculation. Such differences need to be identified and eliminated before comparing data from different studies, especially when dietary data is related to a health outcome[11].

Several studies have been carried out to compare nutrient intake data calculated by different dietary analysis programs used in the same country. Significant differences have been disclosed between the databa-

ses for a number of examined nutrients. For example, Taylor et al.[12] compared nutrient intake data calculated from 24-day dietary records using three major American nutrient database systems. Differences in the mean values were found for nine of the 19 nutrients evaluated. In another study, nutrient intakes of 60 subjects calculated with two databases were compared[11]. The energy and nutrient composition of many commonly used foodstuffs was found to be different[13].

In recognition of these difficulties there are ongoing efforts since 1984 to standardize food composition databases over the world[6]. This is a continuous process because of increased global trade in foods, changes in fortification policies, development of newer assays for nutrient estimation, and addition of new foods in the global diet. In Europe, this effort was followed by other regional initiatives and proposals such as EUROFOODS COST99 and NORFOODS[14, 15, 16] and more recently, an EU concerted action, EFCOSUM, proposed recommendations to harmonize methodology for monitoring national nutritional surveys in Europe, including the use of NDBs[7, 17]. In 2009 EFSA published a guide which contains the general principles for the collection of national food consumption data from the view of a pan-European dietary survey, including those related to FCDBs[17].

The European prospective investigation into cancer and nutrition (EPIC) was designed to investigate the relationships between diet, nutritional status, lifestyle and environmental factors and the incidence of cancer and other chronic diseases. In the absence of a pan-European food composition database, EPIC developed a method to improve the comparability of the nutrient databases among its 10 participating countries (Spain included) and built the EPIC Nutrient Database (ENDB). The main objective of the ENDB project was to provide a standardized nutrient database for calibrating the EPIC dietary data and investigating diet-disease relationships at the nutrient level. The ENDB constitutes the first real attempt to improve the comparability of NDBs across European countries. This methodological work provides a useful tool for nutritional research as well as end-user recommendations to improve NDBs in the future[7].

In the last ten years, the former Network of Excellence (NoE) of the VI Framework programme of the European Union, European Food Information Resource (EuroFIR), now EuroFIR AISBL (http://www.eurofir.org) has contributed in the harmonization of the FCDBs in Europe. It has developed nutrient databases and other food components (bioactive components) that can be compared across more than twelve European countries[17]. One of the results of this work has been the development of a tool, FoodExplorer that allows the comparison of different values of different nutrients for a set of similar foods from different European databases and databases from Australia, Canada and United States. Besides, this organization is supporting the food plant bioactive component database along with NORTOX, formerly known as BioActive Substances in Food Plants Information System (eBASIS, http://ebasis.eurofir.org/)[18].

Nowadays, the information provided by EuroFIR AISBL includes more than 60.000 foods, 13.000 recipes and 3.500 branded foods, included in the tool FoodExplorer. Apart from the food composition information, this tool provides the information related the method of analysis of each component, bibliographic references and further details about the source of the food data. Another important feature is the adoption of the LanguaL thesaurus for describing foods[18].

Food composition data quality

The outstanding growing of FCDBs has provoked that food compilers needed to know the limitations of food composition data to inform the final user about these by following a quality criteria (Finglas, 2014)[18].

Food composition data can be gathered from different sources like private company analysis, universities, government laboratories and food industry. They can also be borrowed from scientific literature or even from the food labelling. Regarding labelling food information, they can be calculated from analytical data of similar products or similar ingredients in case of composite foods. This variability makes the need of having a set of criteria to evaluate the quality of this data. This criteria should include the representativeness of the food data to be published in a FCDB, as well as the availability and the clarity of the information in order to be reviewed and properly selected for a specific use[19, 20].

There are different proposals to evaluate the quality of food composition data. For EuroFIR, data which origin is a report or scientific paper, the quality of the food, based on previous system such as the ones from USDA, AFFSA (ANSES), BASIS, CSPO, BSL, has been classified in different categories: Food Description, Component identification, sampling plan, number of samples for analysis, sample handling, method of analysis, and quality control analysis. For each of these categories it is established a scale from one to five (low quality, medium and high, with two additional values). From this rating it is calculated a quality index (QI) which ranges from seven to thirty-five. Categories and criteria are included in table 1[19, 20, 21].

Documentation of Food component values

For the objective of informing the FCDB user about the quality of food data and the harmonization for the exchange which other FCDBs, it is necessary a process of documentation that includes de detailed description of the foods and their values for each of the food components. Due to this, EuroFIR has developed a complete description and documentation system (Quality

Table I
Categories and criteria for quality assessment to original data from scientific literature and reports in EuroFIR interchange data. (From: 20)

Categories	*Criteria*
Food Description	
	A. FOR ALL TYPES OF FOOD
	Is the **food group** (e.g. beverage, dessert, savory snack, pasta dish) known?
	Was the **food source** of the food or of the main ingredient provided (best if scientific name included, cutivar/variety, genus/species, etc.)?
	Was the **part of plant or part of animal clearly** indicated?
	If relevant was the **analyzed portion** described and is it clear if the food was analyzed with or without the inedible part?
	Is the extent of **heat treatment** known?
	If the food was cooked, were satisfactory **cooking method** details provided?
	Was relevant information on **treatment applied** provided?
	Was information on **preservation method** provided?
	If relevant, was information on **packing medium** provided?
	If relevant, was information about the geographical **origin of the food** provided?
	If relevant, was the **month or season** of production indicated?
	Was the **moisture** content of the sample measured and the result given?
	B: FOR MANUFACTURED PREPACKED FOOD ONLY
	Was the **generic name** provided (e.g. chocolate paste with hazelnuts)?
	Was the **commercial name** provided (e.g. Nutella)?
	Guidelines for quality index attribution to original data… 12/10/2009
	If relevant, Was the **brand** provided (e.g. Ferrero)?
	Was relevant information on **consumer group/ dietary use/label claim** provided?
	C: FOR HOME MADE DISHES OR FOODS SOLD IN RESTAURANTS
	Was the **complete name and description** of the recipe provided?
Component Identification	
	Is the component described unambiguously?
	Is the unit unequivocal?
	Is the matrix unit unequivocal?

Evaluation system for original data from SCIentific literature or REPort, QE-SCIREP) which is being described below.

Food description. For the harmonization task it is necessary that the foods are correctly and accurately described. A food that has composition data of high quality could be a source of error if it is not well described, as it may lead to confusion because of synonyms, not accurate names or a food processing previous to marketing, among other reasons.

There are two types of system to solve this problem, classification and description systems. LanguaL is a Multilanguage description system (it is translated to Czech, Danish, English, French German, Italian, Portuguese, Spanish and Hungarian) and was created at the end of 1970 by the Centre of Food Safety and Applied Nutrition (CFSAN) in the United States, and it is the one that was chosen by EuroFIR[21].

It is a multilevel thesauri formed by fourteen different food facets. The set of terms that form this Thesauri is organized in facets and for each facets, terms are grouped in different levels. As an example the Facet A is the one that classifies the food in all the systems that LanguaL includes. Before entering foods in a FCDB, it is necessary to describe them using the LanguaL thesauri[21].

For the correctness of the codification process, it is necessary in many of the foods, to gather information regarding the nutritional labelling and the ingredients composition, as well as know the technological pro-

Table I (cont.)
Categories and criteria for quality assessment to original data from scientific literature and reports in EuroFIR interchange data. (From: 20)

Categories	*Criteria*
Sampling Plan (For All Types Of Foods)	Was the sampling plan developed **to represent the consumption in the country where the study was conducted**?
	Was the **number of primary samples >** 9?
	If relevant, were samples taken during **more than one season** of the year?
	If relevant, were samples taken from **more than one geographical location**?
	If relevant, were samples taken from **the most important sales outlets (supermarket, local grocery, street market, restaurant, household etc)**?
	If relevant, was **more than one brand** (for manufactured pre-packed product) or more than one cultivar (for plant foods) or **subspecies** (for animal foods) sampled?
Sample Handling	
	If relevant, were appropriate stabilization treatments applied (e.g. protection from heat/air/light/microbial activity)?
	Were the samples homogenized?
Analytical Method	
	Does the analytical method used in the source match the list of appropriate analytical methods given in the guidelines for analytical methods?
	Are the key method steps appropriate for the method described?
Analytical Quality Control	Were analytical portion replicates tested?
	Was the laboratory accredited for this method or was the method validated by performance testing?
	If available, was an appropriate reference material or a standard reference material used?

cesses behind the development of them, their handling and packaging. There is a software named LanguaL Product Indexer to index foods, developed by EuroFIR and LanguaL[21].

Recently the EFSA has developed a new food codification system for the identification of food called FoodEx2 (Food classification and description system)[22].This system has been developed with the aim of being used for trans European studies for nutritional assessment and the exposure of the population to contaminants and other harmful components that are present in food.

Documentation of nutrient data and food components[20, 21]. For the development of a FCDB it is fundamental document in the most detailed way, each of the data values of the different components and nutrients of a food. This should be achieved in case of data from scientific publications, borrowed from other FCDBs or FCT, calculated, estimated or assumed.

For this documentation process, it has been developed a set of Thesaurus for this task by EuroFIR. These are:

- Acquisition type. It includes the different categories of the data value origin, for example, data published in a journal with reviewers, nutritional labelling, other FCT, etc.
- Reference type. It includes the categories for the bibliographic reference of the data value. For example, book, journal article, web page, etc.
- Unit. It includes terms that describe the measurement used for the quantity. It also includes terms for numbers without units. Grams, milligrams, niacin equivalents, ratio, percentage, etc.
- Matrix unit. It includes terms for the quantity of food that contains the value of the described component. Some examples are per 100g dried food, per 100 ml, per 100g of edible portion, etc.
- Value type. It includes the categories for a better description of the data value or for giving a qualitative description of the value when it cannot be chosen a concrete value. Value types can be: media, median, logic zero, trace, less than, etc.
- Method type. It includes the categories assigned to a data value to describe a general description of the type of method used for obtaining it. Analytical, calculated as a recipe, estimated, are some of the terms used.

- Method indicator. It includes the categories and descriptors that identify the method of analysis or calculation that is being used to obtain the value published in the FCT or FCDB. Some example are polarimetry, animal bioassay, gas chromatography, by difference, etc.
- Component. In this last thesaurus it is included the codes and definitions of the different food components. It includes terms such as Energy, saturated fatty acids, beta-carotene calculated from total Vitamin A, vitamin D activity calculated as ergocalciferol, etc.

Including this information in a FCDB gives the possibility of the data values to be evaluated by the users as well as knowing the quality of a concrete value based on criteria such as the value type (analytic, borrowed or calculated), the used method, the quality of the source and the reference, etc. (Figure 1). On the other hand, the standardization and harmonization in the definition of a component, the unit and matrix unit as well as the value type, etc. allow the interchange of food composition data across different FCDBs. All the aforementioned ease the development of transnational multicentric studies in the field of Food, Nutrition and Public Health[18].

Spanish FCDB. BEDCA

In Spain, the first works directed toward the publication of food composition information date from 1932[23, 24]. Several FCTs elaborated by different authors have been published since, although it was in 1996 when the Ministry of Health published an official one[24].

Numerous FCTs exist in Spain, developed by different authors of different Research Centers and Universities. Each of them has been developed with different methods and technologies chosen based on the requirements and the available sources of data. Because of this, it exists a great variability in the description of the foods, and, in general terms, the data of the different components is not analytical but borrowed from bibliography, FCTs or FCDBs and not documented individually[25, 26]. Besides, after reviewing the different studies carried out in Spain in population and group of people like national surveys (ENRICA, DRECE, etc.), regional ones (País Vasco, Comunidad de Madrid, Andalucía, Canarias, etc.) it is found that the transformation of the food consumption data to nutrient intake has been done with different food composition data, some of them coming from one FCT or from on-demand FCTs developed with different national and not national FCTs. Given this, as it has been mentioned before, it cannot be compared, in a reliable way, the results of the intakes obtained in different populations or group of people, even if the applied method to know the food consumption is the same.

In 2004, the AESAN (Spanish Agency of Food Safety and Nutrition) set up a work group including two of the partners of EuroFIR network, INYTA from the University of Granada and CESNID from University of Barcelona. Based on this core, other research centers and universities have incorporated, as well as associations of food industry such as FIAB and foundations related to nutrition (Triptolemos). All of them formed the BDECA network, funded by the Ministry of Science and Education. The objective of this network was the development and support of a reference food composition database in Spain according to the standards to be defined in Europe by the NoE EuroFIR, by working closely with them. For this purpose, the main sources of food data in Spain and other potential sources were identified as well as a website as a platform for the network, its activities and a host for the food composition database was designed and developed[24, 25].

To develop the database, BDECA members which belonged to EuroFIR, ask for candidate food sources to the rest of the BDECA members. Once they were identified a compilation and documentation process began according to the standard EuroFIR was developing. The sources of data for BEDCA database (www.bedca.net) were the different FCTs published in Spain and analytic data granted by University researchers and Public Research Centers[23, 24].

The chosen method for the compilation of data was the indirect method with a detailed scrutiny, unification and processing of the data and metadata granted by the network members. To accomplish this task, an information system developed by the University of Barcelona was used[26]. This system added basic information about the food, components, values and methods and sources related the food composition. (Figure 1)

The compilation model of the data includes:

a. LanguaL codification of foods
b. Documentation of the values of the components from each food according to EuroFIR thesauri regarding value acquisition method, reference, unit, matrix unit, method type, method indicator and component[20, 21, 22, 23, 24]. (Fig. 1).

Nowadays BEDCA is an association that along with AECOSAN which gives it institutional support and funding, develop and support the FCDB, being as well, the national compilers for EuroFIR AISBL in Spain, which they belong to. BEDCA release 1 has a total of 950 foods and 34 components.

BEDCA has been used in the ENIDE study developed by AECOSAN, a national survey about the food consumption with more than 3.000 adult individuals and more than 300.000 food inputs.

For the transformation from food consumption surveys into nutrient intake data in ENIDE study, a food matching algorithm was developed. The algorithm, with a heuristic and ruled based design, allowed us to identify one or more candidate BEDCA foods for a food entry and then calculate the intakes based on the composition of the matched foods. The algorithm results were reviewed manually by nutritionists who were calibrating the algorithm during the development.

Fig. 1.— Screenshots of the Web site of BEDCA Database (www.bedca.net). Documentation of the foods and components.

The use of this algorithm implied a great improvement in time and manual work efficiency as well as a unified criteria for transforming a diary food consumption into a list of database foods. It is also a basis for further work with food consumption data.

It is not sufficient to standardize and harmonize the process of compiling food composition data but also how this information is shared with humans, and also with machines. With this objective several groups in EuroFIR worked on a standard to share food information in electronic format. Using XML as the language to define it, the Food Data Transport Package (FDTP) was developed, nowadays in its 1.4 version. It serves as a container for food composition information and also a basis to validate the information based on a mandatory/optional data definition[27].

Based on the development of FDTP, EuroFIR designed a strategy to share food information between EuroFIR and the national FCDBs that were partners. It was chosen a decentralized mechanism using web services. A set of different operations based on Food Data Query Language (FDQL) were defined thus EuroFIR could search information from different national FCDBs in real time[28]. BEDCA participated in its design and was one if the first partners to implement this web services that nowadays are still available to EuroFIR and other agents.

As a conclusion BEDCA is currently the only food composition database developed in Spain with compiled and documented data following EuroFIR standards and it is included in the tool FoodExplorer. Moreover, for its 2.0 version it has been added all the food that are present in the surveys from the ENIDE study.

Acknowledgements

Our thanks to all members of BEDCA and AECOSAN for their advice and support.

References

1. Elmadfa, I., & Meyer, A L. (2010). Importance of food composition data to nutrition and public health. European Journal of Clinical Nutrition, 64 Suppl 3(S3), S4–7. doi:10.1038/ejcn.2010.202
2. Williamson, C. (2005). EuroFIR. Synthesis report No 2 : The Different Uses of Food Composition Databases.
3. Willett W: Food Frequency Methods. In Nutritional epidemiology. Volume 5. Second edition. Edited by: Willett W. New York, Oxford University Press; 1998:74-100
4. M.A. Roe, S. Bell, M. Oseredczuk, T. Christensen, S. Westenbrink, H. Pakkala, K. Presser and P.M. Finglas, (2013). Updated food composition database for nutrient intake. *EFSA supporting publication* 2013: EN-355, 21 pp.
5. Egan, M. B., Fragodt, a, Raats, M. M., Hodgkins, C., & Lumbers, M. (2007). The importance of harmonizing food composition data across Europe. *European Journal of Clinical Nutrition* 61(7), 813–21.
6. Scrimshaw NS. (1997) INFOODS: the international network of food data systems. *Am J Clin Nutr* 65:1190S-1193S
7. Slimani, N., Deharveng, G., Unwin, I., Southgate, D. a T., Vignat, J., Skeie, G and Riboli, E. (2007). The EPIC nutrient database project (ENDB): a first attempt to standardize nutrient databases across the 10 European countries participating in the EPIC study. *European Journal of Clinical Nutrition* 61(9), 1037–56.
8. Deharveng G, Charrondiere R, Slimani N, Riboli E, Southgate DAT (1999). Comparison of food composition tables available in the nine European countries participating in EPIC. *Eur J Clin Nutr* 53, 60–79.
9. Merchant, A. T., & Dehghan, M. (2006). Food composition database development for between country comparisons. *Nutrition Journal* 5:2
10. Becker W (2010) CEN/TC387 Food Data. Towards a CEN Standard on food data. *Eur J Clin Nutr* 64 Suppl 3:S49-52.
11. Taylor ML, Kozlowski BW & Baer MT (1985): Energy and nutrient values from different computerized data bases. *J Am Diet Assoc* **85**, 1136–1138. Shanklin D, Endres JM & Sawicki M (1985): A comparative study of two nutrient data bases. *J Am Diet Assoc* **85**, 308–313.
12. Hakala, P., Knuts, L.-R., Vuorinen, a, Hammar, N., & Becker, W. (2003). Comparison of nutrient intake data calculated on the basis of two different databases. Results and experiences from a Swedish-Finnish study. *European Journal of Clinical Nutrition* 57(9), 1035–44.
13. Møller, A. (1992). NORFOODS computer group. Food composition data interchange among the Nordic countries: A report. In International Food Databases and Information Exchange, eds. A.P. Simonopoulos, R.R. Butrum, *World Rev Nutr Diet* Vol. 68:104-120. Karger, Basel, Switzerland
14. Schlotke, F. (1996). Using Internet services to improve international food data exchange. *Food Chem* 57, 137-143.
15. Unwin I, Becker W (1996). The component aspect identifier for compositional values. *Food Chemistry* – the Second International Food Database Conference 57, 149–154.
16. EFSA. (2009). General principles for the collection of national food consumption data in the view of a pan-European dietary survey 1, 7(12), 1–51.Available online: http://www.efsa.europa.eu/de/scdocs/doc/1435.pdf
17. Finglas PM, Berry R, and Astley S (2014) Assessing and Improving the Quality of Food Composition Databases for Nutrition and Health Applications in Europe: The Contribution of EuroFIR**.** *Adv Nutr* 5 608S-614S;
18. Kiely M, Black LJ, Plumb J, Kroon PA, Hollman PC, Larsen JC, Speijers, GJ,Kapsokefalou M, Sheehan D, Gry J, Finglas P. (2010) EuroFIR consortium. EuroFIR eBASIS: application for health claims submissions and evaluations. *Eur J Clin Nutr*;64 Suppl 3:S101-7
19. Holden JM. (1996) Expert systems for the evaluation of data quality for establishing the Recommended Dietary Allowances. *J Nutr* 126(9 Suppl):2329S-2336S.
20. Oseredczuk M, Salvini S, Roe M and Moller A (2009). Eurofir workpackage 1. 3, task group 4. Guidelines for quality index attribution to original data from scientific literature or reports for EuroFIR, 35, 1–36.
21. Ireland JD, Møller A. (2010) LanguaL food description: a learning process. *Eur J Clin Nutr* 64 Suppl 3:S44-S48
22. European Food Safety Authority; The food classification and description system FoodEx 2 (draftrevision 1). Supporting Publications 2011:215. [438 pp.]. Available online: www.efsa.europa.eu
23. Martínez Burgos, M. a., Martínez-Victoria, I., Milá, R., Farrán, a., Farré, R., Ros, G, Martínez-Victoria, E. (2009). Building a unified Spanish food database according to EuroFIR specifications. *Food Chemistry* 113(3), 784–788
24. Ros, G., Martínez de Victoria, E., & Farran, a. (2009). Spanish food composition database: A challenge for a consensus. *Food Chemistry* 113(3), 789–794.
25. Requejo AM, Ortega RM, Andrés P, Ruiz F, Sánchez-Muniz F, González-Fernández M. y col. Tablas de Composición de Alimentos Españoles. Edición coordinada por: Carretero ML y Gómez MD. (Subdirección General de Higiene de los Alimentos). Madrid: Ministerio de Sanidad y Consumo (Secretaria General Técnica); 1996

26. Farran Codina, Andreu. Desarrollo y aplicación de un sistema de información para la elaboración de tablas de composición de alimentos. Tesis Doctoral. Universidad de Barcelona, 2004.
27. Møller A, Christensen T (2008). EuroFIR Web Services—Food Data Transport Package, Version 1.3. EuroFIR Technical Report. EuroFIR. Retrieved 13 April 2010 from: http://www.eurofir.net/sites/default/files/TechWeb%20Downloads/WebServices/D1.8.29 CoverWithDocument.pdf
28. Pakkala, Heikki; Christensen, Tue et al. Harmonised information exchange between decentralised food composition database systems. *European Journal Of Clinical Nutrition* 2010 (64)

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):177-188
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Biomarkers: background, classification and guidelines for applications in nutritional epidemiology

Dolores Corella[1,2] and José M. Ordovás[3,4,5]

[1]Unidad de Epidemiología Genética y Molecular. Departamento de Medicina Preventiva y Salud Pública, Ciencias de la Alimentación, Toxicología y Medicina Legal. Universidad de Valencia. [2]CIBER Fisiopatología de la Obesidad y Nutrición. Instituto de Salud Carlos III, Madrid. [3]Department of Cardiovascular Epidemiology and Population Genetics, Centro Nacional de Investigaciones Cardiovasculares (CNIC), Madrid. [4]IMDEA Alimentación, Madrid. Spain. [5]Nutrition and Genomics Laboratory, JM-USDA Human Nutrition Research Center on Aging at Tufts University, Boston, MA. USA.

Abstract

One of the main problems in nutritional epidemiology is to assess food intake as well as nutrient/food component intake to a high level of validity and reliability. To help in this process, the need to have good biomarkers that more objectively allow us to evaluate the diet consumed in a more standardized, valid and precise way has often been commented upon. There are various definitions of biomarkers and also different classifications of the same. In general a biomarker can be defined as a characteristic that can objectively measure different biological samples and that can be evaluated as an exposure marker of normal or pathogenic biological processes or of responses to a certain intervention. The biological samples most commonly used in nutritional epidemiology are blood, red blood cells, plasma, serum, urine, nails, saliva, faeces and samples of different tissues. Exposure biomarkers (dietary intake), biomarkers of effects and biomarkers of disease status can be determined from these samples. In turn, exposure biomarkers can be temporarily categorized into markers of acute, medium term or chronic effects. Many difficulties arise in identifying good biomarkers. Currently, advances in omics are opening up new possibilities for obtaining new biomarkers of various kinds, using genomics, epigenomics, transcriptomics, lipidomics, proteomics and metabolomics. We shall review the present situation of biomarkers in nutritional epidemiology as well as the future trends of the new omic biomarkers.

(*Nutr Hosp* 2015;31(Supl. 3):177-188)

DOI:10.3305/nh.2015.31.sup3.8765

Key words: *Biomarker. Diet. Intake. Biological sample. Genomics. Transcriptomics. Metabolomics.*

Correspondence: Dolores Corella.
Departamento de Medicina Preventiva y Salud Pública.
Facultad de Medicina.
Avda. Blasco Ibáñez, 15.
46010-Valencia.
E-mail: dolores.corella@uv.es

BIOMARCADORES: ANTECEDENTES, CLASIFICACIÓN Y GUÍA PARA SU APLICACIÓN EN EPIDEMIOLOGÍA NUTRICIONAL

Resumen

En los estudios de epidemiología nutricional uno de los principales problemas es conocer la ingestión de alimentos y sus componentes de manera válida y precisa. Para ayudar en este proceso se ha planteado repetidas veces la necesidad de contar con buenos biomarcadores, que de manera más objetiva nos permitan conocer de manera más estandarizada, válida y precisa la dieta consumida. Existen varias definiciones de biomarcador y también distintas clasificaciones de los mismos. En general un biomarcador es una característica que puede medir objetivamente en distintas muestras biológicas y que puede evaluarse como indicador de exposiciones, de procesos biológicos normales o patogénicos o de respuestas a una intervención determinada. Las muestras biológicas más utilizadas en epidemiología nutricional son sangre total, eritrocitos, plasma, suero, orina, uñas, saliva, heces y muestras de distintos tejidos. En estas muestras se pueden determinar biomarcadores de exposición (ingesta dietética), biomarcadores de efectos y biomarcadores de estado de enfermedad. A su vez los biomarcadores de exposición pueden categorizarse temporalmente en biomarcadores de efectos agudos, a medio plazo y crónicos. Existen muchas dificultades en la identificación de buenos biomarcadores. Actualmente los avances en las nuevas ómicas están abriendo nuevas posbilidades para la obtención de nuevos biomarcadores de distintos tipos utilizando genómica, epigenómica, transcriptómica, lipidómica, proteómica y metabolómica. Revisaremos el estado actual de los biomarcadores en epidemiología nutricional así como las tendencias futuras de los nuevos biomarcadores ómicos.

(*Nutr Hosp* 2015;31(Supl. 3):177-188)

DOI:10.3305/nh.2015.31.sup3.8765

Palabras clave: *Biomarcador. Dieta. Ingesta. Muestra biológica. Genómica. Transcriptómica. Metabolómica.*

Background

The limitations of questionnaires are widely recognised when it comes to measuring dietary intake with sufficient validity and accuracy. Although efforts are made to improve the validity of those tools by using dietary records or various 24-h recalls instead of the less accurate food frequency questionnaires, random and systematic bias, which make self-reported dietary measurements diverge from the reality, always exists[1]. Moreover, these errors in measuring food intake extend to nutrients and other food components derived from the food consumed, not only because the intake has not been noted down with sufficient validity and accuracy, but because there are other factors such as variability in the composition of the food consumed, etc. which also contributes to nutrients and food components derived theoretically from food composition tables not being faithfully adjusted to the real consumption. Measuring these intakes well is very important because, on most occasions, nutritional studies not only have the aim of getting to know the dietary intake of a certain population, but also a second step which is to study the associations between food intake and a certain health problem. It is, therefore, clearly true that the accurate assessment of dietary exposure is crucial in investigating associations between diet and disease. Hence, other alternative means are required for getting to know the food and nutrient intake (and non-nutritive food components) contributed by the same with greater validity and accuracy than that obtained through self-reported measures.

Nutritional biomarkers are important for future research into associations between diet and health, as they can provide an objective assessment method for dietary exposure. However, the definition of biomarker is not simple and there are indeed many definitions depending on the application of those biomarkers. A widely used definition of biomarker was provided by the Biomarker Definition Working Group (BDWG)[2] in 2001. According to this, a biomarker is a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes or pharmacologic responses to a therapeutic intervention. However, this definition of biomarker is not well suited to all situations and many variations of the same have been proposed[3]. In nutritional research, we have to use a broad definition and also one that is adaptable to each situation as we will need biomarkers that cover at least the following aspects: dietary intake, nutritional status, nutrient exposure, effects of nutritional interventions on physiological and/or pathological outcomes and to provide information on inter-individual differences in response to diet. We should also bear in mind that many biomarkers can fall into more than one of these categories.

Currently, the study of nutritional biomarkers, whether they be biochemical, functional, or clinical indices of nutrient intake or of metabolism, are revolutionizing our understanding of the role of nutrients and food components in health and disease. Although there is huge interest in the use and development of new biomarkers, the present situation is that we still do not have good biomarkers for most of the previously mentioned important aspects. This is so much so that various public and private research organizations are stressing the need to delve deeper into the investigation of new nutritional biomarkers and are providing an impetus to research along these lines. Thus, since one of the initial conclusions of the European Commission-funded project PASSCLAIM, coordinated by ILSI Europe, was that there is a need for adequate markers in nutrition sciences, research into better biomarkers (among them the recent initiatives of the Joint Programming Initiative (JPI) on food and nutrition in Europe, which this year began financing two new projects (MIRDIET and FOODBALL), has been considered a priority. These projects aim at the validation of biomarkers and the investigation of intake/exposure and nutritional status of biomarkers in the area of nutrition and health, the former being focused on microRNAs and the latter on the application of metabolomics. The United States is now promoting projects aimed at research into nutritional biomarkers and in April, 2012, the Sackler Institute for Nutrition Science and the New York Academy of Sciences organized a conference entitled *Biomarkers in Nutrition: New Frontiers in Research and Application*. The aim of this conference was to get scientists and practitioners from industry, academia, and government organizations to work together on assessing the current state of knowledge about nutritional biomarkers, to identify important challenges and unanswered questions, and to catalyze new research in the field so that soon it may be possible to implement good biomarkers in nutritional epidemiology that will enable a better measuring of food intake, its effects, and its association with states of health-disease.

In this article, we shall review present knowledge on biomarkers in nutritional epidemiology and will go deeper into the new omics as these are poised to revolutionize the identification of new markers in nutritional studies.

Classification of biomarkers and guidelines for use

The use of biomarkers was first described by Isaakson in 1980 when he proposed urinary nitrogen as an independent measure of protein intake and it remains one of the most common biomarkers used[1]. However, not all biomarkers share the same characteristics. There are different classifications of biomarkers. Potischman[4] defined a biomarker as "any biological specimen that is an indicator of nutritional status with respect to intake or metabolism of dietary constituents. It can be biochemical, functional or clinical index of status of an essential nutrient or another dietary constituent". This author classified biomarkers into two large groups:

Biomarkers of nutritional exposure and biomarkers of nutritional status. Exposure biomarkers would be those used for validating dietary measurement, or as a surrogate of dietary intake. Both those and the biomarkers of nutritional status should be evaluated according to precision, accuracy, sensitivity, specificity to the nutrient, variability between subjects and temporality[3]. However, this definition can be extended on taking into account that in nutritional studies, we are not only interested in measuring the diet well, but also its relationship with states of health-disease, so, in nutritional studies, it is also necessary to incorporate the measurements of biomarkers related with disease so as to have more complete determinations. Table I shows this extended classification of biomarkers in nutritional studies for these purposes. The nutritional biomarkers' role in health and disease has evolved from markers of deficiency in one specific disease (e.g. vitamin A and eyes), to a multitude of chronic conditions spanning the endocrine, cardiovascular, respiratory, digestive, immune, and nervous systems, among others.

However, biomarkers can also be classified depending on their temporality[5]. Thus, biomarkers can be categorized into short-term (reflecting intake over past hours/days), medium-term (reflecting intake over weeks/months) and long-term biomarkers (reflecting intake over months/years). The type of biological sample used for the analysis of these biomarkers is a main determinant. For example, biomarkers measured in urine, plasma or serum reflect short-term intakes well, whereas measurements of biomarkers in red blood cells or in adipose tissue are markers of medium-term intake. Likewise, biomarker measurements in hair, nails, or teeth, are more often employed as long-term biomarkers[5].

Another classification of biomarkers distinguishes between *recovery, concentration, replacement and predictive* biomarkers[6]:

Recovery biomarkers are based on the concept of the metabolic balance between intake and excretion over a fixed period of time and then provide an estimate of absolute intake levels. Recovery biomarkers are specific biologic products that are directly related to intake and not subject to homeostasis or substantial inter-individual differences in metabolism. Only a few recovery biomarkers are known. The best examples of recovery biomarkers are as follows: doubly labeled water which is utilized to measure the metabolic rate and total energy expenditure; urinary total nitrogen/potassium which are utilized to estimate total daily protein consumption and potassium intake, respectively[7,8]. The first large validation study with recovery biomarkers was the Observing Protein and Energy Nutrition (OPEN) Study[9], conducted by the National Cancer Institute in 1999-2000. Among the other later studies into these recovery markers, we should mention the work of Dr. Prentice and his group on a sub-sample of women who were participating in the Women's Health Initiative Dietary Modification Trial (WHI-DM)[10,11]. The WHI-DM is a randomized controlled trial among postmenopausal women aimed at analyzing whether a low-fat diet reduced the incidence of breast and colorectal cancer, and secondarily, heart disease[10]. The subset of women, completed a food frequency questionnaire (FFQ), the doubly labeled water protocol, and a 24-hour urine collection (as biomarker for protein consumption). The collection of these recovery biomarkers allowed the researchers to characterize the measurement error distributions of energy and protein assessed by the FFQs[10]. In addition, they were able to identify the general characteristics (age, sex, obesity, etc) of the participants who made the measurement greater errors in the FFQs[10,11]. In this specific study, they were able confirm that FFQs underreported the consumption of energy and protein. They also reported that the energy underreporting was greater among overweight/obese women and younger women. These results enabled them to create regression calibration equations for energy and protein and to apply them to the measurements obtained from the FFQs[10,11].

C*oncentration biomarkers*, are biomarkers that have a correlation with intake, but because they are affected by metabolism or personal characteristics (sex, age, smoking, obesity, etc), they cannot be used as measures of absolute intake or for assessing error

Table I
Classification of biomarkers in nutritional studies

Biomarkers of dietary exposure	Different types of biomarkers aimed at assessing dietary intake of different foods, nutrients, non-nutritive components or dietary patterns (recovery biomarkers, concentration biomarkers, recovery biomarkers and predictive biomarkers). Example: Urinary nitrogen as biomarker of protein intake.
Biomarkers of nutritional status	Biomarkers which reflect not only intake but also metabolism of the nutrient (s) and possibly effects from disease processes. Example: Some of the biomarkers of one-carbon metabolism such as homocysteine, which reflect not only nutritional intake, but also metabolic processes. It is important to note that a single biomarker may not reflect the nutritional status of a single nutrient, but may indicate the interactions of several nutrients.
Biomarkers of health/disease	Biomarkers related to different intermediate phenotypes of a disease or even to the severity of the disease. Example: plasma concentrations of total cholesterol or triglycerides associated for cardiovascular diseases.

of self-reported intakes in validation studied[12]. Examples of concentrations biomarkers are as follows: Serum carotenoids, lipids, vitamins, etc. They can be used to analyze the relationship between the concentration of the above in a certain tissue and variables if health states[6].

Replacement biomarkers are closely related to concentration biomarkers and often the distinction between them is difficult to make. Their differentiating characteristic is that they refer specifically to compounds for which information in food composition databases is unsatisfactory or unavailable. Examples of these replacement biomarkers are some aflatoxins, some phytoestrogens[13], or some of the recent biomarkers identified through metabolomics[6], which we shall refer to later on in this review.

Recently, a newer classification of biomarkers, termed *predictive biomarkers*, has been proposed. These biomarkers show a dose-response relationship with intakes. Like *recovery biomarkers*, predictive biomarkers are sensitive, time dependent, show a dose-response relationship with intake levels and may be affected by personal characteristics but the difference is that their overall recovery is lower[14]. Examples of predictive biomarkers are 24-hour urinary fructose and sucrose[14]. It has also been reported that the use of these Urinary Sugars Biomarker is useful for assessing measurement error in self-reported sugars Intake in the Nutrition and Physical Activity Assessment Study (NPAAS)[15]. Figure 1 summarizes the classification of the above biomarkers as well as their applications in validating dietary assessment methods, measurement error and estimating associations with the different phenotypes of disease.

Biomarkers require the obtaining of different types of biological samples for their measurements. The most commonly employed are blood, urine and saliva, although increasingly more determinations are being taken from other sample such as faeces, hair, nails, adipose tissue and other specific tissues depending on the aims of the study. In the following section, some general comments are made on obtaining and storing biological samples for determining biomarkers in epidemiological studies.

Obtaining and storing biological samples in nutritional epidemiology studies

Given that nowadays several biomarkers are available for use in nutritional epidemiology studies and, in the future, it is expected that many more biomarkers may be incorporated, it is advisable to obtain and store biological samples in any new nutritional epidemiology studies that are initiated. The number of biological samples and their complexity will depend on the aims of the epidemiological studies and the means available for them. It is advisable to at least take biological samples of the saliva and urine of all the participants in a study, as these are the least invasive of biological samples. From these, a considerable number of biomarkers can be determined and from saliva it is even possible to isolate DNA from the bucal cells that are gathered in the same. It is also advisable to not take a single biological sample in the same tube, but to divide it into different aliquots in order to prevent the processes of freezing and defreezing that can affect a number of the biomarkers that one wishes to determine. A good strategy, therefore would be to store a minimum of two or three aliquots for each participant. These samples would have to be frozen at a very low temperature (deep freezing at -80ºC is the most common conservation) in order to ensure the better conservation and avoid the degradation of the biomarkers. If it is not possible to obtain biological samples from all participants, it would at least be advisable to obtain them from a representative sub-sample of the population. If it is possible to obtain and store more samples, it is recommendable to undertake extractions of fasting peripheral venous blood and then process them by means of centrifugation, etc. to obtain serum, plasma and buffy-coat aliquots. These samples will be very valuable later on for determining different biomarkers. Although freezing at -80ºC may be sufficient, it would be ideal to freeze the samples at a lower temperature and store them in liquid nitrogen[16]. However, this type of conservation is not widely available and is limited to a few studies). If, for the research in question, the measurement of biomarkers in red blood cells or in other types of blood cells such as leucocytes is considered to be important, these samples have to be isolated from the extracted blood through the standard protocols and frozen separately from the other components. In the same way, if it is decided to undertake determinations with the DNA or RNA of the participants, these samples will also have to be obtained in a standardized way through the pertinent protocols. Temporality in sample collecting will depend on whether the study is cross-sectional or longitudinal. In cross-sectional studies it will only be necessary to gather them once, whereas in longitudinal studies, samples have to be taken at baseline and at different moments of follow-up depending on the aims of the study. The number of aliquots obtained may be very large in studies that include thousands of participants, so there a good labelling and traceability infrastructure of the frozen stored samples will have to be planned. It is also advisable to think about building some kind of biobanks and to follow the protocols for such purposes[17]. On choosing the protocols for obtaining and storing samples, one must bear in mind several limitations for the subsequent validity of the determinations and the comparability of results. Currently, there are different anti-coagulants that are used in blood sample collection tubes. Later determinations may vary depending on whether citrate, heparin or EDTA are used. For omic studies, one of the limiting samples is obtaining RNA, as this requires prior isolation in fresh samples or blood samples to be collected and stored in the pre-

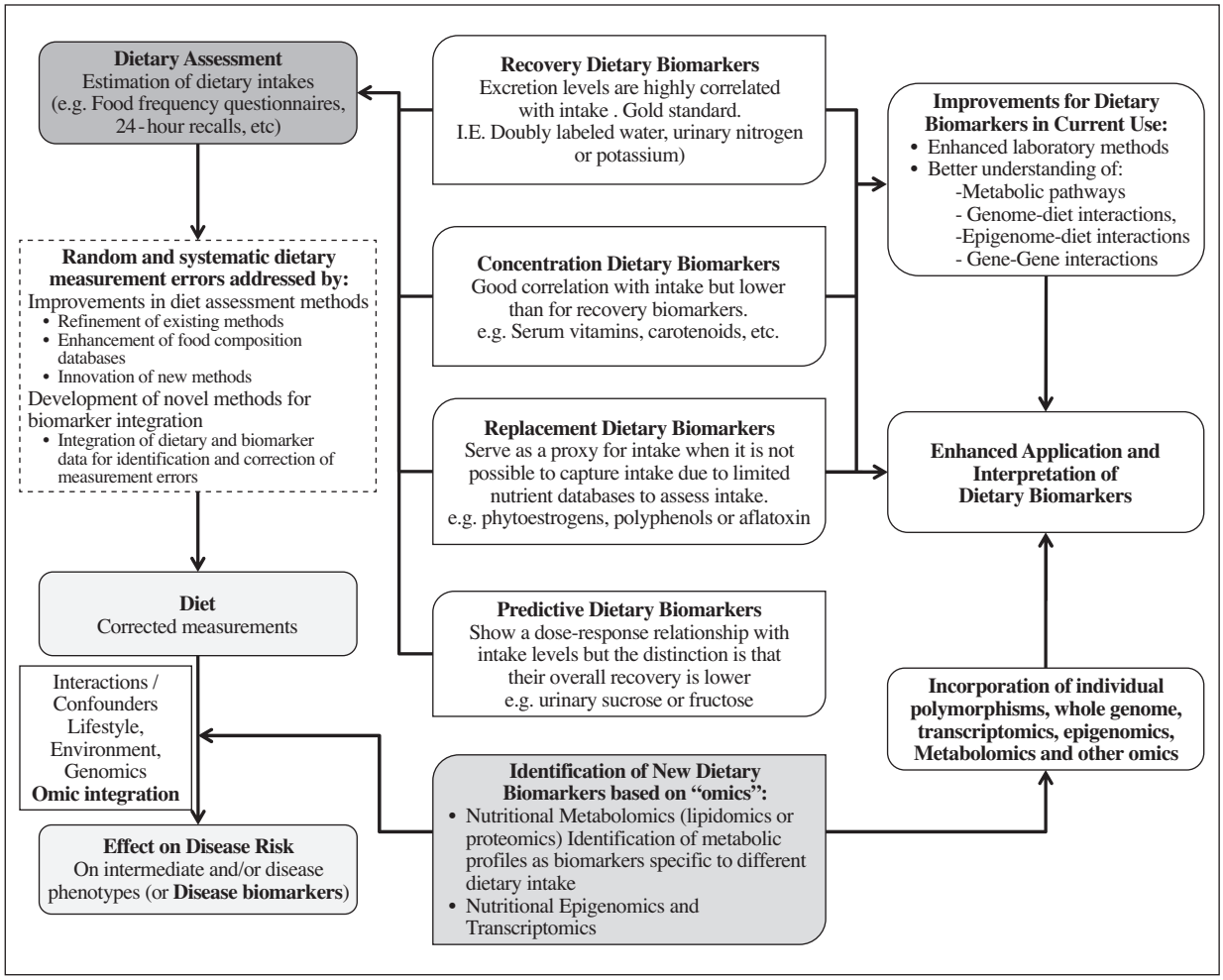


Fig. 1.—Classification of biomarkers and their applications in validating dietary assessment methods, and estimating associations with the different phenotypes of disease (adapted from reference[6]).

sence of RNA preservatives. Although obtaining DNA for genotyping does not present any problems and generally fulfils the quality requirements regardless of the anticoagulant used, storage time, etc., the obtaining of DNA for epigenetic studies such as methylation can be subject to more problems of validity and reproducibility depending on the method employed, the time of the year in which the sample was collected, etc. For further details of the factors that affect the conservation and processing of biological sample in omic studies, the work of Hebels et al[18] is recommended, in which some general guidelines are provided in the context of the European project EnviroGenomarkers (http://www.envirogenomarkers.net). In this Project, blood-derived biobank samples are being analyzed on multiple omic platforms with the aim of discovering new biomarkers of exposure and disease risk. Furthermore, in addition to the good storage of biological samples, valid laboratory procedures for analyzing different biomarkers are required that allow for comparisons among laboratories. Without such comparability, it is not possible to make recommendations regarding appropriate levels.

Use of dietary biomarkers in combination with data from questionnaires

Another approach that can be used is the joint use of intake biomarkers with data coming from questionnaires where self-reported intake is measured. This combination allows one to increase the validity of measurements and also increase the statistical power of the subsequent diet-disease associations. This approach has been used by various authors, among them Freedman et al[19] in the CAREDS study (Age-Related Eye Disease Study). It is an ancillary study of the Women's Health Initiative (WHI) Observational Study, a prospective cohort study of 93,676 postmenopausal women, recruited from 40 sites around the United States. Specifically, the researchers used this study to illustrate that the inverse association between dietary lutein plus zeaxanthin and nuclear cataracts, improved on using biomarkers in an overall way for these carotenoids with data intake from self-reported questionnaires. Dietary intake was assessed by using the WHI semi-quantitative FFQ. Serum samples were collected

after 10 or more hours of fasting at the WHI baseline examinations and were analyzed for lutein and zeaxanthin (sum of their trans isomers). The authors investigated 3 ways of analyzing reported dietary lutein plus zeaxanthin intake and lutein plus zeaxanthin serum level; the third one combining the self-report and biomarker measurements. For the third method, they used a combined score where data from both determinations were used. For further details of that score, the original reference should be consulted[19]. The conclusion to which the authors arrived is that by combining a biomarker of dietary intake with self-reported dietary intake can increase the statistical power for detecting a diet-disease association. Therefore, it is advisable to use this combined method whenever possible. However, they also recognize limitations to that combination when the biomarker is not valid or when the error derived from the food or nutrient measurement through the questionnaires also has great errors.

Limitations and considerations in using biomarkers

Although biomarkers can provide a more objective measurement of dietary intake, for many of them there are various inter-individual factors that could skew biomarker measures of dietary intake and give untrue values[20]. Among these factors, apart from sex, age, tobacco smoking, alcohol consumption, drugs, physical activity and other lifestyle factors, are other factors of diet (nutrient-nutrient interactions), the type of biological sample (e.g. blood, plasma, serum, urine, etc.) and conditions related with the obtaining and storage of the samples (conditions of sample collection, transport, treatment, storage conditions, length of storage, time of collecting the samples including the day of the week, season of the year, etc.), as well as the particularities of the laboratory methodology for determining them (precision, accuracy, detection limits of the analytical technique and inter-laboratory variations)[20]. Apart from all these, genetic markers are becoming increasingly important as research advances on inter-individual variability, in particular, genetic polymorphisms in relevant genes related with each one of the biomarkers analyzed. There are many types of genetic polymorphisms. The most commonly studied are those that consist of a single base change in a genome site and these are called single nucleotide polymorphisms (SNPs). There are millions of SNPs in the human genome and the technology for their determination has developed spectacularly, moving on from rudimentary techniques that were slow and expensive to other much more automated technologies at a lower cost. It is, therefore, now very easy and fast to incorporate genetic determinations into nutritional epidemiology studies[6]. This genetic variation may not only affect the preferences in the choice and consumption of food, but may also play an important role in nutrient metabolism and in bio-availability, absorption, transport, bio-transformation, and excretion of nutrients or food components. There are many examples of the influence of genetic polymorphisms in the concentrations of different biomarkers. Among them we should mention the influence of the genetic polymorphism rs1279683 (A>G) in the SLC23A2 gene and plasma concentrations of vitaminC[21]. Plasma concentrations of vitamin C are determined by dietary intake, as well as by genetic factors. L-ascorbic acid obtained from the diet is transported across the cell membrane by sodium L-ascorbic acid cotransporters (SVCTs). Two isoforms, SVCT1 (encoded by the SLC23A1 gene) and SVCT2 (encoded by the SLC23A2 gene), play central roles in the absorption and accumulation of vitamin C in many tissues. In a study undertaken by our group to investigate the influence of vitamin C plasma concentrations on the risk of glaucoma[21], we found that the rs1279683-SLC23A2 SNP was strongly associated with plasma vitamin C concentrations both in cases and controls (Fig. 2). According to these results, homozygous carriers of the variant G allele have significantly lower plasma vitamin C concentrations than the other genotypes despite having similar intakes. Another relevant example of the influence of genetic polymorphisms on concentrations of a biomarker regardless of intake are the polymorphisms in relevant genes in the metabolism of polyunsaturated fatty acids[22]. The delta-6 desaturase (D6D) and delta-5 desaturase (D5D) are membrane-bound enzymes that catalyze the rate-limiting formation of long-chain polyunsaturated fatty acids. The desaturase-encoding genes (FADS1 for D5D and FADS2 for D6D) form a gene cluster on chromosome 11 together with a third desaturase gene, FADS3, of lesser known function. Several studies have consistently replicated the associations between polymorphisms in the FADS1 and FADS2 genes and polyunsaturated fatty acid concentration measurements in different biological samples[22]. This relevant genetic influence is important to bear in mind in epidemiological studied and, as a guideline, it is recommended to gradually incorporate determinations of the most relevant genetic polymorphisms in nutritional epidemiology studies as a control of the most important inter-individual differences.

New omic-based biomarkers

Whether as control for inter-individual differences in measuring classic biomarkers or properly considered as biomarkers, omic technologies have led to the study and validation of new biomarkers in nutrition and health[23]. Among them are those shown in table II:

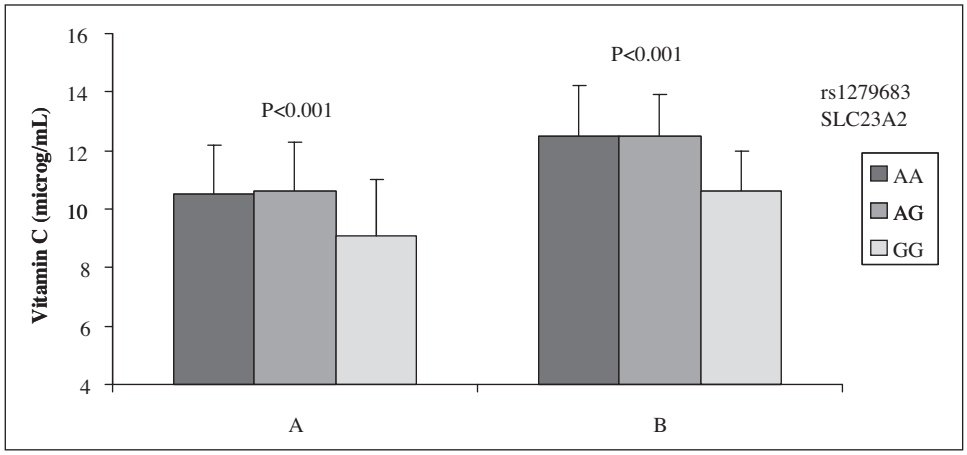


*Fig. 2.—Plasma concentrations of vitamin C (µg/mL) in primary open-angle glaucoma cases (n=150) (**A**) and controls (n=150) (**B**) depending on the rs1279683 (A>G) polymorphism in the SLC23A2 gene (adapted from reference[21]).*

– *Genetic biomarkers:* These biomarkers are based on the determination of genetic polymorphisms (mainly SNPs) and can be either of intake or of effect (metabolism) or as disease risk. They can be determined in the DNA of any biological sample that contains cells with a nucleus (advantage). Their determination does not vary over time and the samples are easily conserved and transported (blood, urine, hair, different tissues, etc. can all be used). In addition, they allow a rapid determination at low economic cost. Furthermore, in recent years high density genotyping arrays have been available that have allowed us to simultaneously determine thousands of genetic polymorphisms. This ability has led to the so-called genome-wide association studies (GWAs) and to the discovery of new genes and SNPs associated with the different levels of the other biomarkers, dietary intake of disease phenotypes. Recently a number of meta-analyses including thousands of individuals have been published identifying new gene variants associated with food and nutrient intake[24,25] or with biomarker concentrations, such as circulating phylloquinone[26]. Also recently, genomic studies into lipids have incorporated the technologies of next generation sequencing for identifying new genetic variants associated with different biomarkers, mainly identifying new low prevalence variants[27].

In the other hand, Mendelian randomization involving genetic biomarkers is currently used as a technique for assessing causal associations in observational data. Genetic variants associated with the risk factor of interest are regarded in a similar way to random assignment in a clinical trial. The modern meaning of Mendelian randomization is based on Mendel's second law, the law of independent assortment, which assumes that the inheritance of one trait is independent of the inheritance of other traits[28]. In terms of nutritional bio-

Table II
Classification of new omic-based biomarkers

Genetic biomarkers	Based on changes in DNA, mainly polymorphisms of a single nucleotide (SNP). Examples: Polymorphisms in the lactase gene (LCT) as proxies of milk consumption in Mendelian randomization analyses.
Epigenetic biomarkers	Biomarkers based on the main epigenetic regulators: DNA methylation, histone modification and non-coding RNAs. Examples: DNA hypermetylation or hypomethylation of specific genes depending on food intake; Levels of circulating microRNAs associated with several nutrion-related diseases.
Transcriptomic biomarkers	Biomarkers based on RNA expression (whole transcriptome or differences in expression of selected genes). Example: Differences in the gene expression profile in subjects following a Mediterranean diet in comparison with control subjects.
Proteomic biomarkers	Biomarkers based on the study of the proteome. Example: Analysis of the proteome of participants fed control diets with the proteome of participants fed low folate diets.
Lipidomic biomarkers	Biomarkers based on the study of the lipidome. Lipidomic profile of human plasma in type 2 diabetic subjects on a high-fat diet versus a high carbohydrate diet.
Metabolomic biomarkers	Biomarkers based on the study of the proteome. Example: The 1H NMR urinary profile in subjects following a traditional Mediterranean diet in comparison with the urinary profile of subject on a low fat diet.

markers, SNPs that have a well-characterized biological function can be utilized to study the effect of a suspected environmental exposure on disease risk. Thus, there are several studies using genetic variants as proxies (instrumental variables) for environmental exposures. A well known example is the lactose polymorphism. The The -13910C>T polymorphism (rs4988235) upstream from the lactase (LCT) gene is strongly associated with lactase persistence (LP) in Europeans[29]. Lactase nonpersistent (LNP) individuals have difficulty in metabolizing lactose and, after consuming dairy products, often have symptoms of abdominal pain and diarrhea. As a result, individuals with LNP tend to consume less lactose-containing dairy products[29] and, therefore, the variant associated with LNP (CC genotype) can be a proxy for low exposure to milk. Likewise, another informative gene is the ALDH2 (aldehyde dehydrogenase). Acetaldehyde is the first metabolite of ethanol ALDH2 is the enzyme primarily responsible for the elimination of acetaldehyde. There is a functional polymorphism (Glu487Lys), resulting in an inactive enzyme. The variant 487Lys allele is associated with reduced ability to metabolize acetaldehyde, and thus contributes to high acetaldehyde concentrations after alcohol drinking (resulting in facial flushing, nausea and headache in response to consumption of alcohol). Because of these adverse reactions, subjects homozygous for the 487Lys allele drink noticeably less alcohol than homozygous subjects for the wide-type allele. Thus, ALDH2 polymorphism can define groups with different amounts of alcohol intake and these variants used as a surrogate of alcohol exposure[30]. However, although the Mendelian randomization approach shows considerable promise in integrating genetic markers into nutritional epidemiology research, its application to other genetic variants has several potential limitations when the Mendelian randomization assumptions are violated[28].

In addition to these considerations, genetic biomarkers are crucial in determining intermediate (plasma lipids, fasting glucose, oxidative markers, inflammation markers, etc) and incidence of disease (cardiovascular diseases, cancer, neurodegenerative diseases, type 2 diabetes, obesity, etc). In nutritional epidemiology, when establishing the association between diet and diseases, the most relevant genetic polymorphisms related with the phenotypes of interest should be determined. Currently there are hundreds of SNPs consistently associated with different phenotypes of nutrition-related diseases that should be considered in studies focused on these phenotypes. By way of example table III[31-37] shows the main genes and genetic variants consistently associated with intermediate and disease phenotypes in cardiovascular epidemiology. The integration of the genetics into nutrition has propelled the advances in gene-diet interactions and Nutritional Genomics[38]. In the PREDIMED study we have found some interesting gene-diet interactions in determining both intermediate and cardiovascular disease phenotypes involving common polymorphisms in the TCF7L2[39] and the MLXIPL[40] genes and intervention with Mediterranean diet.

– *Epigenetic biomarkers*: The term epigenetics/epigenomics is used to describe a variety of modifications to the genome that do not involve changes in the DNA sequence and can results in alteration of gene expression allowing for differential expression of common genetic information[41]. It constitutes the missing link among genetics, the environment and disease. One of the main advantages of the epigenetic biomarkers, unlike the variations in the genome, is that the epigenetic marks are reversible and may allow a rapid adaptation to the environment. There are 3 main categories of epigenetic marks: DNA methylation, histone modification and noncoding RNA. *DNA methylation* is a well characterized epigenetic modification of the genome. Most DNA methylation in humans occurs at cytosine–phosphate–guanine (CpG) dinucleotides and consists of the addition of a methyl group on position 5 of cytosine residues of the CpG island, providing marks in the genome by which genes are set to be transcriptionally activated or silenced[41]. Hypermethylation or hypomethylation of relevant islands have been associated with several phenotypes of disease[42]. Preliminary studies exist that show that the diet can affect the methylation of certain sites of the DNA and that these changes in methylation are dynamic[43,44]. However, many more studies are required to establish them as new biomarkers of intake or disease.

  As regards epigenetic regulation by non-coding RNAs and although different classes of non-coding RNAs such as long non-coding RNAs, small nucleolar RNAs (snoRNAs) microRNA (miRNAs) have been characterized, miRNAs are currently the most important[45]. miRNAs are small (18-25 nucleotide) functional non-coding RNAs, that regulate gene expression of their target mRNA in a post-transcriptional manner and have emerged as crucial epigenetic regulators of many process related to nutrition. Recent evidence highlights how diet may influence several disease phenotypes through modulation of miRNA expression[45]. Additionally, circulating miRNAs are emerging as biomarkers of several diseases[46,47] . Moreover, There are a few studies that indicate that some exogenous microRNAs could be used as biomarkers of food intake (detection of miRNAs of rice consumed in human plasma), but the-

Table III

Main genes and genetic variants associated with intermediate cardiovascular phenotypes and cardiovascular diseases

References	*Gene*	*Genetic variant*	*Intermediate phenotype*	*Cardiovascular disease*
Khan et al, 2013[31]	APOE	Common E2, E3 and E4 polymorphism (rs4420638 and rs7412)	Higher LDL-C and total cholesterol in APOE-E4 allele carriers in comparison with E3/E3 subjects	The APOE-E4 allele associated with higher risk of cardiovascular diseases (stroke and myocardial infarction)
Ridker et al, 2009[32]	CETP	Several common SNPs in partial LD: rs708272, rs7202364 and rs4329913	Higher HDL-C and APOA1 concentrations in carriers of the minor allele	Lower myocardial infarction risk in carriers of the minor allele
Wang et al, 2011[33]	LPL	Several common SNPs in partial LD: rs328 and rs230	Higher HDL-C and lower triglyceride concentrations in carriers of the minor allele	Lower stroke risk in carriers of the minor allele
Zang et al, 2011[34]	APOA5	Common SNP: -1131T>C (rs662799) and S19W (rs3135506)	Higher triglyceride concentrations in carriers of the minor alleles	Higher risk of coronary artery disease in carriers of the minor alleles
Teslovich et al, 2010[35]	LDL-R	SNP rs6511720	Lower LDL-C and total cholesterol in carriers of the minor allele	Lower risk of coronary artery disease in carriers of the minor allele
Teslovich et al, 2010[35]	CILP2	SNP rs10401969	Lower LDL-C and total cholesterol in carriers of the variant allele	Lower risk of coronary artery disease in carriers of the variant allele
Teslovich et al, 2010[35]	SORT1	SNP rs629301	Lower LDL-C and total cholesterol in carriers of the minor allele	Lower risk of coronary artery disease in carriers of the minor allele
Teslovich et al, 2010[35]	KLF14	SNP rs4731702	Higher HDL-C in carriers of the variant allele	Lower risk of coronary artery disease in carriers of the variant allele
Kathiresan and Srivastava, 2012[36]	*TRIB1*	Several common SNPs in partial LD: rs2954029, rs2954022 and rs2980885	Variant allele is associated with lower triglycerides, lower LDL-C cholesterol, and higher HDL-C	Carriers of the variant allele have lower risk of coronary heart disease
Kathiresan and Srivastava, 2012[36]	*PCSK9*	A common missense variant is associated with lower LDL-C	Variant allele is associated with lower LDL-C	Carriers of the variant allele have lower risk of coronary heart disease
Do et al, 2013[37]	*APOA1*	SNP rs10790162	Variant allele is associated with higher triglycerides and LDL-C	Carriers of the variant allele have higher risk of coronary artery disease
Do et al, 2013[37]	*APOB*	SNP rs1367117	Variant allele is associated with higher triglycerides and LDL-C	Carriers of the variant allele have higher risk of coronary artery disease

re is still much controversy over this[45]. In general, regarding the promises of the different types of microRNA biomarkers, careful optimization and standardization of preanalytical and analytical methods is needed to ensure that future results, positive or negative, are reliable[48].

– *Transcriptomic biomarkers*: Transcriptomics provides us with knowledge of the transcriptome, either individually for each specific gene studied or analyzing the expression of various genes simultaneously on different scales. In this way we can investigate how exposure to different dietary factors affects the expression of all genes (genome-wide transcriptome) or the specific genes. These studies of expression can be conducted either by analyzing intervention with whole diets (for example the Mediterranean diet as against a low fat diet)[49] or by administering specific foods (e.g. olive oil) or specific components of the diet (vitamins, etc.). Although initially these transcriptomic studies were carried out independently of other omics, in recent years, the general trend is to integrate them with other omics: genomics, lipidomics/metabolomics and epigenomics[50]. However, it must be borne in mind that one of the limitations of transcriptomics or epigenomics biomarkers is that the transcriptome and the epigenome are not the same for all the cells of the organism, as is also true for genomics, but that the level of expression varies depending on the tissues analyzed, adding a little more difficulty to the investigation into these biomarkers.

– *Proteomic, lipidomic and metabolomics biomarkers*. Proteomics, lipidomics and metabolomics through the comprehensive study of proteins, lipids and metabolites are also beginning to be applied in the nutritional biomarker field, providing promising results. Metabolomics can be defined as the screening of small-molecule metabolites present in samples of biological origins. The characterization of all the metabolites can provide a picture of the metabolism and a molecular fingerprint[51]. Such a characterization is a biomarker of a biological state of the subject. In addition, metabolomics can be used to examine the outcome of nutritional intervention strategies by observing and comparing metabolic marks. This science is still in their infancy but promises to revolutionize nutritional biomarkers. Until just recently, the analysis of food was limited to estimate its nutritional value based on the content: carbohydrates, fats, proteins, water, vitamins, and minerals. In addition, several non-nutritive components have been determining. However, metabolomics is helping to explore the thousands of additional components. A large proportion of the food metabolome consists of phytochemicals. Moreover, metabolomics is able to find a large list of environmental chemicals such as plaguicides and different toxins in foods and beverages. The detection of these compounds in nutritional studies may help to have a more holistic analysis of the influence of food on health and disease. There are several metabolomic studies showing promising results in the nutritional field. Guertin et al[52] carried out a metabolomic investigation in a relatively large (n=502) sample of participants in the Prostate, Lung, Colorectal, and Ovarian (PLCO) Cancer Screening Trial, with the aims of identifying metabolites that are biomarkers of usual dietary intake and to evaluated metabolite reproducibility and required sample sizes to ascertain the potential for metabolomics in nutritional epidemiology. Baseline serum was analyzed by using ultra-high-performance liquid-phase chromatography with tandem mass spectrometry and gas chromatography–mass spectrometry. They detected 412 known metabolites. Green vegetables, citrus, red meat, shellfish, fish, peanuts, rice, butter, coffee, beer, liquor, total ethanol, and multivitamins were each correlated with at least one metabolite and in total, 39 dietary biomarkers were identified (see Tables in reference[52] for more detail). They found some strong associations that replicated previous findings such as the correlation between citrus intake with stachydrine; coffee intake with trigonelline-N-methylnicotinate and quinate) and alcohol intake with ethyl glucuronide. In the PREDIMED Study we also have used metabolomics for detecting new biomarkers of intake. In one of the metabolomic studies[55,] we assessed the effect of the Mediterranean diet intervention (supplemented either with extra-virgin olive oil or nuts) intervention in a sub-sample of non-diabetic participants. The ^{1}H NMR urinary profiles were examined at baseline and after 1 and 3 years of follow-up. In comparison with the control group (low fat diet), the most prominent results for the Mediterranean diet groups was the identification of a characteristic profile related to the metabolism of carbohydrates (3-hydroxybutyrate, citrate, and cis-aconitate), creatine, creatinine, amino acids (proline, N-acetylglutamine, glycine, branched-chain amino acids, and derived metabolites), lipids (oleic and suberic acids), and microbial cometabolites (phenylacetylglutamine and p-cresol). These results showed that the application of NMR-based metabolomics make possible the classification of individuals regarding their dietary pattern and the response to specific dietary interventions.

Overall, proteomics, lipidomics and metabolomics are in general being considered as the great innovation in the discovery of new biomarkers of intake, effect and pathology. Many advances are being made in this field and there are important findings. Although the results are generally speaking still preliminary and te-

chniques are still expensive for large epidemiological studies, these are considered to be important technologies of the future for detecting the intake of specific foods and other relevant biomarkers of health status.

Conclusions

Given the huge advances that methodologically are taking place in the field of biomarkers in nutritional studies with the incorporation of the new omics, it is advisable to obtain and store biological samples in nutritional epidemiology studies in order to be able to undertake determinations of the main biomarkers related with the aims of the study. Currently, there are still limitations to the validity and reliability of many markers, but in future it hoped to minimize many of these limitations and to have low cost validated biomarkers available.

Acknowledgments

This study has been supported by The Spanish Ministry of Health (Instituto de Salud Carlos III) and the Ministry of Economy and Innovation, Spain and Fondo Europeo de Desarrollo Regional (projects CIBER 06/03, CNIC-06, PI11/02505, PI1300462, AGL2010-22319-C03-03) and by the Generalitat Valenciana, Spain (ACOMP/2013/165 and ACOMP/2013/159).

Disclosures

The authors have no conflict of interests

References

1. Hedrick VE, Dietrich AM, Estabrooks PA, Savla J, Serrano E, Davy BM. Dietary biomarkers: advances, limitations and future directions. *Nutr J* 2012;11:109.
2. Biomarkers definitions working group. Biomarkers and surrogate endpoints: preferred definitions and conceptual framework. *Clin Pharmacol Ther* 2001;69:89–95.
3. de Vries J, Antoine JM, Burzykowski T, Chiodini A, Gibney M, Kuhnle G, Méheust A, Pijls L, Rowland I. Markers for nutrition studies: review of criteria for the evaluation of markers. *Eur J Nutr* 2013;52:1685-99.
4. Potischman N, Freudenheim JL. Biomarkers of nutritional exposure and nutritional status: an overview. *J Nutr* 2013; 133:S3873–S3874.
5. Potischman N: Biologic and methodologic issues for nutritional biomarkers. *J Nutr* 2003; 133:875S-880S.
6. Jenab M, Slimani N, Bictash M, Ferrari P, Bingham SA. Biomarkers in nutritional epidemiology: applications, needs and new horizons. *Hum Genet* 2009;125:507-25.
7. Bingham SA. Urine nitrogen as a biomarker for the validation of dietary protein intake. *J Nutr* 2003;133:921S–924S.
8. Day N, McKeown N, Wong M, Welch A, Bingham S. Epidemiological assessment of diet: a comparison of a 7-day diary with a food frequency questionnaire using urinary markers of nitrogen, potassium and sodium. *Int J Epidemiol* 2001;30:309–317.
9. Kipnis V, Subar AF, Midthune D, Freedman LS, Ballard-Barbash R, Troiano RP, et al. Structure of dietary measurement error: results of the OPEN biomarker study. *Am J Epidemiol* 2003;158(1):14-21.
10. Prentice RL, Huang Y, Kuller LH, Tinker LF, Horn LV, Stefanick ML, Sarto G, et al. Biomarker-calibrated energy and protein consumption and cardiovascular disease risk among postmenopausal women. *Epidemiology* 2011;22:170-9.
11. Prentice RL, Mossavar-Rahmani Y, Huang Y, Van Horn L, Beresford SA, Caan B, et al. Evaluation and comparison of food records, recalls, and frequencies for energy and protein assessment by using recovery biomarkers. *Am J Epidemiol* 2011;174(5):591-603.
12. Bingham S, Luben R, Welch A, Low YL, Khaw KT, Wareham N, et al. Associations between dietary methods and biomarkers, and between fruits and vegetables and risk of ischaemic heart disease, in the EPIC Norfolk Cohort Study. *Int J Epidemiol* 2008;37:978–987.
13. Grace PB, Taylor JI, Low YL, Luben RN, Mulligan AA, Botting NP, et al. Phytoestrogen concentrations in serum and spot urine as biomarkers for dietary phytoestrogen intake and their relation to breast cancer risk in European prospective investigation of cancer and nutrition-norfolk. *Cancer Epidemiol Biomarkers Prev* 2004;13:698–708.
14. Tasevska N, Runswick SA, McTaggart A, Bingham SA. Urinary sucrose and fructose as biomarkers for sugar consumption. *Cancer Epidemiol Biomarkers Prev* 2005;14:1287–1294.
15. Tasevska N, Midthune D, Tinker LF, Potischman N, Lampe JW, Neuhouser ML, Beasley JM, et al. Use of a Urinary Sugars Biomarker to Assess Measurement Error in Self-Reported Sugars Intake in the Nutrition and Physical Activity Assessment Study (NPAAS). *Cancer Epidemiol Biomarkers Prev* 2014;23:2874-83.
16. Mercuri A, Turchi S, Borghini A, Chiesa MR, Lazzerini G, Musacchio L, et al. Nitrogen biobank for cardiovascular research. *Curr Cardiol Rev* 2013;9:253-9.
17. Peakman TC, Elliott P. The UK Biobank sample handling and storage validation studies. *Int J Epidemiol* 2008;37:i2-6.
18. Hebels DG, Georgiadis P, Keun HC, Athersuch TJ, Vineis P, Vermeulen R, et al. Performance in omics analyses of blood samples in long-term storage: opportunities for the exploitation of existing biobanks in environmental health research. *Environ Health Perspect* 2013;121:480-7.
19. Freedman LS, Tasevska N, Kipnis V, Schatzkin A, Mares J, Tinker L, Potischman N. Gains in statistical power from using a dietary biomarker in combination with self-reported intake to strengthen the analysis of a diet-disease association: an example from CAREDS. *Am J Epidemiol* 2010;172:836-42.
20. Rubio-Aliaga I, Kochhar S, Silva-Zolezzi I. Biomarkers of nutrient bioactivity and efficacy: a route toward personalized nutrition. *J Clin Gastroenterol* 2012;46:545-54.
21. Zanon-Moreno V, Ciancotti-Olivares L, Asencio J, Sanz P, Ortega-Azorin C, Pinazo-Duran MD, Corella D. Association between a SLC23A2 gene variation, plasma vitamin C levels, and risk of glaucoma in a Mediterranean population. *Mol Vis* 2011;17:2997-3004.
22. Corella D, Ordovás JM. Interactions between dietary n-3 fatty acids and genetic variants and risk of disease. *Br J Nutr* 2012;107:S271-83.
23. Ohlhorst SD, Russell R, Bier D, Klurfeld DM, Li Z, Mein JR, et al. Nutrition research to affect food and a healthy life span. *Am J Clin Nutr* 2013;98:620-5.
24. Tanaka T, Ngwa JS, van Rooij FJ, Zillikens MC, Wojczynski MK, Frazier-Wood AC, et al. Genome-wide meta-analysis of observational studies shows common genetic variants associated with macronutrient intake. *Am J Clin Nutr* 2013;97:1395-402.
25. The Coffee and Caffeine Genetics Consortium, Cornelis MC, Byrne EM, Esko T, Nalls MA, Ganna A, et al. Genome-wide meta-analysis identifies six novel loci associated with habitual coffee consumption. Mol Psychiatry. 2014 (in press).
26. Dashti HS, Shea MK, Smith CE, Tanaka T, Hruby A, Richardson K, et al. Meta-analysis of genome-wide association studies

for circulating phylloquinone concentrations. *Am J Clin Nutr* 2014;100:1462-9.
27. Wood AR, Tuke MA, Nalls M, Hernandez D, Gibbs JR, Lin H, et al. Whole-genome sequencing to understand the genetic architecture of common gene expression and biomarker phenotypes. Hum Mol Genet. 2014 (in press).
28. VanderWeele TJ, Tchetgen EJ, Cornelis M, Kraft P. Methodological challenges in mendelian randomization. *Epidemiology* 2014;25:427-35.
29. Almon R, Patterson E, Nilsson TK, Engfeldt P, Sjöström M. Body fat and dairy product intake in lactase persistent and non-persistent children and adolescents. *Food Nutr Res* 2010;54.
30. Au Yeung SL, Jiang C, Cheng KK, Liu B, Zhang W, Lam TH, et al. Is aldehyde dehydrogenase 2 a credible genetic instrument for alcohol use in Mendelian randomization analysis in Southern Chinese men? *Int J Epidemiol* 2013;42:318-28.
31. Khan TA, Shah T, Prieto D, Zhang W, Price J, Fowkes GR, et al. Apolipoprotein E genotype, cardiovascular biomarkers and risk of stroke: systematic review and meta-analysis of 14,015 stroke cases and pooled analysis of primary biomarker data from up to 60,883 individuals. *Int J Epidemiol* 2013;42:475-92.
32. Ridker PM, Paré G, Parker AN, Zee RY, Miletich JP, Chasman DI. Polymorphism in the CETP gene region, HDL cholesterol, and risk of future myocardial infarction: Genomewide analysis among 18 245 initially healthy women from the Women's Genome Health Study. *Circ Cardiovasc Genet* 2009;2:26-33.
33. Wang C, Sun T, Li H, Bai J, Li Y. Lipoprotein lipase Ser447Ter polymorphism associated with the risk of ischemic stroke: a meta-analysis. *Thromb Res* 2011;128:e107-12.
34. Zhang Z, Peng B, Gong RR, Gao LB, Du J, Fang DZ, et al. Apolipoprotein A5 polymorphisms and risk of coronary artery disease: a meta-analysis. *Biosci Trends* 2011;5:165-72.
35. Teslovich TM1, Musunuru K, Smith AV, Edmondson AC, Stylianou IM, Koseki M, et al. Biological, clinical and population relevance of 95 loci for blood lipids. *Nature* 2010;466:707-13.
36. Kathiresan, S., Srivastava, D. Genetics of human cardiovascular disease. *Cell* 2012;148:1242-57.
37. Do R, Willer CJ, Schmidt EM, Sengupta S, Gao C, Peloso GM, et al. Common variants associated with plasma triglycerides and risk for coronary artery disease. *Nat Genet* 2013;45:1345-52.
38. Corella D, Ordovas JM. Nutrigenomics in cardiovascular medicine. *Circ Cardiovasc Genet* 2009;2:637-51
39. Corella D, Carrasco P, Sorlí JV, Estruch R, Rico-Sanz J, Martínez-González MÁ, et al. Mediterranean diet reduces the adverse effect of the TCF7L2-rs7903146 polymorphism on cardiovascular risk factors and stroke incidence: a randomized controlled trial in a high-cardiovascular-risk population. *Diabetes Care* 2013;36:3803-3811.
40. Ortega-Azorín C, Sorlí JV, Estruch R, Asensio EM, Coltell O, González JI, et al. Amino acid change in the carbohydrate response element binding protein is associated with lower triglycerides and myocardial infarction incidence depending on level of adherence to the Mediterranean diet in the PREDIMED trial. *Circ Cardiovasc Genet* 2014;7:49-58.
41. Rozek LS, Dolinoy DC, Sartor MA, Omenn GS. Epigenetics: relevance and implications for public health. *Annu Rev Public Health* 2014;35:105-22
42. de Mello VD, Pulkkinen L, Lalli M, Kolehmainen M, Pihlajamäki J, et al. DNA methylation in obesity and type 2 diabetes. *Ann Med* 2014;46:103-13.
43. Dominguez-Salas P, Moore SE, Baker MS, Bergen AW, Cox SE, Dyer RA, et al. Maternal nutrition at conception modulates DNA methylation of human metastable epialleles. *Nat Commun* 2014;5:3746.
44. Aslibekyan S, Wiener HW, Havel PJ, Stanhope KL, O'Brien DM, Hopkins SE, et al. DNA methylation patterns are associated with n-3 fatty acid intake in Yup'ik people. *J Nutr* 2014;144:425-30.
45. Ross SA, Davis CD. The emerging role of microRNAs and nutrition in modulating health and disease. *Annu Rev Nutr* 2014;34:305-36
46. Hayes J, Peruzzi PP, Lawler S. MicroRNAs in cancer: biomarkers, functions and therapy.*Trends Mol Med* 2014;20:460-9.
47. Bronze-da-Rocha E. MicroRNAs expression profiles in cardiovascular diseases. *Biomed Res Int* 2014;2014:985408.
48. Witwer KW. Circulating MicroRNA Biomarker Studies: Pitfalls and Potential Solutions. *Clin Chem* 2015;61:56-63.
49. Castañer O, Corella D, Covas MI, Sorlí JV, Subirana I, Flores-Mateo G, et al. In vivo transcriptomic profile after a Mediterranean diet in high-cardiovascular risk patients: a randomized controlled trial. *Am J Clin Nutr* 2013;98:845-53
50. Wu PY, Chandramohan R, Phan JH, Mahle WT, Gaynor JW, Maher KO, et al. Cardiovascular transcriptomics and epigenomics using next-generation sequencing: challenges, progress, and opportunities. *Circ Cardiovasc Genet* 2014;7:701-10
51. Gibbons H, O'Gorman A, Brennan L. Metabolomics as a tool in nutritional research. *Curr Opin Lipidol* 2015;26:30-4
52. Guertin KA, Moore SC, Sampson JN, Huang WY, Xiao Q, Stolzenberg-Solomon RZ, Sinha R, Cross AJ. Metabolomics in nutritional epidemiology: identifying metabolites associated with diet and quantifying their potential to uncover diet-disease relations in populations. *Am J Clin Nutr* 2014;100:208-217
53. Vázquez-Fresno R, Llorach R, Urpi-Sarda M, Lupianez-Barbero A, Estruch R, Corella D et al. Metabolomic Pattern Analysis after Mediterranean Diet Intervention in a Nondiabetic Population: A 1- and 3-Year Follow-up in the PREDIMED Study. J Proteome Res. 2014 (in press).

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):189-195
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

The identification, impact and management of missing values and outlier data in nutritional epidemiology

Rosa Abellana Sangra[1] and Andreu Farran Codina[2]

[1]*Department of Public Health, Faculty of Medicine, University of Barcelona.* [2]*Department of Nutrition and Food Science, Faculty of Pharmacy, University of Barcelona. Spain.*

Abstract

When performing nutritional epidemiology studies, missing values and outliers inevitably appear. Missing values appear, for example, because of the difficulty in collecting data in dietary surveys, leading to a lack of data on the amounts of foods consumed or a poor description of these foods. Inadequate treatment during the data processing stage can create biases and loss of accuracy and, consequently, misinterpretation of the results. The objective of this article is to provide some recommendations about the treatment of missing and outlier data, and orientation regarding existing software for the determination of sample sizes and for performing statistical analysis. Some recommendations about data collection are provided as an important previous step in any nutritional research. We discuss methods used for dealing with missing values, especially the case deletion method, simple imputation and multiple imputation, with indications and examples. Identification, impact on statistical analysis and options available for adequate treatment of outlier values are explained, including some illustrative examples. Finally, the current software that totally or partially addresses the questions treated is mentioned, especially the free software available.

(*Nutr Hosp* 2015;31(Supl. 3):189-195)

DOI:10.3305/nh.2015.31.sup3.8766

Key words: *Missing data. Outliers. Data collection. Epidemiology nutritional.*

IDENTIFICACIÓN, IMPACTO Y MANEJO DE LOS VALORES AUSENTES Y DATOS ATÍPICOS EN EPIDEMIOLOGÍA NUTRICIONAL

Resumen

Cuando se realiza un estudio epidemiológico nutricional, es inevitable que aparezcan valores ausentes y atípicos. Los datos ausentes aparecen, por ejemplo, por la dificultad de recoger los datos en las encuestas dietéticas que conducen a una falta de información sobre la cantidad de alimentos consumidos y una pobre descripción de ellos. Un inadecuado tratamiento durante el proceso de recolección nos conduce a sesgos y pérdida de precisión y consecuentemente una incorrecta interpretación de los resultados. El objetivo de este artículo es proporcionar recomendaciones sobre el tratamiento de datos ausentes y atípicos, y algunas orientaciones sobre el software existente para calcular el tamaño de muestra y realizar el análisis estadístico. También se realizan recomendaciones sobre la recolección de datos que es un paso importante en la investigación nutricional. Se comentan los métodos que se usan para hacer frente a los datos ausentes, específicamente, el método eliminación de casos, imputación simple o múltiple con indicaciones y ejemplos. También se relata cómo se identifican datos atípicos, el impacto que tienen en el análisis estadístico, las opciones para un adecuado tratamiento y se ilustra mediante un ejemplo. Finalmente, se menciona el software existente que aborda total o parcialmente las cuestiones tratadas, específicamente el software de libre distribución.

(*Nutr Hosp* 2015;31(Supl. 3):189-195)

DOI:10.3305/nh.2015.31.sup3.8766

Palabras clave: *Valores ausentes. Valores atípicos. Recogida de datos. Epidemiologia nutricional.*

Abbreviations

WHO: World Health Organization.
MCAR: Missing Completely at Random.
MAR: Missing at Random.
NMAR: Not Missing at Random.
BMI: Body mass index.
EM algorithm: Expectation Maximization algorithm.
GUI: Graphical user interface.

Correspondence: Rosa Abellana Sangrà.
Facultad de Medicina. Universidad de Barcelona.
C/ Casanova, 143.
08036 Barcelona.
E-mail: rabellana@ub.edu

Introduction

According to the World Health Organization (WHO), epidemiology is "the study of the distribution and determinants of health-related states or events (including disease), and the application of this study to the control of diseases and other health problems". Nutritional epidemiology is focused on the aspects of diet that can influence the occurrence of human disease.

Diet is a complex set of exposures that are strongly intercorrelated. Individuals are exposed to diet in different grades with very few clear changes in diet at identifiable points in time. Assessment of food intake is difficult and is subjected to multiple biases. Additionally, the consumption of nutrients is usually determined indirectly based on the reported food consumed or on the level of biochemical measurements. Thus, the most serious limitation of research in nutritional epidemiology is the measurement of exposures to dietary and nutritional factors[1].

Among other problems, missing values in dietary surveys can be due to missing days or meals of intake, missing amounts of foods consumed, inadequate descriptive information for useful coding at an individual level, absence of the consumed food or nutrient of interest in food composition tables, and, in a broader sense, the non-participants in a representative random sample study. If filling in missing gaps is not performed, the effect of this information gap needs to be considered in the interpretation of the results obtained in research studies[2].

The scientific research process can be divided in several stages[3]. Firstly, it is important to review scientific literature and to properly formulate a research objective and related hypothesis. Then, a good research design to answer the question may be elaborated. Sampling procedures and determination of sample size are important parts of this design. All this information should be explained in a research protocol, in which instrumental and procedural details of the study must be stated; for example, questionnaires, biochemical analyses or other procedures that will be used in data collection. Validation of food intake questionnaires is an important point to avoid biases in data. Once the protocol is finished and has been reviewed, field work and data collection can be started. These data obtained should be coded and processed, and this data process is an important part in dietary surveys, especially if food consumptions are used to estimate nutrient intakes. Adequate software allows large data volumes to be entered, managed and processed for the purpose of preparing a data matrix for statistical analysis. In this step, the identification and extraction of outlier values and the completion of missing data are essential to avoid troubles in statistical analysis. Different methods have been developed to deal with outliers and missing data, and correct choice of these methods is critical.

The purpose of this article is to provide some recommendations about the treatment of missing and outlier data, and orientation regarding existing software for the calculation of sample sizes and performing statistical analysis. This software can help to prevent possible incorrect results in statistical analysis and misinterpretation of the observations made.

Data collection. Recommendations.

Data collection is an important part of research. The information of the subjects to be recorded and how the variables are measured conditions the posterior statistical analysis and the validity of the study. It is recommended that original variables be recorded instead of calculated or categorical variables used. For example, the year of birth should be asked instead of the age of the subject or the nutritional status should not be reported with the categories; low weight, normal, overweight and obesity. It is better to ask for the weight and health of the subject and later compute the body mass index. The same occurs with food frequency intake. If the variable frequency is recorded using the categories less than twice a week, between 2 and 5 times and 5 or more times a week. It is impossible to know the number of intakes of a particular food and thus, the variable cannot be modified.

The categorical variables should be correctly codified with their appropriate labels. Usually a number is assigned to each category and then the label is given. This is advisable because most software are key sensitive or detect the accent of the words and a new category is falsely created. This can be solved but not after having lost considerable time.

In the case of recording data using specific software the introduction of validation rules that restrict the range values of the variables is recommended to avoid errors of digitalization.

Missing data and Outliers

Missing data

Once the data have been recorded it is important to consider the information not provided by the subjects, that is, the missing data. According to Rubin (1976)[4] there are basically three types of missing data: Missing Completely at Random (MCAR), Missing at Random (MAR), and Not Missing at Random (NMAR). The first refers to the probability of an observation being missing does not depend on observed or unobserved measurements. Missing at random refers to the fact that the probability of an observation being missing depends only on the values of the observed study variables, and not missing at random refers to the probability that an observation is missing depends on unobserved measurements.

For example, in the supposition that the body mass index is recorded according to the sex of the subjects,

then, regardless of any particular reason why some subjects disclose their weight, the missing data are considered missing completely at random. However, if females are likely to not reveal their weight, missing data depends on the sex and these data are considered to be missing at random. And finally, in the case that obese subjects are more likely to disclose their weight, the probability that body mass index is missing depends on the unobserved value itself. These data are not missing at random.

Illustrative data

A random sample of 58 students of Human Nutrition and Dietetics and Food Science and Technology of the University of Barcelona were studied to evaluate their nutritional status. The food consumption of the students was recorded using the 24h recall, 3-day recalls and the food frequency questionnaires. The students also filled in a questionnaire for assessment and quantification of overweight and obesity-related lifestyles[5]. The aim was to study the relationship between protein intake with respect to sex, body mass index (BMI), total energy intake and index of overweight and obesity. Eight female students did not report their weight and height, thus the BMI had 8 missing data (Table I).

Case deletion

There are two ways by which you can delete cases that have missing values; listwise and pairwise deletion. The listwise method deletes the subjects with missing data. If the data are missing completely at random, listwise deletion does not add any bias, but the sample size is reduced thereby affecting the power of the tests (decreasing) or the standard errors of the estimations (increasing). Moreover, listwise deletion discards considerable information provided by the subject.

Pairwise deletion (or "available case analysis") deletes a subject when data are missing in a variable required for a particular analysis, but includes that subject in analyses for which all required information are present. When pairwise deletion is used, the total sample size for analysis will not be consistent across parameter estimations.

Table II shows the estimates of the linear regression of logarithm of proteins according to sex, BMI, obesity index and total energy intake. The information of the students with missing data in BMI variable is deleting (listwise deletion).

Simple Imputation or multiple imputations

Imputation is the process of replacing missing data with substituted values. Several methods are used: mean imputation, regression imputation, expectation maximization algorithm and multiple imputations.

Mean imputation consists in replacing any missing data by the mean of non-missing data. In our data all the missing data are replaced by the mean BMI (21.32).The problem of the mean imputation is that it attenuates any correlations between the variables that

Table I
Data from 12 students. Missing values for variable of BMI are shown as an empty box

Sex	*Obesity Index*	*BMI*	*ENERGY*	*PROT*	*Mean Imputation BMI*	*Regression imputation BMI*
2	80		901.8	53.1	21.33	27.15
2	78		3197.2	177.6	21.33	24.30
2	72		2295.5	96.0	21.33	19.89
2	65		2229.8	113.6	21.33	19.55
2	62		2131.1	79.0	21.33	21.18
2	82		2137.9	125.4	21.33	27.17
2	80		1453.3	69.7	21.33	22.25
2	63		2927.2	124.4	21.33	19.55
2	69	20.10	2684.6	104.8	20.10	20.10
1	58	23.78	2681.9	144.5	23.78	23.78
2	78	22.12	2677.3	136.4	22.12	22.12
1	67	21.29	2674.6	127.5	21.29	21.29
…	…	...	…	…	...	...

BMI: Body mass index, ENERGY: total energy intake, PROT: protein intake

Table II

Estimation of the linear regression of the logarithm of proteins according to sex, BMI, obesity index and total energy intake using the listwise deletion method (left panel) and multiple imputation (right panel)

Listwise deletion				*Multiple Imputation*			
Variable	*Beta*	*Std. Error*	*P value*	*Beta*	*Std. Error*	*P value*	*R.M.I*
Female	-0.245	0.089	<0.001	-0.240	0.085	<0.001	0.003
BMI	-0.003	0.092	0.009	-0.020	0.013	0.008	0.109
Index obesity	-0.002	0.003	0.001	0.006	0.003	0.001	0.036
Total Energy	0.0003	0.00005	<0.001	0.0003	0.0004	<0.001	0.017
8 observations deleted due to missingness				Non-missing data			

Std. Error: Standard error, R.M.I.: Rate of missing information

are imputed. Table I shows the BMI values using mean imputation.

Regression imputation, the missing data are replaced by the predicted value of the regression derived from the non-missing data. In contrast with the mean imputation, the imputed value is in some way conditional on other information of the subjects. Considering the example of missing data in variable of BMI, with mean imputation all the missing data are replaced by the mean of the BMI. However, with regression imputation you can replace the missing data according to the sex, the overweight and obesity index and total energy intake of the students. The values of BMI filled in by regression imputation are shown in table I. Each student has a different BMI value according to the overweight and obesity index and total energy intake. Thus, there is an improvement on comparing regression imputation with mean imputation, but the predicted value has an error that it is not considered on performing imputation. This causes relationships to be over identified and suggests greater precision in the imputed values than warranted. Nonetheless, this difficulty can be overcome by stochastic regression imputation. This approach adds a randomly sampled residual term from the normal (or other) distribution to each imputed value.

Another way to deal with missing data is a technique called the expectation maximization algorithm abbreviated as the EM algorithm[6]. This method assumes a distribution for the partially missing data and bases inferences on the likelihood under that distribution. It is an iterative process in which the following two steps are repeated until convergence: The E step finds the conditional expectation of the missing data, given the observed values and current estimates of the parameters. These expectations are then substituted for the missing data. In the M step, maximum likelihood estimates of the parameters are computed as though the missing data had been filled in. However, the uncertainty of the missing data are not considered.

In multiple imputation[7] instead of filling in a single value for each missing value, each missing value is replaced by *m* simulated data that represents the uncertainty about the right value to impute. Then, each imputation generates a data set. Each imputed data set is analyzed separately and *m* estimates and their standard errors are obtained. The overall estimate is the average of all the estimates. The standard error of the estimation is performed using the within variance of each data set (average of the *m* standard errors) as well as the variance between the imputed data set (sample variance across the *m* parameter estimates). These two variances are added together and their square root determines the standard error and thus, the uncertainty due to missing data is introduced in the standard error of the estimate. The between variation between imputed data sets also reflects statistical uncertainty due to missing data.

In our data 15 imputations were performed. Thus, we have 15 data sets according to the values of imputation. Table II shows the parameter estimation of the coefficients of the linear regression of logarithm of proteins according to sex, BMI, the students is now used because the missing BMIs are filled in. Furthermore, the rate of missing information quantifies the relative increase in variance due to nonresponse for BMI. The BMI has a rate of 0.109 and the remaining variables are very low because no imputation was performed.

If your data are MCAR, then there is no bias in your data. If only a few cases have missing data, each with many blank spaces, the best option is to choose listwise deletion. If your data are MAR, the best solution is multiple imputation. Maximum likelihood imputation, and stochastic regression imputation are also suitable, but multiple imputation is recommended. If your data are NMAR these methods are often biased and some specific methods can be used[7].

Outliers

An outlier is an observation clearly different from the rest of the data; it is an atypical or extreme observation. There are several methods to detect outliers; plots such as normal probability plots, box plot or others are model-based.

Model-based detection assumes that the data have a normal distribution, such as the Grubbs' test for outliers[8], Pierce's criterion[9], or Dixon's Q test[10].

One common method for outlier detection is the use of inter-quartile rank. An observation is outlier if the value is outside the limits and ; k is normally set at 1.5 or 3.

It is important to study outlier data because most of the statistics used are influenced by these data and are not robust. For example, the mean is sensitive to the extreme observation, but the median is not. Suppose 10 students have a protein intake of between 50 and 160 g/day but one has an intake of 250 g/day. The mean is 166 g/day while the median is 81 g/day. The mean is affected by this extreme value and the median is not.

In regression analysis the outlier values can influence the results. In regression a difference is made between an outlier and an observation that has high leverage.Concretely, an outlier is an extreme observation in a response variable. However, an observation that has an X value far from its mean is called high leverage. Leverage measures the distance between the mean of the X distribution. When the leverage is two or more times greater than the average leverage , it is considered to have high leverage, being p the number of regression parameters, and *n* the sample size.

Data with high leverage and outliers might have potentially influence in regression. An influential observation generates a negative impact because it biases the estimations. Otherwise, not all the points with high leverage or outliers necessarily influence the regression coefficients. It is possible to have a high leverage and yet follow a straight line with the pattern of the rest of the data.

Figure 1 plots the height and the weight of 60 subjects. The variables have a linear relationship. Three different points have been added to the plot (A, B and C). A is an outlier with respect to the weight variable, but not to height. Its leverage is low (0.016) because it is lower than 2*(2/61)=0.06. B is an outlier with respect to weight and has a high leverage, and C is not an outlier compared to weight but has high leverage.

A preliminary analysis to detect outliers involves the use of residuals of the model. One problem with residuals is that their values depend on the scale and units used. Since the residuals are in units of the dependent variable Y there are no cut-off points for defining what a large residual is. This problem is overcome by using standardized residuals, calculated dividing a residual by its standard error. Observations with absolute standardized residuals exceeding 3 require close consideration as potential outliers. Points A, B and C in figure 1 have a standardized residual equal to 6.39, -0.26 and -5.76. Points A and C have a large residual, however B has a low residual and it is an outlier with high leverage.

The Cook's distance[11] is a measure to detect potentially influential observations. The distance measures the effect of deleting an observation. Data points with large residual (outlier) and/ or high leverage may distort the estimation and accuracy of the regression model. Points with a large Cook's distance, operate under the rule that a value greater than 1 is recommended to study the potential influence??? Another common rule considers a threshold of the percentile 1-alpha of the Fisher Snedecor distribution (F(p,n-p, 1-alpha))

Points A, B and C have a Cook's distance of 0.34, 0.02, and 4.25, respectively. Although A is an outlier it has no potential influential observation, but as shown in table III the standard error of the coefficients increased and the goodness of fit (coefficient of determination) decreased from 0.82 to 0.58 (Table III). Points B

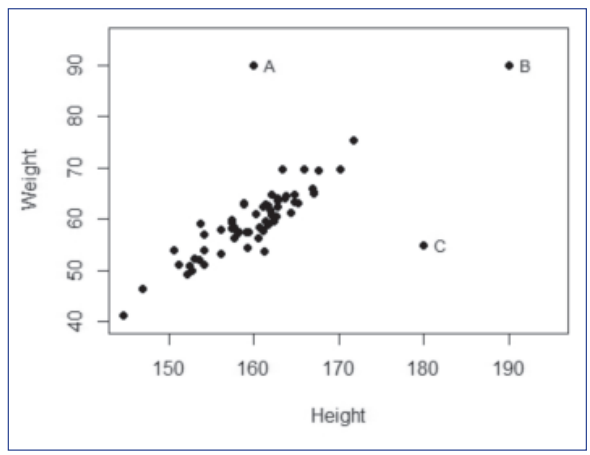


Fig. 1.—Scatterplot of Height and Weight, with three potentially influential observations (A, B and C).

Table III

Estimation of the regression coefficients, standard errors and determination coefficient of the regression of weight and height according to observations (A, B and C) included

	Intercept	*Std. Error Intercept*	*Beta*	*Std. Error Beta*	R^2
Without A, B and C observ.	-106.4	10.13	1.04	0.06	0.82
Observation A	-106.8	18.10	1.04	0.11	0.58
Observation B	-104.9	8.17	1.03	0.05	0.87
Observation C	-68.6	13.69	0.80	0.08	0.60

Linear regression: Weight=intercept+ beta*Height, R2 the coefficient of determination.

and C have high leverage but only C has a potential influential observation. Table III shows that the estimates, the standard errors and the coefficients of determination are modified when C is added to the data.

Other diagnostic methods to detect potentially influential observations are: DFBETAS DFFITS and COVRATIO statistics[12]. All measure the impact of a particular observation deleted from analysis, concretely; DFBETAS measures the effect on the estimation of the coefficients, DFFITD on the predicted value and COVRATIO on the variances (standard errors) of the regression coefficients and their covariance.

When an outlier is detected, what arises from the value should first be evaluated. If the value arises from a human or instrument error the mistake should be corrected. However, outlier data may arise from different causes such as the inherent variability of the variable or if the underlying distribution has an asymmetrical distribution or the data is from another population. Alternatively, outliers may suggest that additional explanatory variables need to be brought into the regression analysis. Deletion of outlier data is a controversial practice and rather than omitting them it is recommend to use robust statistical methods which are not excessively affected by outliers.

Statistical software

Sample size software

It is important to compute the number of subjects to study when the objective and the study design have been defined. The sample must be representative of the population studied. According to the aim to the study and the structure of the population, several sampling types can be used: simple random sampling, systematic, stratified or cluster sampling. Furthermore, sample size computation depends on the main objective, the need to have minimum accuracy in the estimation or the need to have sufficient statistical power. It is also important to consider an extra percentage of individuals because there may be missing values. It is difficult to recommend the percentage of individuals and this depends on the area applied. Moreover, it is convenient to design strategies to guarantee or control that the subjects respond to all the information of the questionnaire.

To calculate sample sizes many commercial or free software are currently available. In relation to the free software EPIDAT 4.0 and GRANMO calculate sample size and power according to statistical methodology.

The EPIDAT 4.0 software was created by *Servizo de Epidemioloxía* de la *Dirección Xeral de Innovación e Xestión da Saúde Pública* de la *Consellería de Sanidade (Xunta de Galicia)* with the support of *Organización Panamericana de la Salud and Universidad CES of Columbia*. It can be downloaded from the page http://www.sergas.es/ in the section of Research and Healthcare Innovation/ data/Software.

GRANMO software was developed by the research group of Cardivascular Risk and Nutrition and Cardiovascular Epidemiology and Genetic of the Research Programme on Cardiovascular and Inflammatory Processes of the IMIM - Hospital del Mar. It can be downloaded from the web page http://www.imim.cat in the section transfer opportunities and service offers/ Freeware.

Statistical analysis software

There is a great variety of statistical software available. At present, the free software most commonly used is the R-project[13]. It is a GNU project which was developed at Bell by John Chambers and colleagues. It compiles and runs on a wide variety of UNIX platforms and similar systems (including FreeBSD and Linux), Windows and MacOS. R is an interpreted language. R has a command-line interpreter and has several of packages that users can download from the web page. The R project does not have a friendly graphical user interface (GUI) but some packages such as R commander[14] or Deducer[15] provide a menu-driven GUI.

Software which can be purchased include: S plus [16](commercial version of the R project), SPSS[17] (statistical packages for the social sciences), SAS institute[18] (Statistical Analysis System), STATA [19](Statistics and Data) or Minitab[20].

Multiple imputation has become increasingly popular, and all these software implement this technique. Yucel (2011)[21] provides a description of the methodology implemented by software.

Finally, all these software perform a wide variety of statistical analyses and have great power to generate graphs of the results. The most appropriate choice of software therefore depends on the costs and preferences of each user.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. Willet W. Nutritional epidemiology. 2nd ed. Oxford: Oxford University Press; 1998.
2. Arab L. Analyses, presentation, and interpretation of results. In: Cameron ME, Van Staveren W, editors. Manual on methodology for food consumption studies. Oxford: Oxford University Press; 1988.
3. Polgar S, Thomas SA. Introducción a la investigación en ciencias de las salud. Madrid: Churchill Livingstone; 1993.
4. Rubin, D.B. Inference and missing data.*Biometrika* 1976; 63: 581-92
5. Pardo A, Ruiz M, Jódar E, Garrido J, De Rosendo J M, Usán L A. Development of a questionnaire for the assessment and

quantification of overweight and obesity related lifestyles. *Nutrición Hospitalaria* 2004;XIX(2):99-109
6. Dempster, AP, Laird NM, Rubin DB. Maximum likelihood estimation from incomplete data via the EM algorithm (with discussion) 1977. *Journal of the Royal Statistical Association* 1977; B39:1-38
7. Rubin, DB. Multiple Imputation for Nonresponse in Surveys. New York: John Wiley and Sons; 1987.
8. Grubbs FE. Sample criteria for testing outlying observations. *The Annals of Mathematical Statistics* 1950; 21(1): 27-58
9. Pierce B.Criterion for the Rejection of Doubtful Observations. *Astronomical Journal* II 1852; 45: 161-310.
10. Dean RB and Dixon WJ. Simplified Statistics for Small Numbers of Observations. *Anal Chem*1951; 23 (4): 636–638.
11. Cook R D Influential Observations in Linear Regression. *Journal of the American Statistical Association*. *1*979; 74 (365): 169–174.
12. Belsley DA, Kuh E, Welsh RE. Regression diagnostics: identifying influential data and sources of collinearity. Wiley series in probability and mathematical statistics. New York 1980.
13. R-project version 3.1.2. Dowload from: http://www.r-project.org/
14. Fox J, Bouchet-Valat M *et a*l. A platform-independent basic-statistics GUI (graphical user interface) for R, based on the tcltk package. Version 2.1-5.2014
15. Fellows I *et al*. Deducer: A data analysis GUI for R. Version 0.7-7. 2014
16. S- PLUS. TIBCO Software Inc.2014.
17. IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.
18. Statistical Analysis System (SAS) Institute Inc. 2013. Unitate States. Version 9.4.
19. StataCorp. 2013. *Stata Statistical Software: Release 13*. College Station, TX: StataCorp LP.
20. Minitab 17 Statistical Software (2010). [Computer software]. State College, PA: Minitab, Inc. (www.minitab.com)
21. Yucel RM. State of the Multiple Imputation Software. *Journal of statistical software* 2011;45(1).

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):196-208
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Assessment of nutritional status in the healthcare setting in Spain

Rocío Campos del Portillo[1], Samara Palma MiIla[1], Natalia García Váquez[2], Bricia Plaza López[1], Laura Bermejo López[1], Pilar Riobó Serván[3], Pedro Pablo García-Luna[4] and Carmen Gómez-Candela[1]

[1]Nutrition Department. Hospital Universitario La Paz (IdiPAZ Health Research Institute). Universidad Autónoma de Madrid. [2]Pharmacy Department. Hospital Universitario La Paz, Madrid. [3]Endocrinology Department. Fundación Jiménez Díaz, Madrid. [4]Nutrition Department . Hospital Virgen del Rocío, Sevilla. Spain.

Abstract

Early identification of undernourished patients in the healthcare setting, and their nutritional treatment, are essential if the harmful effects of poor nourishment are to be avoided and care costs kept down.

The aim of assessing nutritional status is to determine the general health of a patient from a nutritional viewpoint. All hospitalised patients should undergo nutritional screening within 24-48 h of admission, as should any patient who shows signs of being malnourished when visiting any healthcare centre. The infrastructure and resources available, the possibilities of automisation, and the healthcare setting in which such assessment must be performed, etc., determine which method can be used. The European Society of Parenteral and Enteral Nutrition (ESPEN) recommends the use of the Nutritional Risk Screening–2002 (NRS-2002) method for hospitalised patients, the Malnutrition Universal Screening Tool (MUST) in the community healthcare setting, and the first part of the Mini-Nutritional Assessment (MNA) for elderly patients. In centres where screening can be computerised, the CONUT® or INFORNUT® methods can be used.

A nutritional diagnosis is arrived at using the patient's medical history, a physical examination (including anthropometric assessment), biochemical analysis, and functional tests. No single variable allows a diagnosis to be made. The Subjective Global Assessment (SGA) and MNA tests are useful in nutritional assessment, but they are not universally regarded as the gold standard. At our hospital, and at many other centres in the Spanish health system, the Nutritional Status Assessment (NSA) method (in Spanish Valoración del Estado Nutricional) is used, which involves the SGA method, the taking of anthropometric measurements, and biochemical analysis.

After making a nutritional diagnosis, which should be included in the patient's medical history adhering to International Classification of Diseases code 9 (ICD-9), and prescribing a nutritional treatment, the patient should be followed up. No single marker can be used to monitor progress; interpretations will once again require examination of the patient's medical history, the taking of anthropometric measurements and laboratory tests. Depending on whether a patient is ambulatory or hos-

Correspondence: Carmen Gómez Candela.
Nutrition Department.
Hospital U La Paz. Madrid. Spain.
IdiPAZ. University Autonoma of Madrid.
Paseo de la Castellana 261, 28046 Madrid. España.
E-mail: cgcandela@salud.madrid.org

VALORACIÓN DEL ESTADO NUTRICIONAL EN EL ENTORNO ASISTENCIAL EN ESPAÑA

Resumen

La identificación precoz del paciente malnutrido en el entorno asistencial y su abordaje nutricional es esencial para minimizar los efectos deletéreos de la desnutrición así como para disminuir el gasto sanitario.

La valoración nutricional tiene como objetivo determinar el grado de salud desde el punto de vista de la nutrición y debe realizarse en todo paciente hospitalizado en las primeras 24-48 horas, y en el ámbito ambulatorio, ante cualquier paciente que presente sospecha de desnutrición. La elección del método de cribaje depende de la infraestructura y recursos disponibles, posibilidad de automatización y ámbito asistencial, entre otros. Así, la European Society of Parenteral and Enteral Nutrition (ESPEN) recomienda el uso del *Nutritional Risk Screening–2002* (NRS-2002) en el paciente hospitalizado, el *Malnutrition Universal Screening Tool* (MUST) a nivel comunitario y la primera parte del *Mini-Nutritional Assessment* (MNA) en población anciana. En aquellos centros en los que exista posibilidad de informatizar el screening pueden implantarse el CONUT® (Control Nutricional) o el INFORNUT®.

El diagnóstico nutricional se realiza a través de la historia clínica y dietética, exploración física que incluya antropometría, análisis bioquímico y pruebas funcionales. No existe un único parámetro que per sé, que permita el diagnóstico nutricional. La *Valoración Global Subjetiva* (VGS) y el MNA son herramientas útiles para la valoración nutricional, aunque no se cuenta con ellas como el "gold estándar" de forma universal. En algunos de nuestros centros (e.j. el Hospital La Paz) y en muchos otros, nos servimos de lo que llamamos "Valoración del Estado Nutricional", que resulta de la integración de la VGS, antropometría y bioquímica.

Tras un adecuado diagnóstico nutricional, que, idealmente, debería recogerse en la historia según la codificación CIE-9, y una vez hecha la prescripción nutricional, se es necesario un seguimiento para evaluar la adecuación de la misma. Tampoco en el seguimiento nutricional existe un marcador único, basándose de nuevo en la interpretación de un conjunto de datos de historia clínica, antropometría y laboratorio. Según el entorno asistencial en el que nos encontremos (ambulante u hospitalario)

pitalised, the follow-up assessment times and variables measured will differ.

(*Nutr Hosp* 2015;31(Supl. 3):196-208)

DOI:10.3305/nh.2015.31.sup3.8767

Key words: *Nutritional screening. Subjective Global Assessment (SGA). Nutritional Status Assessment (NSA). Undernutrition.*

existirán unos tiempos de evaluación y parámetros de elección distintos.

(*Nutr Hosp* 2015;31(Supl. 3):196-208)

DOI:10.3305/nh.2015.31.sup3.8767

Palabras clave: *Cribado nutricional. Valoración Global Subjetiva (VSG). Valoración del Estado Nutricional (VEN). Desnutrición.*

ABBREVIATIONS

AC: Arm circumference.
APACHE II: Acute Physiology and Chronic Health Evaluation II.
ASPEN: American Society of Parenteral and Enteral Nutrition.
BAPEN: British Association of Parenteral and Enteral Nutrition.
BEI: Bioelectrical impedance.
CONUT®: *Control Nutricional* (Nutritional Control).
CRP: C-reactive protein.
DXA: Dual X-ray absorptiometry.
ESPEN: European Society of Parenteral and Enteral Nutrition.
EWGSOP: European Working Group on Sarcopenia in Older People.
FAACT: Functional Assessment of Anorexia/Cachexia Therapy.
FM: Fat mass.
FFM: Fat free mass.
GNRI: Geriatric Nutritional Risk Index.
ICD: International classification of Diseases.
IL-6: Interleukin 6.
MNA: Mini-Nutritional Assessment.
MQ-SGA: Modified Quantitative Subjective Global Assessment.
MR: Magnetic Resonance.
MST: Malnutrition Screening Tool.
MUST: Malnutrition Universal Screening Tool.
ND: Nutritional diagnosis.
NRI: Nutritional Risk Index.
NRS-2002: Nutritional Risk Screening - 2002.
NSA: Nutritional Status Assessment.
PG-SGA: Patient-Generated Subjective Global Assessment.
RBP: Retinol binding protein.
SGA: Subjective Global Assessment.
SOFA-score: Sequential Organ Failure Assessment score.
TST: triceps skin fold thickness.

Introduction

Undernourishment in the healthcare setting is a serious problem that affects some 30-50% of all hospitalised patients at the time of admission. It has a negative influence on their progress and is associated with an increased number of hospital-acquired infections, a longer hospital stay, and a higher rate of mortality[1]. The early identification of undernourished patients, and their correct nutritional treatment, are essential if the harmful effects of poor nourishment are to be avoided and care costs kept down[2].

The aim of a nutritional diagnosis (ND) is to determine the general health of the patient from a nutritional viewpoint. This allows the identification of those who are undernourished, or who, because of their medical condition or associated treatment, are at risk of becoming undernourished; appropriate treatment can then be prescribed and follow-up initiated[2,3].

Nutritional screening methods

Nutritional screening allows the identification of subjects at risk of undernutrition, as well as those who need a more exhaustive study and an ND. The guides produced by the European Society of Parenteral and Enteral Nutrition (ESPEN) refer to nutritional risk as a situation in which the outcome is related to nutritional factors, and which is improvable by nutritional intervention[4].

Nutritional screening should be included in the initial assessment of all hospitalised patients, thus allowing the early detection of those at risk[3,5]; it should be performed within 24-48 of admission[6]. Nutritional assessment should also be performed in the ambulatory setting whenever a patient presents with anorexia, weight loss, persistent vomiting or diarrhoea, dysphagia, loss of muscle mass, or loss of subcutaneous fat, etc.[6].

Several validated screening methods can be used, the choice of which will depend on the type of population in question, the availability of personnel trained in nutrition, and the possibility of automisation, etc. The most commonly used include the **Malnutrition Screening Tool** (MST), the **Nutritional Risk Screening** (NRS-2002) method, the **Malnutrition Universal Screening Tool** (MUST), and the first part of the **Mini-Nutritional Assessment** (MNA) method. The guides produced by the ESPEN recommend the NRS-2002 method for use with hospitalised patients, MUST in the community healthcare setting, and the MNA method when dealing with elderly people[7]. In the Spanish region of Andalusia, MUST is regularly used.

In recent years, two automated methods were developed and validated in Spain: the **CONUT®**[8] and **INFORNUT®** methods[9]. The CONUT® method can

Table I
Comparison of nutritional assessment with different tools for screening at hospital admission: NRI, MUST, NRS-2002 and CONUT

Tool (N)	*NRI (237)*	*MUST (995)*	*NRS-2002 (995)*	*CONUT-1 (161)*
Sensitivity	43.1	61,2	62,0	78,26
Specificity	89.3	78,6	93,1	89,13
Positive predictive value	76.2	64,6	85,1	84,38
Negative predictive value	66.3	76,1	79,4	84,54
Kappa index	0.24	0.26	0.48	0.680

Gómez-Candela C. et al. Complete process of implantation of a nutritional risk screening system in the University Hospital La Paz, Madrid. Nutr Hosp. 2013.

be used to identify undernourished/at risk patients whose routine blood analyses include serum albumin, total cholesterol and total lymphocytes values. Using information available in the hospital database, and depending on the values of the aforementioned variables, patients receive a risk of undernutrition alert classification of either "low", "moderate" or "high"[8]. Our hospital (*Hospital La Paz*, Madrid) has over five years experience of fully automated nutritional screening using the CONUT® method, covering nearly all our hospitalised patients[10]. Table I compares the sensitivity and specificity of the Nutritional Risk Index (NRI), MUST, NRS-2002 and CONUT® and Subjective Global Assessment (SGA) methods[10].

The recently developed NUTRIC-score method, which determines the nutritional risk of critically ill patients, also deserves mention. This method takes into account the patient's age, the number of comorbidities present, the number of days hospitalised before being sent to the intensive care unit, the patient's SOFA-score and APACHE II results, and plasma interleukin 6 (IL-6) concentration. The latter value is not always available and is not essential to the calculation of the NUTRIC-score, although it does modify the cut-off point for nutritional risk[11].

Methods for assessing nutritional status

An ND requires the following be taken into consideration.

Medical history

Examination of the patient's medical history allows risk factors for undernutrition to be detected. These include chronic disease such as HIV/AIDS, cirrhosis and chronic respiratory failure, and problems such as gastrointestinal disease, cancer, the use of anorexigenic medication, difficulty with chewing, dysphagia, allergies, food intolerances, alcoholism, drug abuse, anxiety, depression, and processes that increase energy requirements (sepsis, trauma, cancer, burns, pregnancy) or nutrient loss (diarrhoea, vomiting, fistulas and malabsorption).

Involuntary weight loss, which is considered clinically relevant when more than 5% of body weight is lost within six months, is a strong predictor of undernutrition both in ambulatory and hospitalised patients[12,13]. In patients with cancer it is also a marker of disease progress and of a poorer prognosis[14].

It is important that medical histories include demographic and socioeconomic data that might influence the nutritional status of a patient, e.g., family structure, educational level, marginalisation, beliefs and lifestyle. Information on the patient's physical activity (type, frequency and duration) is also necessary, as is the type work undertaken (sedentary, physically demanding etc.). Together, these data allow the patient's daily energy needs to be calculated.

A good medical history is so important that two of the six criteria proposed for identifying undernourishment cited in the 2012 ASPEN consensus are based on this[15] (Table II).

Table II
Criteria proposed by A.S.P.E.N consensus for identifying undernourishment

The identification of 2 or more of the following 6 characteristics is recommended for diagnosis of malnutrition:
Insufficient energy intake
Weight loss
Loss of muscle mass
Loss of subcutaneous fat
Localized or generalized fluid accumulation that may sometimes mask weight loss
Diminished functional status as measured by hand-grip strength

Characteristics recommended for the identification of adult malnutrition. JPEN 2012.

Physical examination

A physical examination should pay special attention to signs that indicate a nutritional deficit, e.g., muscular atrophy (the deltoid and quadriceps should be inspected for this), a loss of subcutaneous fat (checked by 'pinching' the skin of the upper torso), the state of hydration, the existence of oedema, and the presence of conjunctival xerosis, Bitot's spots, dry and scaly skin, stomatitis, glositis, discoloured hair, and follicular hyperkeratosis, etc.

Dietary history

This requires qualitative and qualitative information be gathered via questioning regarding the patient's normal food intake. It allows an idea to be formed of the patient's energy intake, and the detection of dietary imbalances. Patients commonly overestimate their food intake[16]. Information should be collected on the type of food consumed, meal frequency, anomalies in nutritional behaviour, problems in chewing or swallowing, and level of autonomy in terms of buying, cooking and eating food. When putting together a dietary history, patients should be asked about their eating patterns for (normally) the past month, along with their intake for the last three days, and the frequency with which they take different foods[16]. In the hospital setting it is very useful to reflect the patient's food intake in the previous 24 h as a percentage of the food provided (<25%, about 50%, about 75% or 100%).

Anthropometric measurements

Such measurements allow body size and proportions to be determined easily and non-invasively. The results are easily reproducible by trained personnel. They allow the comparison with standard figures for the population and can detect changes over time in the same individual.

The anthropometric measurements of greatest use in the assessment of nutritional status are:

Height. This is obtained either directly using a height meter and with the patient standing, or indirectly via, for example, the measurement of the leg or the outstretched arms. The British Association of Parenteral and Enteral Nutrition (BAPEN) recommends measuring the ulna for estimating the height of adults[17].

Body weight. This should be measured using a calibrated balance. The presence of factors that might affect the result, e.g., ascites or oedema, should be taken into account. The following weight-associated variables may need to be determined or calculated:

- Current body weight or weight at the time of assessment.
- Normal body weight or healthy body weight.
- Ideal body weight, calculated taking into account age, sex and patient constitution. Reference can be made to standard tables.
- Adjusted weight. This is the intermediate weight between the real and the ideal weight. It can be useful for calculating energy requirements in obese and in very undernourished patients: adjusted weight = [(real weight – ideal weight) x correction factor] + ideal weight. The correction factor is 0.25 for grade or I or II obesity, and 0.5 for grade III; no correction factor is used when the patient is undernourished.
- Percentage weight loss. This is the variation in body weight with respect to the normal body weight and time. A 2% loss per week is considered serious, as is a 5% loss in one month, 7.5% in three months, or 10% in six months. The greater the weight loss, and the shorter the time within which this occurs, the more severe a situation[16].

Body mass index (BMI). This is a ratio between weight and body height squared. For the non-elderly population, a normal BMI lies between 18.5 and 25 kg/m^2. In adults, a BMI of <16 kg/m^2 is associated with increased mortality, while in elderly people a BMI of <25 kg/m^2 is associated with increased mortality[18].

Body composition analysis

The body composition is the sum of the different tissues and systems that form the human organism. There are two models of body composition: the bicompartmental and multicompartmental models. The former is the most commonly used in clinical practice. This divides the body into fat mass (FM) and fat-free mass (FFM). About 50% of the FM is subcutaneous; it can therefore easily be determined by measuring skin fold thickness. Different skin fold thicknesses can be measured, e.g., the triceps (TST), subscapular, bicipital, and abdominal skin fold thicknesses. The TST is perhaps the most useful given its accessibility and its good relationship with the FM. It is measured on the back of the non-dominant arm midway between the acromion and olecranon processes, with the outstretched arm relaxed, using a Lange- or Harpenden-type lipocaliper. The mean of three consecutive measurements (mm) is taken and compared against normal reference values according to the patient's age and sex.

The somatic protein component of the body is normally measured via the muscular circumference of the arm (MCA), which is determined from the TST and the arm circumference (AC) measured in centimetres midway between the acromion and olecranon processes: CMB MCA = AC - (TST x 0.314). Its value is related to the quantity of muscular protein possessed; values below the 5th percentile represent severe undernourishment.

Body composition can also be determined using more complex (though not always available) techniques such

as bioelectrical impedance (BEI), dual X-ray absorptiometry (DXA) or magnetic resonance (MR). Although DXA provides quite accurate estimates of the FM, FFM and bone mass, it exposes patients to X-rays; it cannot, therefore, be repeatedly used. In contrast, BEI is cheap, innocuous, and can be repeated over and again without harm to the patient. It is based on the resistance of body tissues to the passage of an electrical current. The FFM offer little resistance compared to the FM. It can be used with both healthy persons and patients who are stably hydrated, and its use in the assessment of sarcopenia has been evaluated[19]. However, BEI is not recommended when patients are at the extreme of the BMI range or when they show oedema[20].

Biochemical variables

The plasma concentrations of different protein, vitamin and trace element markers are measured.

Plasma proteins reflect the visceral protein condition. They are synthesised in the liver, and from a clinical standpoint are differentiated according to their half life. They behave as inverse acute phase reactants; their concentration can therefore be reduced independent of the nutritional status if the patient has suffered some severe aggression[21,22]. It can therefore also be important to determine the C-reactive protein (CRP) concentration so that the inflammatory status is known and can be taken into account. The most common plasma proteins analysed are:

- *Albumin*. This is the main protein synthesised in the liver. It has a half life of about 21 days. The body has a large functional reserve of this protein. Low albumin is a good predictor of mortality in hospitalised patients[23], but it is not very useful for monitoring nutritional status. In addition, hypoalbuminaemia can affect plasma calcium, zinc and magnesium levels; this should be taken into account when treating possible deficits[24].
- *Transferrin*. This protein transports iron in the plasma and has a half life of 8-10 days. Its plasma concentration is strongly associated with liver function and the presence of anaemia or infections[25]. Its usefulness is therefore reduced.
- *Prealbumin*. This has a half life of two days. It transports thyroid hormone and, like other plasma proteins, its concentration is conditioned by infections, and other disease processes[26]. However, it is the best protein marker of nutritional status[16]. Unlike albumin, prealbumin is not affected by the state of hydration. High concentrations of prealbumin can be encountered in patients suffering from acute alcohol poisoning and those being treated with corticoids[27].
- *Retinol binding protein* (RBP). This has a half life of just 10 h. Like prealbumin, it can therefore rapidly reflect changes in nutritional status. However, its level is frequently affected by kidney function, or in patients showing signs of stress (it is, therefore, not so useful in hospitalised patients).

A low cholesterol level is a classic sign of undernutrition and is taken into account by automatic screening methods such as CONUT®. However, given the extended use of cholesterol-lowering drugs, even by elderly people, its interpretation in arriving at an ND is limited.

Serum vitamin and mineral concentrations can also provide clues on nutritional status. Concentrations should always be determined when deficits are suspected, and should always be tested in patients with moderate to severe undernutrition.

The creatinine-height index

The creatinine height index is used to assess somatic protein levels and requires all urine be collected over a 24 h period. The values obtained can be affected by kidney failure.

Nitrogenated balance

The nitrogenated balance measures the relationship between the nitrogen provided and that catabolised. The first is determined from the quantity of protein taken in, and the second from the amount of urea excreted at 24 h, the loss of nitrogen in the faeces and sweat, and losses through aspiration tubes, drainages and fistulas.

Functional tests

The functional tests most commonly used in nutritional status testing are dynamometry and immune system function studies.

Undernutrition leads to a fall in the number of T lymphocytes, and counting these cells provides a relatively cheap way of examining nutritional status. Immune function can also be measured via delayed hypersensitivity tests[22]. However, since immune function can be altered by drugs (e.g., corticoids, chemotherapeutic agents, etc.), surgery, or advanced age, it is not always a useful marker, especially in the elderly[28].

Dynamometry is widely used and has been validated for the assessment of muscular strength in the hospital setting[29]. It is a good marker of nutritional status and can be used in nutritional intervention studies[30]. Further, it is easy to perform and provides quantitative data that can be used in the diagnosis of sarcopenia; one diagnostic criterion is a manual compressive force of <30 kg in men and <20 kg in women[19]. Muscular strength is affected early by nutritional depravation, but recovers quickly with nu-

tritional restoration – much more so than muscular mass (whether measured anthropometrically or via BEI, DXA or RM). It is therefore very useful for detecting undernourishment early, and in nutritional monitoring[29]. Flood et al. report an increase in manual compressive strength just 15 days after nutritional intervention in undernourished patients[31]. The measurement of manual compressive strength is that most commonly used to determine muscular strength in clinical practice. An inverse relationship exists between the pressure that can be produced and the number of postoperative complications, the length of hospital stay, and hospital readmission rate[30]. The ASPEN consensus includes this method as a means of identifying undernutrition[15] (Table II). In healthy people, age and sex are the most useful predictors of muscular strength, with no significant differences seen between obese and normal weight subjects. This renders the measurement of this variable of interest in obese patients who become undernourished; in such patients, skin fold thickness measurements and the BMI are of little use. In patients with acute or chronic disease, who are immobilised, who need to take certain medications (corticosteroids), who have comorbidities such as fibromyalgia[30], or in elderly, the use of this variable in monitoring nutritional interventions is somewhat controversial[32].

Matos et al. performed a cross-sectional study to determine the usefulness of dynamometry, employing the manual compressive test as a nutritional screening tool. They concluded it might be of use, but that more work was needed to define cut-off points[33].

Subjective global assessment

The SGA method, which was first described by Detsky over 20 years ago, allows an ND to be arrived at via the examination and complementation of a patient's medical history and a physical examination[34].

SGA can be used with all patients and in all clinical settings. It can be performed quickly and is reproducible, and shows little inter-observer variation when performed by trained personnel[35]. It requires:

- The medical history be complemented to include information of changes in body weight, current food intake be compared to normal food intake, any digestive symptoms in the previous two weeks be recorded, and the patient's functional capacity and metabolic requirements be determined.
- A physical examination, including manual exploration of subcutaneous fat and muscle loss, and checking for oedema and ascites.

Each of the above variables is measured on a qualitative three-point scale. Using these results, patients can then be classified as "A" or well nourished, "B" showing moderate undernourishment or at risk of undernutrition, and "C" undernourished. Weight loss, a low food intake, and the loss of muscular or subcutaneous fat have a greater weighting in the final classification (Table III).

Variations of the SGA method exist, such as Patient Generated Subjective global assessment (PG-SGA), which is used in the oncological setting[36], and the Modified Quantitative Subjective Global Assessment (MQ-SGA) method, which is widely used to monitor patients undergoing dialysis[38]. Both quantify the degree of malnutrition using a points system.

Mini mutritional assessment

The MNA method is the method of choice for use with the elderly. It has been validated for use with both institutionalised[39] and hospitalised[40] elderly persons, and is especially useful for detecting risks before weight loss or hypoptreinaemia occurs. It is a simple, relatively quick test, that reflects food intake and anthropometric measurements well. The score is also correlated with the length of hospital stay and the risk of mortality[4,41,4]. Its sensitivity is 96% and its specificity 98%[41]. It can also be used for nutritional monitoring[4,43].

The method has a screening and a scoring component[4] with a total of 18 sections that cover 30 awarded points. The screening component covers six of these 18 sections, and when these return a total under 12 points the patient can be said to be at nutritional risk. When this is the case, the next 12 sections need to be taken into account. The final score of those who originally scored under 12 points in screening, suggests the type of nutritional intervention that should be followed[44].

- Over 23.5 points: patient well nourished. The MNA should be repeated in the future and nutritional education given regarding healthy eating.
- From 17 to 23.5 points: patient at risk of undernutrition. The causes of this risk should be determined and education given to enrich the diet, with supplements prescribed in some cases.
- Under 17 points: clear undernutrition. Nutritional intervention is needed, the type depending on the cause of the patient's condition.

The MNA is of limited use in elderly persons with dementia, who are in a confused state, or who suffer aphasia or apraxia. In such patients, and when no body weight is available, the Geriatric Nutritional Risk Index (GNRI) can be used instead, or in a complementary fashion. The latter is an adaptation of the NRI, which instead of the true weight of the patient uses the ideal weight (according to the Lorenz formula). GNRI gives greater weight to the plasma albumin concentration than does the NRI, rendering the former useful

Table III
Subjective Global Assessment with laboratory parameters

	A	*B*	*C*
Changes in body weight	<5%	5-10%	>10%
Feeding*	Normal	Mild to moderate impairment	Severe impairment
Eating problems	No	Mild to moderate	Severe
Activity*	Normal	Mild to moderate impairment	Severe impairment
Age	<65	>65	>65
Ulcers	No	No	Yes
Fever/corticosteroids	No	Mild to moderate	High
Cancer treatment	Low risk	Moderate risk	High risk
Loss of subcutaneous fat	No	Mild to moderate	Severe
Loss of muscle mass	No	Mild to moderate	Severe
Edema/ascites	No	Mild to moderate	Severe
Albumin (g/dl) (Pretreatment)*	>3,5	3,5-3	<3
Prealbumin (mg/dl) (After treatment)	>18	15-18	<15

The final result is expressed by the letters A, B or C according to the predominant answer in each item. The answers that have the greatest impact are marked with*.

as a predictor of mortality. Indeed, GNRI is a good predictor of the risk of undernutrition, but does not provide a diagnosis of this[45,46].

Nutritional status assessment method

Although the SGA and MNA methods are useful in determining the nutritional status, there is no universally accepted gold standard for use in arriving at an ND. In our hospital, and in many others, the SGA is used alongside anthropometric measurements and the results of biochemical analyses. This we term the Nutritional Status Assessment (NSA) method. It is generally carried out by personnel trained in nutrition (Table IV).

Diagnosis and codification of undernutrition

The International Classification of Diseases system allows health professionals to identify diagnoses and medical procedures via a code. International classification of disease code 9 (ICD-9) is the system used in Spain. As recorded in the SENPE-SEDOM consensus document, when a diagnosis of undernutrition is reached

Table IV
Nutritional Status Assessment (NSA)

Anthropometry	• Current weight, normal weight, ideal weight and adjusted weight • Weight loss in the last 6 months (% weight loss) • Height • BMI • Triceps skin fold and upper arm muscle circumference
Physical examination	• Loss of subcutaneous fat • Loss of muscle mass • Presence of edema or ascites
Oral intake	• Changes in oral intake: increase, decrease or no change • Duration in time of changes in the oral intake • Type of Intake: fasting, low calorie liquid diet, full liquid diet, insufficient solid diet
Gastrointestinal symptoms	• Absence of symptoms • Nausea, vomiting, diarrhea, anorexia, dysphagia, other symptoms...
Stress	• No stress • Stress: mild - moderate - severe
Biochemestry	• Lymphocytes, albumin, other…
Dynamometry	• Normal values vary with age and sex (Male > 30kg, Women> 20kg)

in the hospital setting it is essential that the medical professional responsible for discharging the patient include an ND at that time, accompanied by its ICD-9 code.

The ICD-9 classification codes for undernutrition in the hospital setting are[47]:

- Energy undernutrition:
  - Mild (ICD-9: 263,1).
  - Moderate (ICD-9: 263,0).
  - Serious/severe (ICD-9: 261).
  - Not specified (ICD-9: 263,9).
- Protein undernutrition: any grade (ICD-9: 260).
- Mixed or energy-protein undernutrition:
  - Mild (ICD-9: 263,8).
  - Moderate (ICD-9: 263,8).
  - Serious/severe (ICD-9: 262).
  - Not specified (ICD-9: 263,9).
- Non-specified undernutrition:
  - Mild (ICD-9: 263,1).
  - Moderate (ICD-9: 263,0).
  - Serious/severe (ICD-9: 261).
  - Not specified (ICD-9: 263,9).
- Excess weight:
  - Overweight (ICD-9: 278.02).
  - Non-specified obesity (ICD-9: 278.00).
  - Morbid obesity (ICD-9: 278.01).

In addition, in patients who have received nutritional support, the therapy followed should receive an ICD-9 code:

- Parenteral nutrition (ICD-9: 99.15).
- Enteral nutrition at >1000 kcal/day (ICD-9: 96,6).

A more recent version of the coding system is known as ICD-10. However, its Spanish adaptation, known as ICD-10-ES, does not come into force until 2016. Until this time, ICD-9 is the accepted coding system[48].

Although sarcopenia and cachexia still have no diagnostic codes, they have an important nutritional impact. **Sarcopenia** is the progressive loss of skeletal muscle and strength, and is associated with a risk of incapacity and greater mortality[19]. Primary sarcopenia is a geriatric syndrome. Secondary sarcopenia is caused by neoplasms, immobilisation and living where there is no gravity; it can occur at any age. Its diagnosis requires a loss of muscular mass, muscular strength and/or reduced physical performance. These variables can be measured in different ways according to the possibilities of each centre (Table V). The algorithm developed by the European Working Group on Sarcopenia in Older People (EWGSOP) for the detection of the problem proposes walking speed be measured as a clinical screening method, with a risk cut-off of 0.8 m/s[19].

Cachexia is a multifactorial metabolic syndrome characterised by weight loss – mainly skeletal mass loss (with or without loss of FM) – plus increased protein catabolism, as a result of underlying disease. Indeed, the inflammation derived from that disease plays a vital part in the physiopathology of cachexia. Undernutrition can be involved, but not every undernourished patient is cachexic[49], although all patients with cachexia are undernourished.

There are several degrees of cachexia[50]:

- **Precachexia**. This requires the existence of all of the following:
  - Chronic disease.
  - Chronic or recurrent inflammatory response (raised CRP).
  - Anorexia (quantifiable via the Functional Assessment of Anorexia/Cachexia Therapy (FAACT) questionnaire).
  - An involuntary weight loss of <5% within six months.
- **Cachexia**. This requires the existence of at least one of the following:

Table V
Definition and diagnosis of Sarcopenia

Diagnosis of sarcopenia *Criterion 1 + criterion 2 or criterion 3*	*Measurement techniques available*	
	Research	*Clinical Practice*
1. Muscle mass (Essential criteria)	Computed tomography Magnetic resonance imaging BIA DXA	BIA DXA Anthropometry
2. Muscle strength	Handgrip strength Knee flexion/extension Peak expiratory flow	Handgrip strength
3. Physical performance	Short Physical Performance Battery Usual gait speed Timed get-up-and-go test Stair climb power test	Short Physical Performance Battery Usual gait speed Get-up-and-go test

Cruz- Jentof A.J, et al. Sarcopenia: European consensus on definition and diagnosis. Br Geriatr Soc.

- An involuntary weight loss of >5% within six months.
- A BMI of <20kg/m^2 and an involuntary weight loss of >2%.
- Sarcopenia and an involuntary weight loss of >2%.

– **Refractory cachexia**. This requires the existence of all of the following:
  - A catabolic status.
  - A lack of response to oncological treatment.
  - Poor functional status (<50%).
  - A life expectancy of <3 Tmonths.

A patient may have both sarcopenia and cachexia; in fact, most patients with cachexia are sarcopenic. Sometimes these conditions can be difficult to distinguish; indeed, they can be quite similar. The main feature of cachexia is sudden weight loss, in which the inflammatory and catabolic status play important roles; such patients show a weak response to nutritional support. In sarcopenia, in contrast, the loss of muscular mass and muscle function is more gradual and responds better to treatment (resistance exercise and nutritional supplementation).

Monitoring the nutritional status

Following an ND and the prescription of a nutritional treatment to follow, the patient should be followed up (Fig. 1). Ideally an easily and inexpensively measurable marker should be monitored. This should be measurable in most centres and not affected by the inflammatory status. Unfortunately, no such marker exists. Therefore, just like when arriving at the diagnosis, nutritional monitoring requires the use of the patient's medical history, anthropometric values and laboratory results. The variables followed will depend on whether the patient is being monitored in the hospital or ambulatory setting.

Once of the most important and simple tools for nutritional monitoring is following dietetic history via the 24 h recall method, but it is hardly enough on its own. The PG-SGA is useful over the long term, but not much use for short term monitoring.

Plasma prealbumin is the biochemical marker of choice for early monitoring of nutritional responses, despite its being influenced by patient inflammatory status. Theoretically, plasma prealbumin should increase by 2g/dL if nutritional support is adequate [27,51]. Indeed, if they rise at all with an intervention, one can be sure that at least 65% of protein requirements have been met. If, however, an increase of 4g/dL is not made within eight days, the treatment needs to be intensified[27].

Changes in body weight are a good means of monitoring patients in the ambulatory setting over the long – but not the short – term (changes that occur over a short period of time are more due to the amount of water in the body than the amount of lean mass).

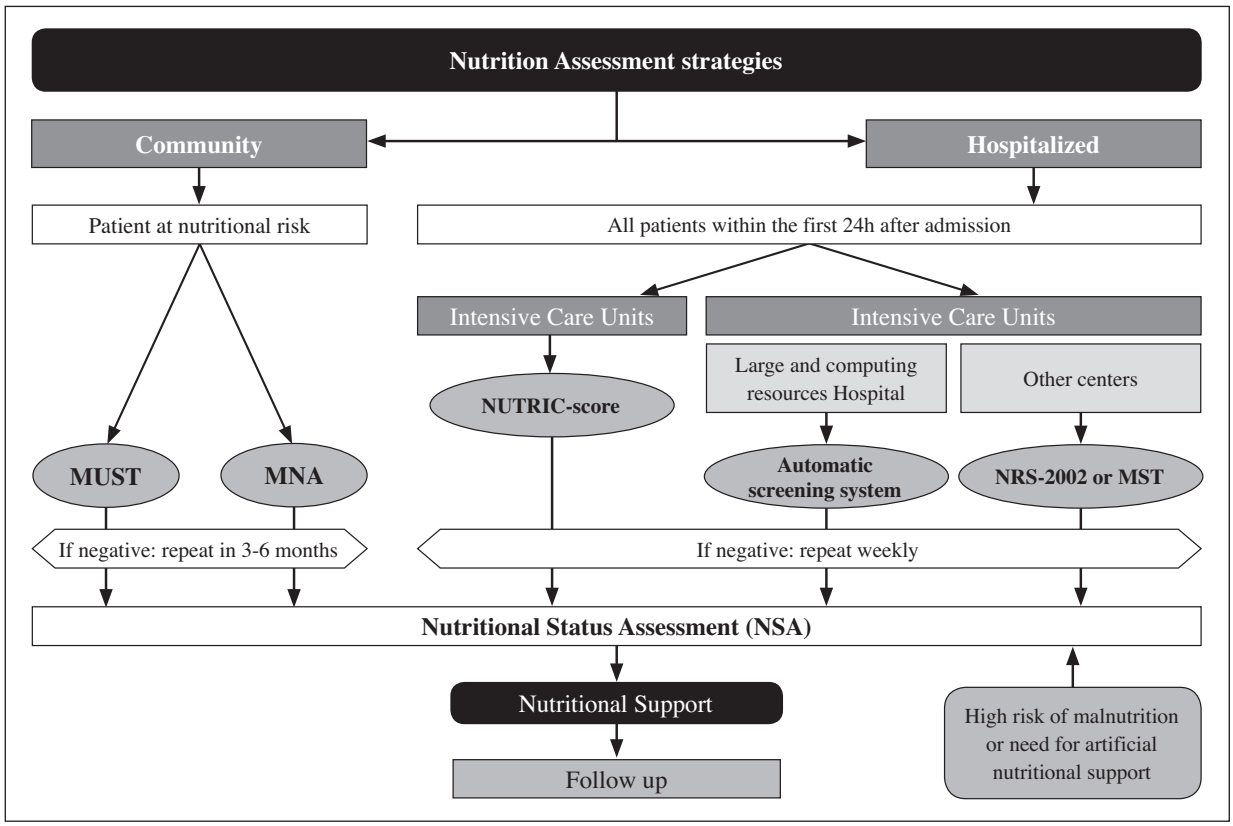


Fig. 1.—Nutritional assessment algorithm.

The MCA and TST are two classic anthropometric variables used in the measurement of nutritional status. However, their use is not without limitations, especially in hospitalised patients since the references against which the results are compared were developed with ambulatory subjects[16]. However, they are useful for monitoring changes if sufficient time is left between one measurement and another.

Recently, dynamometry has been used in the monitoring of nutritional status, but no consensus has yet been reached regarding its value[31,33].

The duration of monitoring of the response to a nutritional intervention will depend on each patient, but it would appear reasonable that weekly records be taken in the hospital setting and monthly or three-monthly records in the ambulatory setting, depending on the severity of the patient's condition and the type of nutritional support prescribed (Table VI).

Conclusion

The early identification of undernourished patients, or at risk of becoming undernourished, allows for diagnoses to be made that should be recorded in the medical history according to the ICD-9 system. There

Table VI
Monitoring of nutrition support at hospital and community

Hospitalized patient	*Screening*	*CONUT* *NRS-2002 NST* *NUTRIC-score*	*Perform to all patients within the first 24 h after admission* *If screening is positive: perform nutritional assessment (NSA)* *If screening is negative: repeat at least weekly*	
	NSA	*Initial*	*Follow-up after nutritional support*	
	Indication	If positive screening, high risk of malnutrition or artificial nutritional support	4-8 days	>15-20 days
	Symptoms (diarrhea, nausea, vomiting)	✔	✔	✔
	Diet history (intake rate)	✔	✔	✔
	Weight loss	✔	✗	✔
	Triceps skin fold + Upper arm muscle circumference	✔	✗	✔
	Dynamometry	✔	¿?	✔
	Albumin	✔	✗	✔
	Prealbumin	✗	✔	✔
	C-reactive protein	✔	✗	✗/✔
Community patient	*Screening*	*MUST* *MNA-screening*	*Perform to those patients with malnutrition risk factors* *If screening is positive: perform nutritional assessment (NSA)* *If screening is negative: repeat at least every 3-6 months*	
	NSA	*Initial*	*Follow-up after nutritional support*	
	Indication	If positive screening, high risk of malnutrition or artificial nutritional support	<1 month	>3 months
	Symptoms (diarrhea, nausea, vomiting)	✔	✔	✔
	Diet history (intake rate)	✔	✔	✔
	Weight loss	✔	✔	✔
	Triceps skin fold + Upper arm muscle circumference	✔	✔	✔
	Dynamometry	✔	✔	✔
	Albumin	✔	✗	✔
	Prealbumin	✗	✔	✔
	C-reactive protein	✗/✔	✗/✔	✗/✔

is no gold standard for assessing patients, but the NSA method may be recommendable since it integrates the SGA method, anthropometric measurements, and biochemical analyses. When a nutritional intervention is prescribed, the patient should be followed up, with monitoring performed according to the clinical setting, the means available, and the medical condition of the patient.

References

1. Roldán Aviña JP, Pérez Camacho I, Irles Rocamora JA, Martín Gómez R. Malnutrition in hospitalized patients: a prospective and randomized study. *Nutr Hosp* 1995;10(4):192-8.
2. Norman K, Pichard C, Lochs H, Pirlich M. Prognostic impact of disease-related malnutrition. *Clin Nutr* 2008 Feb;27(1):5-15.
3. Mueller C, Compher C, Ellen DM. A.S.P.E.N. clinical guidelines: Nutrition screening, assessment, and intervention in adults. *JPEN J Parenter Enteral Nutr* 2011 Jan 1;35(1):16-24.
4. Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. *Clin Nutr* 2003 Aug;22(4):415-21.
5. Rasmussen HH, Holst M, Kondrup J. Measuring nutritional risk in hospitals. *Clin Epidemiol* 2010 Jan;2:209-16.
6. García de Lorenzo A, Álvarez Hernández J, Planas M, Burgos R, Araujo K. Multidisciplinary consensus on the approach to hospital malnutrition in Spain. *Nutr Hosp* 2011;26(4):701-10.
7. Elia M, Stratton R. On the ESPEN guidelines for nutritional screening 2002. *Clin Nutr* 2004 Feb;23(1):131-2.
8. Ignacio de Ulíbarri J, González-Madroño A, de Villar NGP, González P, González B, Mancha A, et al. CONUT: a tool for controlling nutritional status. First validation in a hospital population. *Nutr Hosp* 2005;20(1):38-45.
9. Villalobos Gámez JL, García-Almeida JM, Guzmán de Damas JM, Rioja Vázquez R, Osorio Fernández D, Rodríguez-García LM, et al. Proceso INFORNUT®: validación de la fase de filtro -FILNUT- y comparación con otros métodos de detección precoz de desnutrición hospitalaria. *Nutr Hosp* 2012;21(4):491-504.
10. Gómez-Candela C, Serrano Labajos R, García-Vazquez N, Valero Pérez M, Morato Martínez M, Santurino Fontecha C, et al. Complete process of implantation of a nutritional risk screening system in the University Hospital La Paz, Madrid. *Nutr Hosp* 2013;28(6):2165-74.
11. Heyland DK, Dhaliwal R, Jiang X, Day AG. Identifying critically ill patients who benefit the most from nutrition therapy: the development and initial validation of a novel risk assessment tool. *Crit Care* 2011 Jan;15(6):R268.
12. Aquino R de C de, Philippi ST. Identification of malnutrition risk factors in hospitalized patients. *Rev Assoc Med Bras* 2011;57(6):637-43.
13. Windsor JA, Hill GL. Weight loss with physiologic impairment. A basic indicator of surgical risk. *Ann Surg* 1988;207(3):290-6.
14. Dewys WD, Begg C, Lavin PT, Band PR, Bennett JM, Bertino JR, et al. Prognostic effect of weight loss prior to chemotherapy in cancer patients. Eastern Cooperative Oncology Group. *Am J Med* 1980 Oct;69(4):491-7.
15. White J V, Guenter P, Jensen G, Malone A, Schofield M. Consensus statement: Academy of Nutrition and Dietetics and American Society for Parenteral and Enteral Nutrition: characteristics recommended for the identification and documentation of adult malnutrition (undernutrition). *JPEN J Parenter Enteral Nutr* 2012 May;36(3):275-83.
16. García de Lorenzo A, Álvarez Hernández J, Planas M, Burgos R, Araujo K. Consenso multidisciplinar sobre el abordaje de la desnutrición hospitalaria en España. Documentos de consenso de la SENPE. p. 9-41.
17. MAG of the British Association for Parenteral and Enteral Nutrition. The "MUST" Explanatory Booklet. A Guide to the "Malnutrition Universal Screening Tool" ("MUST") for Adults. 2003.
18. Kvamme J-M, Holmen J, Wilsgaard T, Florholmen J, Midthjell K, Jacobsen BK. Body mass index and mortality in elderly men and women: the Tromso and HUNT studies. *J Epidemiol Community Health* 2012 Jul;66(7):611-7.
19. CRUZ-JENTOF AJ, BAEYENS J-P, BAUER JM, BOIRIE Y, CEDERHOLM T, LANDI F. Sarcopenia: European consensus on definition and diagnosis. *Br Geriatr Soc* 2010;39:412-23.
20. Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Manuel Gómez J, et al. Bioelectrical impedance analysis-part II: utilization in clinical practice. *Clin Nutr* 2004 Dec;23(6):1430-53.
21. Benjamin DR. Laboratory tests and nutritional assessment. Protein-energy status. *Pediatr Clin North Am* 1989 Feb;36(1):139-61.
22. Burritt MF, Anderson CF. Laboratory assessment of nutritional status. *Hum Pathol* 1984 Feb;15(2):130-3.
23. Jellinge ME, Henriksen DP, Hallas P, Brabrand M. Hypoalbuminemia is a strong predictor of 30-day all-cause mortality in acutely admitted medical patients: a prospective, observational, cohort study. *PLoS One* 2014 Jan ;9(8):e105983.
24. Villamayor Blanco L, Llimera Rausell G, Jorge Vidal V, González Pérez-Crespo C, Iniesta Navalón C, Mira Sirvent M. C, et al. Valoración nutricional al ingreso hospitalario: iniciación al estudio entre distintas metodologías. *Nutr Hosp* 2006;21(2):163-72.
25. Fletcher JP, Little JM, Guest PK. A comparison of serum transferrin and serum prealbumin as nutritional parameters. *JPEN J Parenter Enteral Nutr* 1987;11(2):144-7.
26. Tuten MB, Wogt S, Dasse F, Leider Z. Utilization of prealbumin as a nutritional parameter. *JPEN J Parenter Enteral Nutr* 1985;9(6):709-11.
27. Beck FK, Rosenthal TC. Prealbumin: a marker for nutritional evaluation. *Am Fam Physician* 2002 Apr 15;65(8):1575-8.
28. Kuzuya M, Kanda S, Koike T, Suzuki Y, Iguchi A. Lack of correlation between total lymphocyte count and nutritional status in the elderly. *Clin Nutr* 2005 Jun;24(3):427-32.
29. Bellace J V, Healy D, Besser MP, Byron T, Hohman L. Validity of the Dexter Evaluation System's Jamar dynamometer attachment for assessment of hand grip strength in a normal population. *J Hand Ther* 2000;13(1):46-51.
30. Norman K, Stobäus N, Gonzalez MC, Schulzke J-D, Pirlich M. Hand grip strength: outcome predictor and marker of nutritional status. *Clin Nutr* 2011 Apr;30(2):135-42.
31. Flood A, Chung A, Parker H, Kearns V, O'Sullivan T a. The use of hand grip strength as a predictor of nutrition status in hospital patients. *Clin Nutr* 2014 Mar;33(1):106-14.
32. Milne AC, Avenell A, Potter J. Meta-analysis: protein and energy supplementation in older people. *Ann Intern Med* 2006 Jan 3;144(1):37-48.
33. Matos LC, Tavares MM, Amaral TF. Handgrip strength as a hospital admission nutritional risk screening method. *Eur J Clin Nutr* 2007 Sep;61(9):1128-35.
34. Detsky AS, McLaughlin JR, Baker JP, Johnston N, Whittaker S, Mendelson RA, et al. What is subjective global assessment of nutritional status? *JPEN J Parenter Enteral Nutr* 1987;11(1):8-13.
35. Barbosa-Silva MCG, Barros AJD. Indications and limitations of the use of subjective global assessment in clinical practice: an update. *Curr Opin Clin Nutr Metab Care* 2006 May;9(3):263-9.
36. Ferguson M. Patient-generated subjective global assessment. Oncology (Williston Park). 2003 Feb;17(2 Suppl 2):13-4; discussion 14-6.
37. Bauer J, Capra S, Ferguson M. Use of the scored Patient-Generated Subjective Global Assessment (PG-SGA) as a nutrition assessment tool in patients with cancer. *Eur J Clin Nutr* 2002 Aug;56(8):779-85.
38. Kalantar-Zadeh K, Kleiner M, Dunne E, Lee GH, Luft FC. A modified quantitative subjective global assessment of nutrition for dialysis patients. *Nephrol Dial Transplant* 1999 Jul;14(7):1732-8.

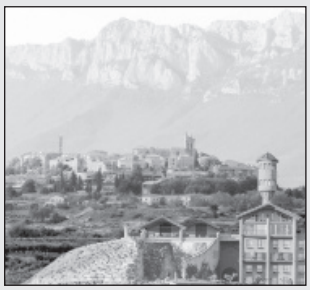
39. Bleda MJ, Bolibar I, Parés R, Salvà A. Reliability of the mini nutritional assessment (MNA) in institutionalized elderly people. *J Nutr Health Aging* 2002 Jan;6(2):134-7.
40. Calvo I, Olivar J, Martínez E. Uso del mini nutritional assessment como herramienta de cribaje nutricional en la población mayor de 65 años en el ámbito hospitalario; conveniencia y factibilidad. *Nutr Hosp* 2012 Sep 1;27(n05).
41. Vellas B, Guigoz Y, Garry PJ, Nourhashemi F, Bennahum D, Lauque S, et al. The Mini Nutritional Assessment (MNA) and its use in grading the nutritional state of elderly patients. *Nutrition* 1999 Feb;15(2):116-22.
42. Guigoz Y, Lauque S, Vellas BJ. Identifying the elderly at risk for malnutrition. The Mini Nutritional Assessment. *Clin Geriatr Med* 2002 Nov;18(4):737-57.
43. Guigoz Y. The Mini Nutritional Assessment (MNA) review of the literature--What does it tell us? *J Nutr Health Aging* 2006;10(6):466-85; discussion 485-7.
44. Matía Martín P, Triana F-MC. Nutrición en el anciano hospitalizado. *Rev Esp Geriatr Gerontol* 2006;41(06):340-56.
45. Durán Alert P, Milà Villarroel R, Formiga F, Virgili Casas N, Vilarasau Farré C. Assessing risk screening methods of malnutrition in geriatric patients: Mini Nutritional Assessment (MNA) versus Geriatric Nutritional Risk Index (GNRI). *Nutr Hosp* 2012;27(2):590-8.
46. Cereda E, Limonta D, Pusani C, Vanotti A. Assessing elderly at risk of malnutrition: the new Geriatric Nutritional Risk Index versus Nutritional Risk Index. Nutrition. 2006 Jun;22(6):680-2.
47. Álvarez J, Río J Del, Planas M, Peris PG, Lorenzo AG de, Calvo V, et al. Documento SENPE-SEDOM sobre la codificación de la desnutrición hospitalaria. Nutr Hosp. 2008;23(6):536-40.
48. Ministerio de Sanidad Servicios Sociales e Igualdad. PROYECTO DE TRANSICION DE CIE-9-MC A CIE-10-ES. Portal Estadístico del SNS. 2014.
49. Muscaritoli M, Anker SD, Argilés J, Aversa Z, Bauer JM, Biolo G, et al. Consensus definition of sarcopenia, cachexia and pre-cachexia: joint document elaborated by Special Interest Groups (SIG) "cachexia-anorexia in chronic wasting diseases" and "nutrition in geriatrics". *Clin Nutr* 2010 Apr;29(2):154-9.
50. MacDonald N. Terminology in cancer cachexia: importance and status. *Curr Opin Clin Nutr Metab Care* 2012 May;15(3):220-5.
51. Spiekerman AM. Nutritional assessment (protein nutriture). *Anal Chem* 1995 Jun 15;67(12):429R - 436R.

ENERGY EXPENDITURE AND PHYSICAL ACTIVITY: METHODOLOGICAL ISSUES

GASTO ENERGÉTICO Y ACTIVIDAD FÍSICA: ASPECTOS METODOLÓGICOS

"Consensus Meeting on the Methodology of Dietary Surveys, Classification of Physical Activity and Healthy Lifestyles"

"Reunión de Consenso sobre la Metodología de las Encuestas Alimentarias, Tipificación de la Actividad Física y Estilos de Vida Saludables"



Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):211-218
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Physical activity assessment in the general population; validated self-report methods

Ignacio Ara[1], Raquel Aparicio-Ugarriza[2,3], David Morales-Barco[2,3], Wysllenny Nascimento de Souza[2,3], Esmeralda Mata[1] and Marcela González-Gross[2,3,4]

[1]GENUD Toledo Research Group. University of Castilla La Mancha. [2]ImFINE Research Group. Technical University of Madrid. [3]Department of Health and Human Performance. Faculty of Physical Activity and Sport Science-INEF. Technical University of Madrid. [4]CIBERobn CB 12/03/30038 (Fisiopatología de la Obesidad y Nutrición). Spain.

Abstract

Self-reported questionnaires have been commonly used to assess physical activity levels in large cohort studies. As a result, strong and convincing evidences that physical activity can protect health are widely recognized. However, validation studies using objective measures of physical activity or energy expenditure (double labelled water, accelerometers, pedometers, etc.) indicate that the accuracy and precision of survey techniques are limited. Physical activity questionnaires could fail in estimating particularly non-vigorous physical activity. They have a disproportionate focus on volitional type exercise (i.e. biking, jogging, and walking), while not capturing the activities of daily living and low to moderate intensity movements. Energy expenditure estimates from these data are not recommended. On the other hand, despite objective tools should be the measurement of choice to assess PA level, self-reported questionnaires remain valid, and have many advantages. i.e. low costs. These kind of recalls are designed and validated for different age groups and provide value and important information, mainly about physical activity pattern. Future studies will require more precision and accuracy in physical activity measurement than those provided by traditional survey methods. We can conclude that probably a mixed approach that combines both the objective and subjective techniques involving novel devices and electronic capture of physical activity questionnaires will be more effective.

(*Nutr Hosp* 2015;31(Supl. 3):211-218)

DOI:10.3305/nh.2015.31.sup3.8768

Key words: *Physical activity. Questionnaire. Objective methods. Subjective methods.*

Correspondence: Ignacio Ara.
Laboratorio de Actividad Física y Función Muscular.
Campus Tecnológico de la Fábrica de Armas.
Universidad de Castilla La Mancha (UCLM).
Avda Carlos III, s/n.
45071 Toledo, España.
E-mail: ignacio.ara@uclm.es

ESTIMACIÓN DE LA ACTIVIDAD FÍSICA EN POBLACIÓN GENERAL; CUESTIONARIOS VALIDADOS

Resumen

Los cuestionarios auto-administrados han sido comúnmente utilizados en los estudios con grandes cohortes con el fin de evaluar la actividad física de sus participantes. Como consecuencia de ello, existe una considerable cantidad de evidencias científicas sobre el efecto protector de la actividad física sobre la salud. Sin embargo, los estudios de validación que utilizan métodos objetivos para la cuantificación de la actividad física o el gasto energético (el agua doblemente marcada, los acelerómetros, los podómetros, etc.) indican que la precisión de los cuestionarios es limitada. Los cuestionarios de actividad física pueden fallar especialmente al estimar la actividad física no vigorosa, y suelen centrarse de forma desproporcionada en los tipos de ejercicios planificados (ir en bicicleta, correr, andar,…), mientras que no suelen recoger las actividades de la vida diaria y movimientos de intensidad más moderada no planificada. La estimación del gasto energético a partir de estos datos no es recomendable. Por otro lado, y a pesar de que los métodos objetivos deberían de ser la primera elección a la hora de evaluar la actividad física, los cuestionarios se mantienen como herramientas válidas y con muchas ventajas, una de ellas, el bajo coste. Este tipo de instrumentos están específicamente diseñados y validados para diferentes grupos de edad y proporcionan información valiosa e importante, sobre todo, del patrón de actividad física. Los futuros estudios requieren de más precisión a la hora de medir la actividad física respecto a la que proporcionan los cuestionarios. Podemos concluir que probablemente un método mixto que combine los métodos objetivos y subjetivos y que incluya nuevos sistemas y registros electrónicos sería lo recomendable.

(*Nutr Hosp* 2015;31(Supl. 3):211-218)

DOI:10.3305/nh.2015.31.sup3.8768

Palabras clave: *Actividad física. Cuestionarios. Métodos objetivos. Métodos subjetivos.*

Background

In order to investigate the role of physical activity (PA) in maintaining health, many large cohort studies have been performed using self-reported PA questionnaires (PAQs). These studies have provided strong and convincing evidence that PA can protect health. Knowledge has accumulated in recent decades concerning the significance of PA in relation to a number of diseases: metabolic syndrome related disorders (insulin resistance, type 2 diabetes, dyslipidemia, hypertension, obesity), heart and pulmonary diseases (chronic obstructive pulmonary disease, coronary heart disease, chronic heart failure, intermittent claudication), muscle, bone and joint diseases (osteoarthritis, rheumatoid arthritis, osteoporosis, fibromyalgia, chronic fatigue syndrome) and cancer, depression, asthma and type 1 diabetes[1]. As a result new scientific questions (dose-response relationships; health protection in different populations; effectiveness of interventions to increase PA behaviours, etc.) are currently being researched. These kind of studies require more precision and accuracy in measurement than can be provided by the traditional survey methods.

Validation studies using objective measures of PA or energy expenditure (EE) indicate that the accuracy and precision of survey techniques are limited. A recent review of PA surveys as estimates of EE concluded that none of the 23 questionnaires evaluated had both acceptable correlations and mean differences compared to the "gold standard method", the doubly labelled water (DLW) measures of EE, at the group level, as well as reasonable individual estimates of the total energy expended in PA[2]. The authors concluded that apart from reporting errors, discrepancies between PAQs and DLW estimates may be partly attributable to 1) PAQs not including key activities related to active EE; 2) PAQs and DLW ascertaining different time periods; or 3) inaccurate assignment of metabolic equivalents to self-reported activities. Besides, small sample sizes, the use of correlation coefficients, and limited information on individual validity were also problematic[2].

Intensity of activity plays an important role in the accuracy of PA recalls, with reasonable accuracy and precision for vigorous PA, but not for less intense activities[3-5]. According to Colbert and Schoeller[6] convincing evidence for the inadequacy of our current questionnaires comes from examinations of PA in the 2003–2004 and more recently, the 2005–2006 NHANES study, in which the PA of U.S. adults was measured by accelerometer[7-8]. In these studies, the proportion of adults self-reporting enough PA to meet current recommendations was 6- to 10-fold higher than when measured by accelerometer.

Moreover, one of the most important studies in this field was performed by Atienza et al.[9], in which self-reported PA was independently associated with various health biomarkers even after adjustment for accelerometer-determined PA. Despite the uniqueness of questionnaire assessment was reported in this large population study with self-reported PA, it is important to note that accelerometers had much stronger associations and also picked up more relationships (e.g., systolic blood pressure, triglycerides, glucose, etc.) than did self-report.

Limitations

Colbert et al.[10] compared various objective and self-reported methods of measuring PA and demonstrated that all three objective measures (Sensewear armband, accelerometer and pedometer) correlated better with DLW-derived PA EE and had lower error than any of the three surveys PAQs (CHAMPS, PASE and YALE). The authors concluded that our current self-report methodologies lack precision and accuracy and thus may lead to faulty conclusions and overestimated recommendations regarding the dose of PA needed to maintain health.

It is noteworthy that none of the PAQs cited were specifically designed for activity EE estimation. It is also important to comment that despite DLW is widely considered the reference method for EE measurements, it has some limitations. One basic argument is that it only measures the energy cost of PA and not the behaviour itself. Thus, DLW does not provide relevant information regarding frequency, intensity, duration, pattern, and type of activity. Some of these components may be important predictors of specific health outcomes and knowledge of these will facilitate more accurate PA recommendations[6]. DLW is also quite expensive and requires specific expertise for its use. The cost limitation, however, is mediated in many applications, because the precision allows investigators to obtain statistically significant results with a smaller sample.

Although accelerometers cannot capture all activities (water-based activity, cycling, upper-body or resistance exercise) and are limited to the assessment of current activity, in combination with a simple PA log they have great utility, particularly in intervention studies. Reduction in cost and increased awareness of their capabilities will make them more appealing in larger studies. While there are still needs for traditional survey techniques such as the assessment of historical levels of activity among adults, or the assessment of resistance exercise, swimming, biking or activities in rough terrain, the increase in accuracy and precision available with the use of PA monitors reduces the value of traditional survey methods for most studies[7,10]. Coupled with dramatic price reductions most investigations are including the use of these monitors because of their superior accuracy and precision[6].

In relation to muscle-strengthening activities assessment, and in addition to aerobic activities, general recommendations of PA (2-3 days of muscle-streng-

thening activities in youth and in adults)[11], musculoskeletal fitness is increasingly identified as related to mortality[12] and morbidities[12-13]. Assessment of resistance/muscle strengthening activities and the associated measurement issues are similar to those suggested for aerobic PA, but accelerometers, pedometers, or DLW cannot assess involvement in this specific muscle-strengthening activities.

Controversy

Despite the major efforts placed into developing reliable and valid PAQs, they remain not sufficiently accurate for the majority of the population. The error is thought to originate from a disproportionate focus on volitional type exercise (biking, jogging, and walking), while not capturing low to moderate intensity movements that accumulate a significant proportion to total activity EE[14]. The use of self-reported behaviours will remain a staple in telephone-based and large epidemiological studies (for more information see a summary of the main PAQs in table I) but improved questionnaires should be created to enhance capturing non-exercise (household chores, standing, walking for purpose) and sedentary behaviours (sitting or lying) that are uniquely associated with public health. The inclusion of such behaviours in these questionnaires will help distinguish types of activities that might have a critical role in health and potentially distinct interactions with volitional exercise. The development of such questionnaires is ongoing for these purposes [78].

Conclusion

There will always be specific situations both in research and in clinical settings that will need self-reports; however, whenever possible, objective measures should be the measurement of choice as they will provide more accuracy for the measurement of PA and also for the measure of sedentary time.

We do not currently possess or utilize the perfect PA assessment tool. The notion that objective PA tools are more valid or accurate than non-objective tools such as PA questionnaires should be considered with caution as these tools may in fact assess different aspects of PA. Hence, the use of simple, less intrusive tools like questionnaires will always be of relevance. It is a research challenge to devise "the best method" that combines both the objective and subjective techniques involving electronic gadgetry and PAQs-based registry (special consideration to the future should be given to accelerometers and GPS of smartphones monitoring daily movement patterns, including locations and times of activities).

Given the limited validity of self-reported PA and the inability of objective measurement tools to capture

Table I

Main Physical Activity Questionnaires (PAQ) found in scientific literature classified by age groups

Age group	*Acronym*	*Definition*	*Reference*
CHILDREN (<12 AÑOS) PAQ	Activitygram Assessment	Physical Activity Recall	Cooper Institute 1999 [15]
	CDPAQ	Computer Delivered Multimedia 1-Day Physical Activity Questionnaire	Ridley et al. 2001 [16]
	CLASS	Children's Leisure Activity Study Survey Questionnaire	Telford et al. 2004 [17]
	CPAR	Computerized Physical Activity Recall	McMurray et al. 1998 [18]
	FELS PAQ	Fels Physical Activity Questionnaire for Children	Treuth et al. 2005 [19]
	GAQ	Girls Health Enrichment Multisite Study Activity Questionnaire	Treuth et al. 2003 [20]
	GSQ	Godin-Sephard Physical Activity Questionnaire	Jürisson & Jürimäe 1996 [21]
	KidActive-Q	KidActive Web-based Proxy Questionnaire	Bonn et al. 2012 [22]
	MARCA	The Multimedia Activity Recall for Children and Adolescents	Ridley et al. 2006 [23]
	MRPARQ	Many Rivers Physical Activity Recall Questionnaire	Gwynn et al. 2010 [24]
	OPAQ	Oxford Physical Activity Questionnaire	Lubans et al. 2008 [25]

Table I *(cont.)*
Main Physical Activity Questionnaires (PAQ) found in scientific literature classified by age groups

Age group	*Acronym*	*Definition*	*Reference*
	PAQ-C	Physical Activity Questionnaire for Older Children	Crocker et al. 1997 [26]
	PAQ-S	Physical Activity Questionnaire for Schoolchildren	Manios et al. 2013 [27]
		Parental Report Outdoors Questionnaire	Burdette et al. 2004 [28]
	Pre-PAQ	Pre-school-age Children's Physical Activity Questionnaire	Dwyer et al. 2011 [29]
	SAPAC	Self-Administered Physical Activity Checklist	Sallis et al. 1996 [30]
	SHAPES PAQ	School Health Action, Planning Evaluation System Physical Activity Questionnaire	Wong et al. 2006 [31]
	Y-PASS Questionnaire	Youth Physical Activity Survey for Specific Settings	Stanley et al. 2014 [32]
ADOLESCENT (12-16 years) PAQ	LTEQ	Leisure Time Exercise Questionnaire	McCormack & Giles-Corti 2002 [33]
	PTLAQ	Past Year Leisure Time Activity Questionnaire	McCormack & Giles-Corti 2002 [33]
	PDPAR	Previous Day Physical Activity Recall	McCormack & Giles-Corti 2002 [33]
	APARQ	Adolescent Physical Activity Recall Questionnaire	McCormack & Giles-Corti 2002 [33]
	MACQ	Modifiable Physical Activity Questionnaire for Adolescents	McCormack & Giles-Corti 2002 [33]
	YRBS	Youth Risk Behaviour Survey	Troped et al. 2007 [34]
	SAPAC	Self-Administratered Physical Activity Checklist	Ekelund et al. 2006 [35]
	WAC	Weekly Activity Checklist (modified)	Mota et al. 2002 [36]
	IPAQ-A	International Physical Activity Questionnaire for Adolescents	Hagströmer et al. 2008 [37]
	BAD	Bouchard Activity Diary	Martinez-Gómez et al. 2010 [38]
	PAQ-A	Physical Activity Questionnaire for Adolescents	Kowalski et al. 1997 [39]
	HBSC	Health Behaviour in School Children Questionnaire	Rangul et al. 2008 [40]
ADULTS (16-65 years) PAQ	CBPAQ	Cognitive Behavioral Physical Activity Questionnaire	Schembre et al. 2014 [41]
	PPAQ	Paffenbarger Physical Activity Questionnaire Among Healthy Adults	Simpson 2011 [42]
	MLTAQ	Minnesota Leisure Time Physical Activity Questionnaire	Elosua R et al. 1994 for Spanish men [43] Elosua R et al. 2000 for Spanish women [44]
	IPAQ	International Physical Activity Questionnaire	Dweyer et al. 2011 [29]
	IPAQ-L	International Physical Activity Questionnaire-Long Version	Hagströmer et al. 2006 [45]
	1WPAR	One-Week Physical Activity Recall	Timperio et al. 2003 [46]
	7DPAR	7-Day Physical Activity Recall	Conway et al. 2002 [47]
	7-DR	7-Day Recall	Bonnefoy et al. 2001 [48]

Table I ***(cont.)***
Main Physical Activity Questionnaires (PAQ) found in scientific literature classified by age groups

Age group	*Acronym*	*Definition*	*Reference*
	AAFQ	Arizona Activity Frequency Questionnaire	Staten et al. 2001 [49]
	AAS	Active Australian Survey	Brown et al. 2008 [50]
	AWAS	Australian Women's Activity Survey	Fjeldsoe et al. 2009 [51]
	BAD	Bouchard Activity Diary	Martinez-Gomez et al. 2010 [38]
	BAQ	Bouchard Activity Questionnaire	Philippaerts et al. 1999 [52]
	BAQ- mod	Baecke Activity Questionnaire Modified Version	Bonnefoy et al. 2001 [48]
	CAPS-4WR	Cross-cultural Activity Participation Study-4 Weeks Activity Recall	Mahabir et al. 2006 [53]
	CAPS-TWR	Cross-cultural Activity Participation Study - Typical Week Activity Recall	Mahabir et al. 2006 [53]
	FCPQ	Five City Project Questionnaire	Mahabir et al. 2006 [53]
	FPACQ	Flesmish Physical Activity Computerized Questionnaire	Matton et al. 2007 [54]
	GPAQ	Global Physical Activity Questionnaire	Bull et al. 2009 [55]
	HEPA99	Swiss Health Enhancing Physical Activity Survey 1999	Mader et al. 2006 [56]
	HUNT2	Nord-Trondelag Health Study Questionnaire-Version 1	Kurtze et al. 2007 [57]
	KPAS	Kaiser Physical Activity Survey	Ainsworth et al. 2000 [58]
	KPAS-mod	Kaiser Physical Activity Survey- Modified Version	Smichtd et al. 2006 [59]
	MLTPAQ	Minnesota Leisure Time Physical Activity Questionnaire	Slinde et al. 2003 [60]
	NHS-PAQ	Nurses' Health Study II- Physical Activity Questionnaire	Pettee-Gabriel et al. 2009 [61]
	OIMQ	Office in Motion Questionnaire	Mader et al. 2006 [56]
		Occupational Physcial Activity Questionnaire	Reis et al. 2005 [62]
	PAAT	Physical Activity Assessment Total	Meriwether et al. 2006 [63]
	PMMAQ	Past Month – Modifiable Activity Questionnaire	Pettee-Gabriel et al. 2009 [61]
	PWMAQ	Past Week Modifiable Activity Questionnaire	Pettee-Gabriel et al. 2009 [61]
	PYTPAQ	Past-year Total Physical Activity Questionnaire	Friedenreich et al. 2006 [64]
	RPAQ	Recent Physical Activity Questionnaire	Besson et al. 2010 [65]
	S7DR	Stanford 7 - Day Recall	Richardson et al. 2001 [66]
		Scottish Physical Activity Questionnaire	Lowther et al. 1999 [67]
	SAPAC-modified	Self-Administered Physical Activitiy Checklist	Affuso et al. 2011 [68]
	OSPAQ	Occupational Sitting and PAQ	Chau et al. 2012 [69]
	MOSPA-Q	MONICA Optional Study on Physical Activity Questionnaire	Roeykens et al. 1998 [70]

Table I (*cont.*)
Main Physical Activity Questionnaires (PAQ) found in scientific literature classified by age groups

Age group	*Acronym*	*Definition*	*Reference*
ELDERLY (>65 years) PAQ	CHAMPS	Community Healthy Activities Model Program for Seniors	Harada et al. 2001 [71]
	CHAMPS-MMSCV	Healthy Activities Model Program for Seniors - Modified Mailed Self-Complete Version	Giles & Marshall 2009 [72]
	DQ-mod	Dallosso Questionnaire-Modified Version	Bonnefoy et al. 2001 [48]
	IPAQ-E	International Physical Activity Questionnaire Short Version Modified for Elderly	Hurtig-Wennlöf et al. 2010 [73]
	PAQ-EJ	Physical Activity Questionnaire for Elderly Japanese	Yasunaga et al. 2007 [74]
	PASE	Physical Activity Scale for the Elderly	Washburn et al. 1993 [75]
	QPASE	Questionnaire d'Activitév Physique Saint-Etienne	Bonnefoy et al. 2001 [48]
	VAPAQ	Veterans Physical Activity Questionnaire	Betz et al. 2014 [76]
	YPAS	Yale Physical Activity Survey	Dipietro et al. 1993 [77]

all types of PA, a hybrid approach may be optimal for future PA assessments. Indeed, continuous advancements in the technology of objective PA assessment tools combined with online self-reported PA data collection are likely to lead the way in the following years towards a modernized and, potentially, more accurate and comprehensive estimation of PA with the inclusion of objective monitoring in very large observational studies.

References

1. Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. Scandinavian *Journal of Medicine and Science in Sports* 2006;16 (SUPPL. 1):3-63.
2. Neilson HK, Robson PJ, Friedenreich CM, Csizmadi I. Estimating activity energy expenditure: How valid are physical activity questionnaires? *Am J Clin Nutr* 2008;87(2):279-91.
3. Besson H, Brage S, Jakes RW, Ekelund U, Wareham NJ. Estimating physical activity energy expenditure, sedentary time, and physical activity intensity by self-report in adults. *Am J Clin Nutr* 2010;91(1):106-14.
4. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35(8):1381-95.
5. Mäder U, Martin BW, Schutz Y, Marti B. Validity of four short physical activity questionnaires in middle-aged persons. *Med Sci Sports Exerc* 2006;38(7):1255-66.
6. Colbert LH and Schoeller DA. Expending our physical activity (measurement) budget wisely. *J Appl Physiol* 2011;111: 606-607.
7. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, Mcdowell M. Physical activity in the united states measured by accelerometer. *Med Sci Sports Exerc* 2008;40(1):181-8.
8. Tucker JM, Welk GJ, Beyler NK. Physical activity in US adults compliance with the physical activity guidelines for Americans. *Am J Prev Med* 2011; 40: 454-461.
9. Atienza AA, Moser RP, Perna F, Dodd K, Ballard-Barbash R, Troiano RP, Berrigan D. Self-reported and objectively measured activity related to biomarkers using NHANES. *Med Sci Sports Exerc* 2011;43(5):815-21.
10. Colbert LH, Matthews CE, Havighurst TC, Kim K, Schoeller DA. Comparative validity of physical activity measures in older adults. *Med Sci Sports Exerc* 2011; 43: 867-876.
11. World Health Organization. Global recommendations on physical activity for health, 2010.
12. Ruiz JR, Sui X, Lobelo F, Lee D-, Morrow Jr. JR, Jackson AW, Hébert JR, Matthews CE, Sjöström M, Blair SN. Muscular strength and adiposity as predictors of adulthood cancer mortality in men. *Cancer Epidemiology Biomarkers and Prevention* 2009;18(5):1468-76.
13. Jackson AW, Lee D-, Sui X, Morrow Jr. JR, Church TS, Maslow AL, Blair SN. Muscular strength is inversely related to prevalence and incidence of obesity in adult men. *Obesity* 2010; 18(10):1988-95.
14. Westerterp KR. Pattern and intensity of physical activity. *Nature* 2001;410(6828):539.
15. Cooper Institute for Aerobic Research (1999) The FITNESSGRAM test administration manual (6.0 ed.) Champaign, IL: Human Kinetics.
16. Ridley K, Dollman J, Olds T. Development and validation of a computer delivered physical activity questionnaire (CDPAQ) for children. *Pediatric Exercise Science* 2001;13(1):35-46.
17. Telford A, Salmon J, Jolley D, Crawford D. Reliability and validity of physical activity questionnaires for children: The children's leisure activities study survey (CLASS). *Pediatric Exercise Science* 2004;16(1):64-78.
18. McMurray RG, Harrell JS, Bradley CB, Webb JP, Goodman EM. Comparison of a computerized physical activity recall

with a triaxial motion sensor in middle-school youth. *Med Sci Sports Exerc* 1998;30(8):1238-45.
19. Treuth MS, Hou N, Young DR, Maynard LM. Validity and reliability of the fels physical activity questionnaire for children. *Med Sci Sports Exerc* 2005;37(3):488-95.
20. Treuth MS, Sherwood NE, Butte NF, McClanahan B, Obarzanek E, Zhou A, Ayers C, Adolph A, Jordan J, Jacobs Jr. DR, Rochon J. Validity and reliability of activity measures in african-american girls for GEMS. *Med Sci Sports Exerc* 2003;35(3):532-9.
21. Jürisson A, Jürimäe T. The validity of the godin-shephard physical activity questionnaire in children. *Biology of Sport* 1996; 13(4):291-5.
22. Bonn SE, Surkan PJ, Trolle Lagerros Y, Bälter K. Feasibility of a novel web-based physical activity questionnaire for young children. *Pediatric Reports* 2012;4(4).
23. Ridley K, Olds TS, Hill A. The multimedia activity recall for children and adolescents (MARCA): Development and evaluation. *International Journal of Behavioral Nutrition and Physical Activity* 2006;3.
24. Gwynn JD, Hardy LL, Wiggers JH, Smith WT, D'Este CA, Turner N, Cochrane J, Barker DJ, Attia JR. The validation of a self-report measure and physical activity of australian aboriginal and torres strait islander and non-indigenous rural children. *Aust N Z J Public Health* 2010;34(SUPPL):S57-65.
25. Lubans DR, Sylva K, Osborn Z. Convergent validity and test-retest reliability of the oxford physical activity questionnaire for secondary school students. *Behaviour Change* 2008;25(1):23-34.
26. Crocker PRE, Bailey DA, Faulkner RA, Kowalski KC, Mcgrath R. Measuring general levels of physical activity: Preliminary evidence for the physical activity questionnaire for older children. *Med Sci Sports Exerc* 1997;29(10):1344-9.
27. Manios Y, Androutsos O, Moschonis G, Birbilis M, Maragkopoulou K, Giannopoulou A, Argyri E, Kourlaba G. Criterion validity of the physical activity questionnaire for schoolchildren (PAQ-S) in assessing physical activity levels: The healthy growth study. *J Sports Med Phys Fitness* 2013;53(5):502-8.
28. Burdette HL, Whitaker RC, Daniels SR. Parental report of outdoor playtime as a measure of physical activity in preschool-aged children. *Archives of Pediatrics and Adolescent Medicine* 2004;158(4):353-7.
29. Dwyer GM, Hardy LL, Peat JK, Baur LA. The validity and reliability of a home environment preschool-age physical activity questionnaire (pre-PAQ). *International Journal of Behavioral Nutrition and Physical Activity* 2011;8.
30. Sallis JF, Strikmiller PK, Harsha DW, Feldman HA, Ehlinger S, Stone EJ, Williston J, Woods S. Validation of interviewer- and self-administered physical activity checklists for fifth grade students. *Med Sci Sports Exerc* 1996;28(7):840-51.
31. Wong SL, Leatherdale ST, Manske S. Reliability and validity of a school-based physical activity questionnaire. *Med Sci Sports Exerc* 2006;38(9):1593-600.
32. Stanley RM, Ridley K, Olds TS, Dollman J. Development and psychometric properties of the Y-PASS questionnaire to assess correlates of lunchtime and after-school physical activity in children. *BMC Public Health* 2014;14(1).
33. McCormack G, and Giles-Corti B. Report to the Physical Activity Task Force, Evaluation and Monitoring Group: An assessment of selfreport questionnaires and motion sensors for measuring physical activity in children. Department of Public Health, The University of Western Australia. 2002.
34. Troped PJ, Wiecha JL, Fragala MS, Matthews CE, Finkelstein DM, Kim J, Peterson KE. Reliability and validity of YRBS physical activity items among middle school students. *Med Sci Sports Exerc* 2007;39(3):416-25.
35. Ekelund U, Neovius M, Linné Y, Rössner S. The criterion validity of a last 7-day physical activity questionnaire (SAPAQ) for use in adolescents with a wide variation in body fat: The stockholm weight development study. *Int J Obes* 2006;30(6):1019-21.
36. Mota J, Santos P, Guerra S, Ribeiro JC, Duarte JA, Sallis JF. Validation of a physical activity self-report questionnaire in a portuguese pediatric population. *Pediatric Exercise Science* 2002;14(3):269-76.
37. Hagströmer M, Bergman P, De Bourdeaudhuij I, Ortega FB, Ruiz JR, Manios Y, Rey-López JP, Phillipp K, Von Berlepsch J, Sjöström M. Concurrent validity of a modified version of the international physical activity questionnaire (IPAQ-A) in european adolescents: The HELENA study. *Int J Obes* 2008;32(SUPPL. 5):S42-8.
38. Martínez-Gómez D, Wärnberg J, Welk GJ, Sjöström M, Veiga OL, Marcos A. Validity of the bouchard activity diary in spanish adolescents. *Public Health Nutr* 2010;13(2):261-8.
39. Kowalski KC, Crocker PRE, Kowalski NP. Convergent validity of the physical activity questionnaire for adolescents. *Pediatric Exercise Science* 1997;9(4):342-52.
40. Rangul V, Holmen TL, Kurtze N, Cuypers K, Midthjell K. Reliability and validity of two frequently used self-administered physical activity questionnaires in adolescents. *BMC Medical Research Methodology* 2008;8.
41. Schembre SM, Duran CP, Blissmer BJ, Greene GW. Developmental and Validation of the Cognitive Behavioral Physical Activity Questionnaire. *Am J Health Promot* 2014 (in press) .
42. Simpson K (2011) Validity and Reliability of the Paffenbarger Physical Activity Questionnaire among Healthy Adults (2011). University of Connecticut. *Master's Theses*. Paper 52.
43. Elosua R, Marrugat J, Molina L, Pons S, Pujol E. Validation of the Minnesota Leisure Time Physical Activity Questionnaire in Spanish men. The MARATHOM Investigators. *Am J Epidemiol* 1994;139(12):1197-209.
44. Elosua R, Garcia M, Aguilar A, Molina L, Covas MI, Marrugat J. Validation of the Minnesota Leisure Time Physical Activity Questionnaire In Spanish Women. Investigators of the MARATDON Group. *Med Sci Sports Exerc* 2000;32(8):1431-7.
45. Hagströmer M, Oja P, Sjöström M. The international physical activity questionnaire (IPAQ): A study of concurrent and construct validity. *Public Health Nutr* 2006;9(6):755-62.
46. Timperio A, Salmon J, Crawford D. Validity and reliability of a physical activity recall instrument among overweight and non overweight men and women. *J Sci Med Sport* 2003; 6:477-491.
47. Conway JM, Seale JL, Jacobs DR Jr, Irwin ML, Ainsworth BE. Comparison of energy expenditure estimates from doubly labeled water, a physical activity questionnaire, and physical activity records. *Am J Clin Nutr* 2002; 75:519-525.
48. Bonnefoy M, Normand S, Pachiaudi C, Lacour JR, Laville M, Kostka T. Simultaneous validation of ten physical activity questionnaires in older men: a doubly labeled water study. *J Am Geriatr Soc* 2001; 49:28-35.
49. Staten LK, Taren DL, Howell WH, Tobar M, Poehlman ET, Hill A, Reid PM, Ritenbaugh C. Validation of the arizona activity frequency questionnaire using doubly labeled water. *Med Sci Sports Exerc* 2001;33(11):1959-67.
50. Brown WJ, Burton NW, Marshall AL, Miller YD. Reliability and validity of a modified self-administered version of the Active Australia physical activity survey in a sample of mid-age women. *Aust N Z J Public Health* 2008; 32:535-541.
51. Fjeldsoe BS, Marshall AL, Miller YD. Measurement properties of the australian women's activity survey. *Med Sci Sports Exerc* 2009;41(5):1020-33.
52. Philippaerts RM, Westerterp KR, Lefevre J. Doubly labelled water validation of three physical activity questionnaires. *Int J Sports Med* 1999; 20:284-289.
53. Mahabir S, Baer DJ, Giffen C, Clevidence BA, Campbell WS, Taylor PR, Hartman TJ. Comparison of energy expenditure estimates from 4 physical activity questionnaires with doubly labeled water estimates in postmenopausal women. *Am J Clin Nutr* 2006; 84:230-236.
54. Matton L, Wijndaele K, Duvigneaud N, Duquet W, Philippaerts R, Thomis M, Lefevre J. Reliability and validity of the Flemish physical activity computerized questionnaire in adlults. *Res Q Exerc Sport* 2007; 78:293-306.
55. Bull FC, Maslin TS, Armstrong T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *J Phys Act Health* 2009; 6:790-804.

56. Mader U, Martin BW, Schutz Y, Marti B. Validity of four short physical activity questionnaires in middle-aged persons. *Med Sci Sports Exerc* 2006; 38:1255-1266.
57. Kurtze N, Rangul V, Hustvedt BE, Flanders WD. Reliability and validity of self-reported physical activity in the Nord-Trondelag Health Study (HUNT 2). *Eur J Epidemiol* 2007; 22:379-387.
58. Ainsworth BE, Sternfeld B, Richardson MT, Jackson K. Evaluation of the kaiser physical activity survey in women. *Med Sci Sports Exerc* 2000; 32:1327-1338.
59. Schmidt MD, Freedson PS, Pekow P, Roberts D, Sternefld B, Chasan-Taber L. Validation of the Kaiser Physical Activity Survey in Pregnant Women. *Medicine & science in sports & exercise* 2006;38(1):42-50.
60. Slinde F, Arvidsson D, Sjoberg A, Rossander-Hulthen L. Minnesota leisure time activity questionnaire and doubly labeled water in adolescents. *Med Sci Sports Exerc* 2003; 35:1923-1928.
61. Pettee Gabriel K, McClain JJ, Lee CD, Swan PD, Alvar BA, Mitros MR, Ainsworth BE. Evaluation of physical activity measures used in middleaged women. *Med Sci Sports Exerc* 2009, 41:1403-1412.
62. Reis JP, Dubose KD, Ainsworth BE, Macera CA, Yore MM. Reliability and validity of the occupational physical activity questionnaire. *Med Sci Sports Exerc* 2005; 37:2075-2083.
63. Meriwether RA, McMahon PM, Islam N, Steinmann WC. Physical activity assessment: validation of a clinical assessment tool. *Am J Prev Med* 2006; 31:484-491.
64. Friedenreich CM, Courneya KS, Neilson HK, Matthews CE, Willis G, Irwin M, Troiano R, Ballard-Barbash R. Reliability and validity of the Past Year Total Physical Activity Questionnaire. *Am J Epidemiol* 2006; 163:959-970.
65. Besson H, Brage S, Jakes RW, Ekelund U, Wareham NJ. Estimating physical activity energy expenditure, sedentary time, and physical activity intensity by self-report in adults. *Am J Clin Nutr* 2010; 91:106-114.
66. Richardson MT, Ainsworth BE, Jacobs DR, Leon AS. Validation of the stanford 7-Day Recall to assess habitual physical activity. *Ann Epidemiol* 2001; 11:145-153.
67. Lowther M, Mutrie N, Loughlan C, McFarlane C. Development of a Scottish physical activity questionnaire: a tool for use in physical activity interventions. *Br J Sports Med* 1999; 33:244-249.
68. Affuso O, Stevens J, Catellier D, McMurray RG, Ward DS, Lytle L, Sothern MS, Young DR. Validity of self-reported leisure-time sedentary behavior in adolescents. *J Negat Results Biomed* 2011; 10:2.
69. Chau JY, Van Der Ploeg HP, Dunn S, Kurko J, Bauman AE. Validity of the occupational sitting and physical activity questionnaire. *Med Sci Sports Exerc* 2012; 44(1):118-25.
70. Roeykens J, Rogers R, Meeusen R, Magnus L, Borms J, De Meirleir K. Validity and reliability in flemish population of the WHO-MONICA optional study of physical activity questionnaire. *Med Sci Sports Exerc* 1998; 30(7):1071-5.
71. Harada ND, Chiu V, King AC, Stewart AL. An evaluation of three self-report physical activity instruments for older adults. *Med Sci Sports Exerc* 2001;33(6):962-70.
72. Giles K, Marshall AL. Repeatability and accuracy of CHAMPS as a measure of physical activity in a community sample of older australian adults. *Journal of Physical Activity and Health* 2009; 6(2):221-9.
73. Hurtig-Wennlöf A, Hagströmer M, Olsson LA. The international physical activity questionnaire modified for the elderly: Aspects of validity and feasibility. *Public Health Nutr* 2010;13(11):1847-54.
74. Yasunaga A, Park H, Watanabe E, Togo F, Park S, Shephard RJ, et al. Development and evaluation of the physical activity questionnaire for elderly japanese: The nakanojo study. *J Aging Phys Act* 2007;15(4):398-411.
75. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): Development and evaluation. *J Clin Epidemiol* 1993;46(2):153-62.
76. Betz HH, Myers J, Jaffe A, Smith K, Dalman R. Reproducibility of the Veterans Physical Activity Questionnaire in an Elderly Population. *J Phys Act Health* 2014.
77. Dipietro L, Caspersen CJ, Ostfeld AM, Nadel ER. A survey for assessing physical activity among older adults. *Med Sci Sports Exerc* 1993;25(5):628-42.
78. Gardiner PA, Clark BK, Healy GN, Eakin EG, Winkler EAH, Owen N. Measuring older adults' sedentary time: Reliability, validity, and responsiveness. *Med Sci Sports Exerc* 2011;43(11): 2127-33.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):219-226
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Physical activity assessment in the general population; instrumental methods and new technologies

Raquel Aparicio-Ugarriza[1,2], Juan Mielgo-Ayuso[1,2], Pedro J. Benito[2,3], Raquel Pedrero-Chamizo[1,2], Ignacio Ara[4] and Marcela González-Gross[1,2,5] on behalf of EXERNET Study Group

[1]ImFINE Research Group. Technical University of Madrid. [2]Department of Health and Human Performance. Faculty of Physical Activity and Sport Science-INEF. Technical University of Madrid. [3]EFISAF Research Group. Technical University of Madrid. [4]GENUD Toledo Research Group. University of Castilla La Mancha. [5]CIBERobn CB 12/03/30038 (Fisiopatología de la Obesidad y Nutrición). Spain.

Abstract

The objective measurement of human movement and the quantification of energy expenditure due to physical activity is an identified need in both research and the clinical setting. Validated and well-defined reference methods (double labelled water, direct calorimetry, indirect calorimetry) are expensive and mostly limited to the laboratory setting. Therefore, in the last years, several objective measurement devices have been developed which are appropriate for field studies and clinical settings. There is no gold standard among them, as all have limitations. Pedometers are small, non-expensive, count the steps taken and give information on total physical activity, but not about physical activity patterns and behaviour. Accelerometers are expensive, save information about frequency and intensity of physical activity, but not about type of physical activity. Both pedometers and accelerometers only save information about lower body movement, but reliability about the estimation of energy expenditure is limited. Heart rate monitoring relates intensity to energy expenditure, but gives no information about physical activity. GPS watches are portable, relatively inexpensive, non-invasive and provide distance, speed, and elevation with exact time and location, but are maybe limited for the assessment of brief higher speed movement and energy expenditure. Combined motion sensors combine accelerometry with the measurement of physiological variables and share advantages of single devices and are more precise. Manufacturer software which applies activity-specific algorithms for the calculation of energy expenditure can affect energy expenditure results. Most of the devices estimate energy expenditure more accurately at light to moderate intensities; underestimation increases at very light and higher intensity activities.

(*Nutr Hosp* 2015;31(Supl. 3):219-226)

DOI:10.3305/nh.2015.31.sup3.8769

Key words: *physical activity, energy expenditure, accelerometer, pedometer, GPS.*

Correspondence: Marcela González-Gross.
ImFINE Research Group.
Departamento de Salud y Rendimiento Humano.
Facultad de Ciencias de la Actividad Física y del Deporte-INEF.
Universidad Politécnica de Madrid.
C/ Martín Fierro 7.
E. 28040 Madrid, España.
E-mail: marcela.gonzalez.gross@upm.es

ESTIMACIÓN DE LA ACTIVIDAD FÍSICA EN POBLACIÓN GENERAL; MÉTODOS INSTRUMENTALES Y NUEVAS TECNOLOGÍAS

Resumen

La medición objetiva del movimiento humano y la cuantificación del gasto energético debido a la actividad física es una necesidad identificada tanto en investigación como en clínica. Los métodos de referencia validados y bien definidos (el agua doblemente marcada, la calorimetría directa, la calorimetría indirecta) son caros y prácticamente se limitan a la investigación en el laboratorio. Por lo tanto, en los últimos años, se han desarrollado diferentes dispositivos de medición objetiva que son apropiados para los estudios de campo y clínicos. No hay ningún estándar de oro entre ellos, ya que todos tienen limitaciones. Los podómetros son ligeros, poco costosos, cuentan los pasos y aportan información sobre la actividad física total, pero no sobre el comportamiento y los patrones de actividad física. Los acelerómetros son caros, aportan información sobre patrón, frecuencia e intensidad de la actividad física, pero no sobre el tipo de actividad física. Los podómetros y acelerómetros únicamente recogen información sobre el movimiento del movimiento corporal, pero la validez en la estimación del gasto energético es limitada. La monitorización de la frecuencia cardíaca relaciona intensidad del ejercicio con gasto de energía, pero no aporta información sobre la actividad física. Los dispositivos GPS son portátiles, relativamente asequibles, no invasivos y recogen distancia, velocidad y elevación con hora y lugar exactos, pero quizás estén limitados para la evaluación de movimientos cortos de alta intensidad y elevado gasto energético. Los dispositivos de última generación combinan acelerometría con la medición de variables fisiológicas, comparten las ventajas de los dispositivos individuales y son más precisos. Para el cálculo del gasto energético se aplican algoritmos específicos de la actividad incluidos en el software del fabricante que pueden afectar a los resultados. La mayoría de los dispositivos estiman con mayor precisión el gasto energético a intensidades ligeras y moderadas, pero subestiman el gasto a intensidades muy ligeras y de mayor intensidad.

(*Nutr Hosp* 2015;31(Supl. 3):219-226)

DOI:10.3305/nh.2015.31.sup3.8769

Palabras clave: *Actividad física. Gasto energético. Acelerómetro. Podómetro. GPS.*

Background

Scientific evidence accumulating during the last decades has stated the benefits of regular physical activity on health and disease prevention[1]. Physical activity (PA) reduces both morbidity and mortality and can minimize the physiological effects of an otherwise sedentary lifestyle increasing the active lifespan[2]. Therefore, it is essential to provide reliable and valid methods to measure PA for population studies and the clinical setting.

Since Lavoisier performed his study introducing a dog in a metabolic chamber at the end of the 18th Century, scientists know that PA is associated with an increase in oxygen consumption, carbon dioxide output and heat production when compared to rest. Even today, the methods linked to metabolism like direct and indirect calorimetry and doubly-labelled water (DLW) are considered as reference values for energy expenditure (EE) and PA and have been used to validate other methods and devices for assessing PA and EE. The doubly-labelled water method is considered the gold standard for measuring EE in free-living subjects[3]. It is ideal for free-living settings because it does not require any type of restrictive device and it yields accurate measurements of total energy expenditure (TEE) over periods of several days to a few weeks. However, DLW is limited as it does not provide information about frequency, intensity and duration of PA. Moreover, the high cost associated with the isotopes and sample analysis forbids widespread use of DLW in many clinical and research settings[3].

Direct calorimetry is accurate over time and adequate for resting metabolic measurements. But it is not practical for performing population studies, as it needs specific expensive equipment, only one person at a time can be measured and if PA is performed, sweat can create error measurements, among other limitations[4].

Indirect calorimetry estimates total body EE based on O_2 used and CO_2 produced. There are portable models which can be used in field studies. It is based on measures of respiratory gas concentrations, but it is only accurate for steady-state oxidative metabolism. The older methods of analysis are accurate but slow and the new methods are faster but expensive.

Observational methods are out of the scope of this review. Briefly, self-report is a common method used in assessing PA due to the fact that it is inexpensive, quick and a reliable alternative in a large sample size[5]. Self-reports can be carried out by interviewers (face to face or phone) or by the subject him/herself, and can be done in a prospective or retrospective way. But there is consensus in the literature that currently there is no questionnaire which can be considered optimal. Self-reports have the inconvenience of relying on the subjects memory and honesty. There are many PA questionnaires published in the literature. Several recent reviews[6,7] conclude that for children and adolescents, the most reliable are PDPAR (Previous Day Physical Activity Recall) and 3DPAR (3day PA recall, but filled in as a dairy or recalling maximal the previous day); for adults IPAQ (International Physical Activity Questionnaire) and FPACQ (Flemish PA computerized questionnaire in adults); and for elderly, the Standford Usual Activity Questionnaire. One can conclude that PA questionnaires must be adapted to the age group which is going to be studied, apart from socioeconomic, cultural and other aspects that should be considered as they can bias the information.

Interest

Since WHO started to include regular PA among the global recommendations related to health and non-communicable disease prevention, there has been a growing interest in assessing PA in an accurate way. Both researchers and policy makers identified the need to know how active subjects are in order to get deeper into scientific aspects and to launch public health policies. Interest on PA has grown also among nutrition experts, as EE has been given less attention over the years than energy intake when analysing the obesity epidemic. Energy balance is gaining in importance among the scientific community[8]. All in all, it is necessary in terms of health to know the accurate quantification of physical activity and to determine the effectiveness of physical activity intervention programmes[8]. All this has pushed the R&D of devices aiming at quantifying PA more objectively than when reporting PA by means of self-reports. Objective measures of PA quantify the level, and with some devices, the duration, intensity and patterning of daily PA in people from all ages in ways that are not influenced by recall ability, ethnicity, culture or socioeconomic status. As a result, objective measures can provide important insights into the true activity levels of people.

The aim of this review is to provide an overview of pros and cons of selected objective methods which can realistically be used to quantify PA in population studies. Specifically, we will analyse current state of the art of accelerometers, pedometers, heart rate monitoring, GPS technology, and some novel activity monitors combining several methods.

Controversy

When planning a study, the objective must be clearly stated in regard to monitoring PA and/or EE. PA is any bodily movement produced by skeletal muscles that results in caloric expenditure[9] and is commonly described by the following four dimensions: frequency, intensity, duration and types of activities[10]. There are different methods to quantify PA, often quantified by measuring EE. TEE is the energy spent, on average, in a 24 hour- period by an individual or a group of in-

dividuals. TEE comprises the resting metabolic rate (~ 60%), the thermic effect of food (~10 %) and EE due to PA (~30%).

Many authors agree that the method used to calculate the EE of aerobic and anaerobic activities significantly affects the EE estimates[11]. Most devices include manufacturer software which applies activity-specific algorithms for the calculation of EE based on analysis of the pattern of signals from the sensors. Most devices are continuously being improved and the software updated. Using one or the other algorithm can influence results.

PA intensity is usually classified into three categories: light, moderate and vigorous. One of the main difficulties is in establishing cut offs for these domains, mainly based on metabolic equivalents[12] (or METS). At which intensity does an activity not be moderate any more but vigorous? There is also quite a controversy regarding the *terminus* "moderate to vigorous PA" (MVPA). The cut points used have implications, not only for the time estimates of activity associated with accelerometer data *per se*, but also for self-report measures that may be validated using accelerometers as their criterion[13].

Limitations

Despite their potential benefits, modern activity monitors are not without limitations.

Most notably, they have a high cost compared with self-reports, which means they are generally not well suited to large population studies that would require the purchase of hundreds of devices. Compliance can be another limiting factor. Most of the devices, such as heart rate monitors, accelerometers and pedometers must be worn consistently and in a prescribed method to gather reliable data. Some study participants may view adhering to these requirements as inconvenient[7], mainly during rest or during specific activities.

Units of measurement vary between PA measuring instruments, i.e. beats per minute, counts, gas exchange, etc. For converting these values into PA assessment it is necessary to use several algorithm or equations. As stated above, the variety of devices currently on the market and the different algorithms used to calculate EE turns this controversy also into a limitation. Some devices even include the possibility to use diverse equations with the same recorded data, and therefore, the results can oscillate. Additionally, this variability limits comparability between results.

Potential tampering and influencing the results cannot be excluded. Once wearing the device, people could have a tendency to be more active or even to shake the monitor, among others. Specifically with pedometer, they can delete the step count displayed on the device's read-out screen by pushing an easily identified button. All these issues can affect reliability of data.

Another identified limitation is that several of the validation studies of the devices reviewed have been performed on a convenience sample of participants and/or on a relatively small sample size[14].

Current state and perspective

The methods of quantifying PA and EE can be summarized establishing a clear definition of the outcome variables with aims, characteristics, advantages and disadvantages (Table I). Using objective measures, PA can be assessed by registration of body movements or the physiological consequences of them. Some of the methods can be used for both aims, i.e accelerometers. Objective measures can provide important insights into the true activity levels of people as they are not influenced by recall ability, ethnicity, culture or socioeconomic status. Combination of methods generally increases accuracy.

Accelerometers are among the most commonly used methods to quantify PA objectively and have been used in all populations[15,16]. Acceleration is defined as the change in velocity over time. As accelerometers quantify movement over time, frequency, time and intensity of PA can be assessed, as well as PA patterns. During the past decade there has been a great increase in the number and variety of commercially available objective physical activity monitors on the market. Accelerometers are reasonably reliable and valid measures of PA. The small size makes it user-friendly. Several reviews agree that accelerometers can provide a rich, comprehensive profile of PA behavior that describes the total amount and intensity of PA, when and how PA is accumulated, and when periods of inactivity occur[7, 17]. But they do not provide information about the kind of activity and cannot estimate if people are walking with bags or with nothing. Moreover, the measurement can be influenced by the position of the accelerometer placed on the body (waist, wrist, ankle). Another inconvenient is that it does not capture upper body movement or cycling, and that it must be taken off for swimming, having a shower or bathing, unlike it is a waterproof device. Unfortunately, the costs linked to accelerometers make their utilization not always feasible in research, especially with a high sample size.

Accelerometers can be used to calculate EE (by introducing time, frequency and intensity on specific formula). Results seem to be more accurate for light and moderate than for vigorous activities. Accelerometers have been shown to underestimate EE at higher intensities due to a plateau around ten METs[18]. In addition, accelerometers were shown to inaccurately assess EE during incline walking. Massel L et al.[19] suggested that data processing of the accelerometer has a significant impact on the outcome depending on the rules employed in analysing the data. Additionally, analysis of accelerometer data is complex and time-consuming.

Table I
An overview to quantify physical activity assessment

	Methods	*Aim*	*Characteristics*	*Advantages*	*Disadvantages*
Objective methods	*Accelerometer*	– Measure of acceleration of the body or segments of the body in one or more directions. – Monitoring of frequency, intensity and duration of physical activity.	– Relationship between movement and time. – 3 types: uniaxial (vertical movement), biaxial and triaxial (several planes).	– An objective method to assess levels of physical activity. – Extensively validated. – Small size. – Suitable for use across all age groups.	– Cost. – No information about type of physical activity.
	Pedometer	– Provides data on the total ambulatory activity.	– Should be placed on the hip.	– Inexpensive. – Suitable for all age population including children.	– Cannot measure intensity, frequency and duration. – Cannot calculate energy expenditure, need an extrapolation formula. – No information about type of physical activity. – Unreliability in different situations as non-impact activity, abdominal fat and slow walking.
Subjective methods	*Self-report*	– To collect information provided by subjects.	– Subjective methods of quantifying physical activity.	– Patterns of activity can be identified. – Inexpensive.	– Not adequate for children. – Participants may be do not complete the diary.
	Behavioural observational	– Data about physical activity behaviour.	– Contextual information. – The observer collects the information.	– Observers can be evaluates different behaviours.	– Expensive. – Trained observer needed.
Reference methods	*Doubly labelled water*	– Measures total energy expenditure across CO_2 production.	– Beverage is marked to differentiate it from metabolic water.	– Suitable for all population. – Moderate response burden. – Valid estimation for energy expenditure.	– Expensive. – Cannot be provide information about frequency, duration and intensity.
	Direct calorimeter	– Direct measures energy expenditure.	– Measures total heat produced by the body in a time frame.	– Accurate over time. – Good for resting metabolic energy measurement.	– Expensive – Slow. – Exercise equipment adds extra heat. – Sweat creates errors in measurements. – Not practical or accurate for exercise. – Cannot provide information about metabolites.
	Indirect calorimeter	– Provides estimation of energy expenditure.	– Objective measure.	– Accurate and reliable measure of energy expenditure. – Valid estimation in laboratory and field in short periods of times.	– Expensive – Difficult to use long time in free living conditions.

Table I (*cont.*)
An overview to quantify physical activity assessment

	Methods	*Aim*	*Characteristics*	*Advantages*	*Disadvantages*
Physiological variables	*Heart rate*	– Direct measure of energy expenditure.	– Estimation of energy expenditure from monitoring heart rate.	– Information about frequency, intensity and duration. – Suitable for the majority of populations. – Can use in waterproof. – Relatively inexpensive. – Easy and quick data and analysis.	– Only measures aerobic activities. – It is necessary calibration. – Can be affected by: temperature, contamination, gender, genetic, body composition, metabolism, medicine, age, time of the day.

In reference to types of accelerometers, triaxial accelerometer perceives acceleration in several planes. As human movement is multidimensional, it has been suggested by some authors that results in three dimensions are better methods to evaluate acceleration and EE than in uniaxial and biaxial models[20]. If additionally to PA we also want to analyse sedentary and/or sleeping behaviour, a triaxial accelerometer would be more indicated as it differentiates if the subject is sitting or lying. One of the debates going on in scientific literature is regarding the number of days subjects must wear the accelerometer in order to obtain reliable data. Ideally, the accelerometer should be worn for seven days, in order to record a whole week including the week-end, as subjects do not follow the same PA pattern each day. Other author indicates that the accelerometer should be worn for at least for 5 days[21]. In order to analyse compliance, most authors agree that subjects should filled in an "Incidences sheet" in order to record any incidence like wearing off the accelerometer during some activities, etc. Compliance in the wearing of accelerometers has turned out to be a critical issue. In the HELENA study, a representative study on nutritional status and PA behaviour, among others, carried out in European adolescents, subjects were asked to wear the accelerometer for 7 days. After a thoughtful review of recorded data, subjects were considered as valid if they had worn the accelerometer at least for 3 days during 8 consecutive hours[15]. This is in line with current recommendations. The accelerometer should be worn the number of days which guarantee reliable data for at least three days. One of these days should be a week-end day.

A pedometer is a much simpler device which counts steps. It must be placed on the hips, because it counts the times the legs move up and down during ambulation. This information is recorded and displayed as steps are taken during walking or running. Pedometers have also been widely used during the last years and have a good reliability both in children and adults and can be used to establish PA guidelines. Step count is a simply way to quantify the amount of PA. Currently, user-friendly PA guidelines do not only include recommendations on type and time spent performing PA and exercise, but also the number of steps per day that should be taken to be considered active (at least 6000 steps/day), to prevent obesity (10000 steps/day) or to lose weight (12000 steps/day)[22]. For children and adolescents, 9000 steps/day are recommended[23]. Unlike accelerometers, pedometers do not give information about intensity, frequency and duration of PA. A low reliability has been observed when participants walk slowly (less than 60m/min), perform upper body movement, have high body fat mass or perform non-impact activities (like bicycling). Pedometers cannot be worn in water and, this fact combined with their measurement solely of ambulation results in a lack of capacity to assess activities such as swimming, diving or water play[7]. They may not be able to reliably detect

Table II
New technologies to quantify physical activity

	Methods	*Aim*	*Characteristics*	*Advantages*	*Disadvantages*
Future developments	*GPS*	– Provides objective data about location, domain of activity, speed and training burden.	– Provide distance, speed, and elevation with exact time and location.	– Information about frequency, intensity and duration. – Heart rate. – Distance. – Altitude. – Can obtain information on real-time.	– Expensive. – Qualified staff.
	Combined motion sensors	– To measure direct energy expenditure and body movement (frequency, intensity and duration).	– Combined heart rate and body movement by accelerometer.	– Direct measure (combined physiological measure of heart rate and body movement, i.e. frequency, duration and intensity).	– Price. – Data processing is time consuming.

steps in individuals with gait abnormalities. PA assessment using accelerometers is more accurate than with pedometers when people walk slowly[24]. For getting data on EE, a formula must be used considering age, height and weight, distance walked and the length of the stride.

Heart rate monitors register the heart rate response to the intensity of the PA. However, they may not be able to accurately estimate energy expenditure and physical activity levels because heart rate is influenced by a wide range of factors that are unrelated to PA[5]. Heart rate is dynamic and known to be influenced by a number of different factors. Body temperature, food intake, body posture, medications, individual cardio-respiratory fitness level, genetics and PA can all influence heart rate and, as a result, can confound estimates of PA and EE derived through heart rate monitoring[8]. In addition, the ability of heart rate monitors to accurately estimate EE and assess PA patterns during low intensity and extremely high intensity activity has been questioned. Most of authors agree that combining accelerometry with heart rate monitoring increases accuracy in assessing PA[25].

Over the years, techniques for the study of human movement have improved in complexity and precision. New technologies as GPS (Table II), high frequency methods and combined motion sensors give a new perspective and should be taken into account when measuring PA or EE.

GPS technology has been used in athletes to quantify movement in training. However, commercial GPS watches maybe limited for the assessment of brief higher speed movement. The results of this main study's suggested that the GPS watches tested provide less reliable estimates of EE during walking, especially at higher speeds (7 km/h). Nevertheless, GPS watches are portable, relatively inexpensive, non-invasive and provide distance, speed, and elevation with exact time and location. The measurement error should be considered when comparing results from individuals wearing different GPS watches and other devices measuring EE, such as an accelerometer. Currently, heart rate monitors are used for short periods of time (training bouts), currently the GPS does not improve the accuracy of this type of PA; however, they are very useful for activities where there is displacement[26].

A new generation of monitors that either combine multiple accelerometers on different body segments or that combines accelerometry with other physiological signals in a single device has contributed to a progress in the PA assessment field.

One of these new devices is the SenseWear Armband (SWA) (BodyMedia, Inc.,Pittsburgh, PA). SWA, an extremely simple and inexpensive apparatus, provides quite accurate measurements of energy expenditure in humans and in baboons. It is worn on the back of the upper arm and combines five different sensors. Data are collected from a skin temperature sensor, near body temperature sensor, heat flux sensor, galvanic skin response sensor, and a biaxial accelerometer. The biaxial accelerometer registers the movement of the upper arm and provides information about body position. The information from the sensors, together with gender, age, height, and weight, are incorporated into proprietary algorithms to estimate EE. These algorithms are activity specific and are automatically applied on the basis of an analysis of the pattern of signals from the sensors.

The SWA has been shown to accurately assess EE at rest and during low to- moderate intensity PA in adults[27] and children[28] using either indirect calorimetry or doubly labelled water. The SWA did not provide accurate estimates of energy expenditure at high intensity levels (above ten METs or a running speed of 6 mph (161 m/min)) in young adults. In this study, in addition, the measurement error increased with increasing exercise intensity due to the plateau or ceiling effect in energy estimations of the SWA. In the validation study of performed by Arvidsson et al.[16] in 11 to 13 year aged children, the SenseWear Pro2 Armband underestimated energy cost of most activities, an underestimation that increased with increased physical activity intensity. These findings have important implications for monitoring total daily energy expenditure and activity

energy expenditure in humans engaging in high intensity physical activity.

In a recent study comparing several of the available activity monitors (SenseWear Pro3 Armband (SWA, v.6.1), the SenseWear Mini, the Actiheart, ActiGraph, and ActivPAL), the difficulty in estimating accurately EE during light to moderate intensity was observed[28]. The SWA and AH multi-sensor monitors provided accurate group estimates of EE during light and moderate semi-structured intensity activities, but showed larger individual estimation error. On the other hand, the accelerometry-based activity monitors showed larger error for estimation of lower intensity activities of daily living. Only the SenseWear Mini assessed low intensity activities in an accurate manner. The authors recommend that future research should focus on assessing lower intensity activities using the newly developed techniques to improve MET estimates of accelerometry-based activity monitors (i.e., artificial neural networking and Hidden Markov Modeling), making direct comparisons to multi-sensor activity monitors.

Danneker et al.[29] analysed a shoe-based PA monitor, which incorporates insole pressure sensors and triaxial accelerometry to classify major postures/activities and estimate EE and compared it with other PA monitors (Actical, ActiGraph, IDEEA, DirectLife, and Fitbit). Estimated EE using the shoe-based device was not significantly different than measured EE. The IDEEA and the DirectLlife estimates of EE were not significantly different than the measured EE, but the ActiGraph and the Fitbit devices significantly underestimated EE. The authors proposed that estimating EE based on classification of PA can be more accurate and precise than estimating EE based on total physical activity

Fitbit One (Fitbit Inc., San Francisco, CA), another novel activity monitor, is a stepcounter and distance monitor. In their recent validation study, Tacaks et al.[30] concluded that these kind of devices are valid and reliable for measuring step count at multiple speeds, but that they are inaccurate at measuring distance travelled. Placement of the Fitbit One activity monitor (whether in a pocket or on the hip) did not affect the accuracy of the step counts reported. The variability in underestimation of EE for the different activities may be problematic for weight loss management applications.

Conclusions

The objective measurement of human movement and the quantification of energy expenditure due to physical activity is an identified need in both research and the clinical setting. Validated and well-defined reference methods are expensive and mostly limited to the laboratory setting. Newly objective measurement devices have been developed which are appropriate for field studies and clinical settings, but all have limitations. Pedometers count the steps taken and give information on total physical activity, but not about PA patterns and behaviour. Accelerometers save information about frequency and intensity of PA, but not about type of PA. Both pedometers and accelerometers only save information about lower body movement and reliability about the estimation of energy expenditure is limited. Heart rate monitoring relates intensity to EE, but gives no information about PA. GPS watches are maybe limited for the assessment of brief higher speed movement and EE. Combined motion sensors share advantages of single devices and are more precise, but activity-specific algorithms for the calculation of EE can affect EE results. Most of the devices estimate EE more accurately at light to moderate intensities; underestimation increases at very light and higher intensity activities.

Acknowledgements

The EXERNET Study Group (Research Network on Exercise and Health in Special Populations) has been supported by the Ministerio de Educacion y Ciencia (DEP2005-00046/ACTI).

References

1. Foulds HJ, Bredin SS, Charlesworth SA, Ivey AC, Warburton DE. Exercise volume and intensity: a dose-response relationship with health benefits. *Eur J Appl Physiol* 2014;114(8):1563-71.
2. Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc* 2009;41(7):1510-30.
3. Schoeller DA, Taylor PB, Shay K. Analytic requirements for the doubly labelled water method. *Obes Res* 1995;3 Suppl 1:15-20.
4. Ara I, Casajús Mallén JA, Vicente-Rodríguez G.Valoración de la actividad física. En: Casajús Mallén JA, Vicente-Rodríguez G (coord). Ejercicio físico y salud en poblaciones especiales. Colección CSD, Imprenta Nacional del BOE. 2011. Pp 63-77.
5. Taylor HL, Jacobs DR, Jr., Schucker B, Knudsen J, Leon AS, Debacker G. A questionnaire for the assessment of leisure time physical activities. *J Chronic Dis* 1978;31(12):741-55.
6. Helmerhorst HJ, Brage S, Warren J, Besson H, Ekelund U. A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *Int J Behav Nutr Phys Act* 2012;9:103.
7. Bates H. Daily physical activity for children and youth: a review and synthesis of the literature. 2006. ISBN 0-7785-4751-5.
8. Hill JO, Trowbridge FL. Childhood obesity: future directions and research priorities. *Pediatrics* 1998;101(3 Pt 2):570-4.
9. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports* 1985; 100(2):126-131.
10. Warren JM, Ekelund U, Besson H, Mezzani A, Geladas N, Vanhees L. Assessment of physical activity - a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. *Eur J Cardiovasc Prev Rehabil* 2010;17(2):127-39.
11. Vezina JW, Der Ananian CA, Campbell KD, Meckes N, Ainsworth BE. An examination of the differences between two methods of estimating energy expenditure in resistance trai-

ning activities. *J Strength Cond Res* 2014;28(4):1026-31.
12. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;32(9 Suppl):S498-504.
13. Anderson CB, Hagstromer M, Yngve A. Validation of the PDPAR as an adolescent diary: effect of accelerometer cut points. *Med Sci Sports Exerc* 2005;37(7):1224-30.
14. Dannecker KL, Sazonova NA, Melanson EL, Sazonov ES, Browning RC. A comparison of energy expenditure estimation of several physical activity monitors. *Med Sci Sports Exerc* 2013;45(11):2105-12.
15. Ruiz JR, Ortega FB, Martínez-Gómez D, Labayen I, Moreno LA, De Bourdeaudhuij I, Manios Y, Gonzalez-Gross M, Mauro B, Molnar D, Widhalm K, Marcos A, Beghin L, Castillo MJ, Sjöström M; HELENA Study Group. Objectively measured physical activity and sedentary time in European adolescents: the HELENA study. *Am J Epidemiol* 2011;174(2):173-84.
16. Arvidsson D, Slinde F, Larsson S, Hulthen L. Energy cost of physical activities in children: validation of SenseWear Armband. *Med Sci Sports Exerc* 2007;39(11):2076-84.
17. Calahorro F, Torres-Luque G, López-Fernández I, Santos-Lozano A, Garatachea N, Álvarez E. Actividad física y acelerometría; orientaciones metodológicas, recomendaciones y patrones. *Nutr Hosp* 2015;31(1):115-128.
18. Corder K, Brage S, Wareham NJ, Ekelund U. Comparison of PAEE from combined and separate heart rate and movement models in children. *Med Sci Sports Exerc* 2005;37(10):1761-7.
19. Masse LC, Fuemmeler BF, Anderson CB, Matthews CE, Trost SG, Catellier DJ, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc* 2005;37(11 Suppl):S544-54.
20. Brage S, Brage N, Franks PW, Ekelund U, Wareham NJ. Reliability and validity of the combined heart rate and movement sensor Actiheart. *Eur J Clin Nutr* 2005;59(4):561-70.
21. Murphy SL. Review of physical activity measurement using accelerometers in older adults: considerations for research design and conduct. *Prev Med* 2009;48(2):108-14.
22. Tudor-Locke C, Craig CL, Brown WJ, Clemes SA, De Cocker K, Giles-Corti B, Hatano Y, Inoue S, Matsudo SM, Mutrie N, Oppert JM, Rowe DA, Schmidt MD, Schofield GM, Spence JC, Teixeira PJ, Tully MA, Blair SN. How many steps/day are enough? For adults. *Int J Behav Nutr Phys Act* 2011 Jul 28;8:79.
23. Adams MA, Johnson WD, Tudor-Locke C. Step/day translation of the moderate-to-vigorous physical activity guideline for children and adolescents. *Int J Behav Nutr Phys Act* 2013;10:49.
24. Dijkstra B, Zijlstra W, Scherder E, Kamsma Y. Detection of walking periods and number of steps in older adults and patients with Parkinson's disease: accuracy of a pedometer and an accelerometry-based method. *Age Ageing* 2008;37(4):436-41.
25. Domene PA, Easton C. Combined triaxial accelerometry and heart rate telemetry for the physiological characterization of Latin dance in non-professional adults. *J Dance Med Sci* 2014;18(1):29-36.
26. Hongu, N, Orr, BJ, Roe, DJ, Reed, RG, and Going, SB. Global positioning system watches for estimating energy expenditure. *J Strength Cond Res* 27(11): 3216-3220, 2013.
27. St-Onge M, Mignault D, Allison DB et al. Evaluation of a portable device to measure daily energy expenditure in free-living adults. *Am J Clin Nutr* 2007; 85(3):742-9.
28. Calabro M, Lee JM, Saint-Maurice PF, Yoo H, Welk GJ. Validity of physical activity monitors for assessing lower intensity activity in adults. *Int J Behav Nutr Phys Act* 2014;11(1):119.
29. Dannecker KL, Sazonova NA, Melanson EL, Sazonov ES, Browning RC. A comparison of energy expenditure estimation of several physical activity monitors. *Med Sci Sports Exerc* 2013;45(11):2105-12.
30. Takacs J, Pollock CL, Guenther JR, Bahar M, Napier C, Hunt MA. Validation of the Fitbit One activity monitor device during treadmill walking. *J Sci Med Sport* 2014;17(5):496-500.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):227-236
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Evaluation of nutritional status and energy expenditure in athletes

Juan Mielgo-Ayuso[1,2], Beatriz Maroto-Sánchez[1,2], Raquel Luzardo-Socorro[1,2], Gonzalo Palacios[1,2,3], Nieves Palacios Gil-Antuñano[4] and Marcela González-Gross[1,2,3] on behalf of EXERNET Study Group

[1]ImFINE Research Group. Technical University of Madrid. Spain. [2]Department of Health and Human Performance. Faculty of Physical Activity and Sport Science-INEF. Technical University of Madrid. [3]CIBERobn (Fisiopatología de la Obesidad y la Nutrición CB12/03/30038), Instituto de Salud Carlos III, Spain. [4]Sport Medicine Center. High Sports Council. Spain.

Summary

Continuous physical exercise leads the athlete to maintain an unstable balance between dietary intake, energy expenditure and the additional demands of a high amount of physical activity. Thus, an accurate assessment of nutritional status is essential to optimize the performance, since it affects health, body composition, and the recovery of the athlete. Specific aspects like the type of sport, specialty or playing position, training schedule and competition calendar, category, specific objectives, which differ from the general population, must be considered. A biochemical assessment can give us a general idea of the nutritional status, lipid profile, liver or kidney function, if diet is too high in proteins or fats, as well as possible nutritional deficiencies and the need for supplementation. Sport kinanthropometry has great utility that enables the assessment of body mass, height, length, diameter, perimeter and skinfolds, where information is processed by applying different equations, obtaining information on somatotype, body composition, and the proportionality of different parts of the body. To give proper nutritional counselling, energy needs of the athlete must be known. If objective measurement is not possible, there are tables including theoretically established energy requirements of different sports. Dietary assessment should include information about food consumption and nutrient intake to establish the relationship between diet, health status and athlete's performance. On the other hand, an adequate hydration status in athletes is essential to maintain adequate performance. Hence, the knowledge of fluid intake by the athlete is a matter of the utmost importance. Dehydration can cause harmful effects on athletes' health. As there is no gold standard, urine gravidity and urine colour are the most extended methods for analyzing hydration status. There is consensus that due to complexity, the combination of different methods assures an effective data collection which will be useful to proceed in dietary and nutritional intervention..

(*Nutr Hosp* 2015;31(Supl. 3):227-236)

DOI:10.3305/nh.2015.31.sup3.8770

Key words: *Antioxidants. Cineanthropemetry. Hydration. Diet. Sport.*

Correspondence: Marcela González-Gross.
ImFINE Research Group.
Department of Health and Human Performance.
Facultad de Ciencias de la Actividad Física y del Deporte-INEF.
Universidad Politécnica de Madrid.
C/ Martín Fierro 7. E.
28040 Madrid.
E-mail: marcela.gonzalez.gross@upm.es

VALORACIÓN DEL ESTADO NUTRICIONAL Y DEL GASTO ENERGÉTICO EN DEPORTISTAS

Resumen

El ejercicio físico continuo conduce al atleta a mantener un equilibrio inestable entre la ingesta dietética, el gasto de energía y las exigencias adicionales de un alto grado de actividad física. Por lo tanto, una evaluación precisa del estado nutricional es esencial para optimizar el rendimiento, ya que afecta a la salud, la composición corporal, y la recuperación del atleta. Aspectos específicos como tipo de deporte, especialidad o posición de juego, programa de entrenamiento y calendario de competiciones, la categoría, objetivos específicos, que difieran de la población en general, deben ser tenidos en cuenta. La evaluación bioquímica nos puede dar una idea general del estado nutricional, del perfil lipídico, del funcionamiento de hígado o riñón, de si la dieta es demasiado alta en proteínas o grasas, así como las posibles deficiencias nutricionales y la necesidad de suplementación. La cineantropometría deportiva tiene gran utilidad ya que permite la evaluación de la masa corporal, altura, longitud, diámetro, perímetro y pliegues cutáneos, donde la información se procesa mediante la aplicación de diferentes ecuaciones, obteniendo información sobre el somatotipo, la composición corporal y la proporcionalidad de las distintas partes del cuerpo. Para poder dar una orientación nutricional adecuada, las necesidades de energía de los atletas deben ser conocidas. Si la medición objetiva no es posible, existen tablas que incluyen los requerimientos de energía teóricamente establecidos para diferentes deportes. La evaluación dietética debe incluir información sobre el consumo de alimentos y nutrientes para establecer la relación entre la dieta, el estado de salud y el rendimiento del atleta. Por otro lado, un estado adecuado de hidratación en los atletas es esencial para mantener un rendimiento óptimo. Se debe valorar específicamente la ingesta de líquidos por parte del deportista. La deshidratación puede causar efectos nocivos en la salud de los atletas. Como no existe un método "gold standard", la gravidez y el color de la orina son los métodos más extendidos para analizar el estado de hidratación. Hay consenso en que la combinación de diferentes métodos asegura una captura efectiva de datos para la valoración nutricional del deportista que permitirá proceder a la intervención dietética y nutricional.

(*Nutr Hosp* 2015;31(Supl. 3):227-236)

DOI:10.3305/nh.2015.31.sup3.8770

Palabras clave: *Antioxidantes. Cineantropometría. Hidratación. Dieta. Deporte.*

Abbreviations

BIA: Bioelectrical impedance analysis.
EE: Energy expenditure.
ISAK: The International Society of Advancement of Kinanthropometry.
MET: Metabolic equivalent.
RDAs: Recommended Dietary Allowances.
RMR: Resting metabolic rate.
USG Urine specific gravity.

Background

Physical exercise carried out on a continuous basis and at certain intensity leads the athlete to maintain an unstable balance between dietary intake (energy, macro and micro nutrients), daily life energy expenditure and the additional demands of a high amount of physical activity. Thus, an accurate assessment of nutritional status is essential to optimize the performance of the athlete, since it affects health, body composition, and the recovery of the athlete[1, 2].

There are different methods to assess the nutritional status of an individual. It is often useful to combine several of them to get a more complete and accurate assessment. The isolated assessment of any of its components should not be understood as an outcome of diagnosis, but as a complementary method to the total nutritional assessment[1].

There are several methods used for a proper nutritional evaluation. This review will get deeper into selected biochemical markers, some specific anthropometrical aspects, and evaluation of dietetic – nutritional and hydration status. Data obtained from these methods must be interpreted according to the competitive phase of the athlete[1, 2]. The complexity of information gathered both individually and in nutritional studies requires validated tools and trained researchers and professionals to facilitate the analysis of the collected information.

Some issues that should be familiar in the nutritional assessment of athletes and that differ from the population in general are[1]:

- The type of sport (strength, endurance, speed or team (acyclic) or even aesthetics (rhythmic gymnastics) and specialty or playing position.
- The days, schedules and time spent in trainings and competitions.
- Category in which the athletes are competing (amateur or professional).
- What is the main objective at a specific moment (get fit, a particular competition,..). It is important to prioritize actions.

Likewise, it is also important to know the training planning, focusing on the microcycles and daily workouts[1, 2].

Interest

Nutritional assessment in the field of sport is necessary and beneficial for both health and performance. One of the aims is making a proper diet-nutrition intervention, which should include, among others[1]:

- Evaluation of energy balance (caloric intake - energy expenditure), verified by maintaining a stable body weight, a good health status and an optimal physical performance.
- Compliance with nutrient recommendations according to sport, type of training and season.
- Organizing meal schedules, adapted to training and competition. In this way, the athlete will be able to optimize training, having maximum performance and ensuring a correct post-exercise recovery.
- Evaluating and correcting excesses and deficiencies of nutrients as well as errors related to hydration.
- Continuous nutrition education to achieve understanding and compliance.

Controversy

There is no doubt that an adequate diet will contribute to support consistent intensive training while limiting the risks of illness or injury. It is essential to get the right amount of energy and nutrients to stay healthy and to perform well. But there is no simple formula to predict how much energy an athlete needs and there is no consensus if regular training increases nutrient requirements. In the same way, the use of one or the other method in the evaluation of dietary intake can provide different data of dietary assessment. Energy (and nutrient) demands will fluctuate throughout the season and even between training sessions. Monitoring body weight can be misleading as it is not a reliable indicator of energy balance in athletes. While an increase of fat mass negatively affects athletic performance and increases energy demands, an increase in musculoskeletal mass is seen as a positive indicator of sports performance, by contributing to increased power production during exercise as well as greater size and strength with high dynamic and static loads. Therefore, measuring skinfold thickness across the season can provide more useful information to know athletes body composition. Formula developed for the general population can bias results on body composition and energy expenditure in athletes. There is also controversy around how much dehydration can be acceptable without compromising performance. Health-related aspects are often forgotten in elite sports.

Limitations

Every athlete is different. They have different requirements for energy and nutrients depending on multiple factors like body size, sports discipline, training load, number of training days, etc. This makes nutritional assessment quite difficult, as numerous confounding variables have to be taken into account. In addition, they have individual genetic, physiological, biochemical and biomechanical characteristics which determine their nutrient needs[2]. Comparison with recommended dietary intakes and reference ranges for the general population will be misleading. Each athlete, man or woman, must identify his/her nutritional goals in terms of requirements of energy, carbohydrate, protein, fat, vitamins, minerals and water in order to be healthy and to have an optimum performance. Comparability of results among athletes is limited. They should monitor body composition and biochemical markers throughout the season to have their own registry.

Current state and perspective

Biochemical assessment

A biochemical assessment of the nutritional status in athletes is essential[2]. Biochemical markers are obtained from clinical analyses, well through blood or urine samples. These parameters can give us a general idea of the nutritional status, lipid profile, liver or kidney function, if diet is too high in proteins or fats, as well as possible nutritional deficiencies. A sustained interest has developed around vitamins and trace element nutrition and metabolism, as it relates to athletic performance[4]. Concretely, vitamin and minerals are necessary for a number of metabolic processes in the body including numerous reactions related to exercise and physical activity, such as energy, carbohydrate, fat and protein metabolism, oxygen transfer and delivery, and tissue repair. Therefore, it is important to examine if exercise affects the function of these elements or not[4].

Vitamin C and vitamin E

Vitamins C and E are one of the most studied biochemical compounds as they have a strong relationship with physical activity and sport performance. Following this fact, we will focus on these two vitamins.

It has been widely noted that vitamins C and E show numerous beneficial effects because of and beyond their antioxidant properties. Consequently, vitamins C and E are expected to prevent diseases related to free radical excess. In the field of sports medicine, many studies dealing with vitamins C and E have been conducted originally from the point of view of its effects on physical performance. Although some earlier studies indicated that vitamin C and/or vitamin E supplementation could improve physical performance, differences in the study design, kind of sport and statistical analysis may explain the discrepancies appearing when comparing results from these different reports. However, some recent studies could enhance our understanding of vitamin effect on physical activities.

Vitamin C acts in humans as an electron donor (antioxidant agent) for eight enzymes of which three are involved in collagen hydroxylation and two are involved in carnitine biosynthesis. Vitamin C has been also shown to protect lipids in human plasma and low density lipoprotein. It also interacts with other nutrients, aiding in the absorption of iron and copper, maintenance of glutathione in the reduced form, and stabilization of folate. Recommended Dietary Allowances (RDAs) are set to 75 mg/day and 90 mg/day for women and men, respectively[5]. In addition to its activities as an antioxidant, vitamin E is involved in immune function, cell signaling, regulation of gene expression, and other metabolic processes. Alpha-tocopherol, the main biochemical bioactive form of vitamin E family members, inhibits the activity of protein kinase C. Vitamin allows blood vessels to be more able to resist blood-cell components adhering to their surface. Vitamin E also increases the expression of two enzymes that suppress arachidonic acid metabolism. RDAs for vitamin E are set at 15 mg/day, corresponding to 22.4 UI of α-tocopherol. Vitamin E deficiency is rare[5], even some newly published data are indicating that vitamin E deficiency, at least at subclinical level, is may be increasing.

Paschalis et al. have shown recently that low vitamin C concentrations are associated with a poor physical performance and an increase of oxidative stress markers[6]. This situation can be reversed by using vitamin C supplementation, obtaining better exercise performance and reducing oxidative stress. For this purpose, authors have selected 10 individuals with the lowest and 10 with the highest vitamin C values from an initial group of 100 males. Using a placebo-controlled crossover design, the 20 selected subjects performed aerobic exercise until exhaustion before and after vitamin C supplementation for 30 days. Results have been obtained by using F_2-isoprostanes and protein carbonyls as oxidative stress markers.

In contrast, very high levels of vitamin C intake, with doses surpassing 1,000 mg/day seem to be detrimental to increase physical endurance as shown by Paulsen and collaborators[7]. Researchers analyzed 54 young and healthy men and women for 11 weeks. Participants were divided in two groups, the first one with an intake of 1,000 mg of vitamin C and 235 mg of vitamin E per day (consistent with the amount found in available supplements), and the second group received a placebo each day. All subjects were required to carry out an endurance training program that consisted of three to four training sessions each week, mainly involving running. They

also underwent fitness tests, muscle biopsies, and had blood samples taken at the baseline of the study and after the study ceased. Results of the study revealed that markers for the production of new muscle mitochondria only increased in the participants who received placebo. Because vitamins C and E are antioxidants, high doses of them seem to inhibit to some extent the free radicals action and to block the positive proceeding of the oxidative stress process on training, for example, in the development of muscular endurance.

Trace elements: Iron, zinc, chromium and selenium

Trace elements, like iron, zinc, selenium, and chromium are ingested in very small amounts and are fundamental to regulate whole-body metabolism, including energy utilization and work performance.

Iron is the mineral most studied in athletes due to its implication in several physiological mechanisms related to physical performance and endurance. A deficiency in the deposit can lead to an iron-deficiency anemia, state in which athletic performance can be compromised[8]. Mechanisms that cause iron deficiency anemia in athletes include hemolysis, deficiency of dietary origin due to low intake of non-hem iron coming from vegetarian diets or potential food interference, as well as by the increase of oxidative stress[8]. To avoid iron deficiency, a recommendation is to test iron status regularly. The evidence confirms that athletes must include iron-rich foods in their diet such as lean red meat and breakfast cereals fortified with iron, among others[9]. Vegetables rich in iron, such as whole-grain cereals, spinach and legumes should be combined with animal iron sources or sources of vitamin C (e.g. a glass of orange juice consumed with breakfast cereals) that improves iron absorption.

Zinc is required to serve either a catalytic or structural role in more than 200 enzymes in mammals. Zinc-containing enzymes participate in many pathways of macronutrient metabolism and cell replication. In addition, some zinc-containing enzymes, such as carbonic anhydrase and lactate dehydrogenase, are involved in intermediary metabolism during exercise. Another zinc-containing enzyme, superoxide dismutase, presents a protective role as an endogenous antioxidant against free radical damage. Selenium, another main trace element, is essential for major metabolic pathways, including oxidative stress, as it is a component of glutathione peroxidase enzyme. Finally, mammals need chromium to maintain balanced glucose metabolism, and thus chromium may facilitate insulin action and has therefore indirect insulinogenic properties. Biochemical properties of trace elements have been extensively described by many authors, including Lukasky[10].

There is no definitive data on suitable concentrations of trace elements for people having regular physical activity. One possible approach to study these elements under a certain physical stress is to evaluate their fluctuations during exercises. A recent study[11] has been carried out to investigate the effect of swimming frequency on serum concentrations of some trace elements, including among others, chromium, zinc and selenium. Three groups of different-level male swimmers were included in the study, as elite swimmers (n = 14), amateur swimmers (n = 11), and sedentary individuals (n = 10). Elite and amateur swimmers followed a 3-week training program. At the end of the period, all volunteers had to perform a controlled swimming test, and blood samples were collected at the beginning (time 0), immediately after (time 1), and 1 h after the activity (time 2). Authors observed that changes in magnesium, calcium, copper, zinc, and selenium levels exhibited a common pattern in all study groups, with higher post-test serum concentrations. A drop of copper, zinc, and selenium levels at 1 h after the test in elite swimmers was also observed. Anyway, further studies on relationship between trace elements and physical performances should be carried out in order to better understand mechanisms and consequences of this possible association.

Anthropometric assessment

Sport kinanthropometry has great utility as it enables the assessment of morphological characteristics, as well as its control throughout the sport season. The anthropometric technique allows us to measure body mass, height, length, diameter, perimeter and skinfolds. Information is processed by applying different equations, obtaining information on somatotype, body composition, and the proportionality of different parts of the body[12].

Anthropometric measurement should be performed following the protocol of "The International Society of Advancement of Kinanthropometry" (ISAK)[12]. This Protocol recommends that measures should be on the right side, contrary to the recommendation of the WHO, who recommends on the left side. The anthropometric material used is: (a) height measuring rod, with a precision of 1 mm and a range (130-210 cm); (b) body mass scale with a precision of 0.1 kg and a range (2 kg - 130 kg); (c) metal, narrow and inextensible metric tape, with a precision of 1 mm; (d) small bone diameters caliper, with a precision of 1 mm; (e) large osseous diameters caliper, with a precision of 1 mm; (f) skinfold caliper, with a precision of 0.2 mm (accuracy: 0.2 mm) g) supplementary material (pencil identified to mark the individual, template for collection of measures and software for data processing).

Once all data are collected, the fat mass and the muscle mass (Table I) of athletes can be estimated by means of different equations[12].

Table I
Equations used in the calculation of the fat mass and musculoskeletal mass

Fat mass

Faulkner's equation.
Derived from the Yuhasz's equation after studying a swimmers' team.
% Fat mass (males) =0.153 x (TS+ SBS+ SPS+ AS)+5.783
% Fat mass (females) = 0.213 x (TS+ SBS+ SPS+ AS)+7.9
Fat mass (kg)= (% fat mass x body mass (kg)) / 100

Carter's equation.
Derived from the Yuhasz's equation, and applied to Olympic athletes (Studies published in the Montreal Olympic Games Anthropometric Project).
% Fat mass (males) =0.1051 x (TS + SBS + SPS+ AS + MTS + CS)+2.58
% Fat mass (females) = 0,1548 x (TS + SBS + SPS+ AS + MTS + CS)+3.58
Fat mass (kg)= (%fat mass*body mass (kg)) / 100

Jackson & Pollock's equation.
Sample: 403 males 18-61 years.
The results allow to obtain the density and subsequently body fat percentage as calculated from the Siri's equation (% Fat mass = (495/BD) – 450).
BD males= 1.17615 - 0.02394 x log ∑7S - 0.00022 x (A) - 0.0075 x (AP) + 0.02120 x (FP)
BD females= 1.112 – 0.00043499 x (∑7S) + 0.0000055 x (∑7S) 2 - 0.00028826 x (A)

Withers' equation.
The results allow to obtain the density and subsequently body fat percentage as calculated from the Siri's equation (% Fat mass = (495/BD) – 450).
BD males = 1.078865 – 0.000419 x (AS + MTS +CS + CHS) + 0.000948 x (NP)– 0.000266 x (A) – 0.000564 x (S-M P)
BD females = 1.14075 – 0.04959 x (AS + MTS +CS + CHS) + 0.00044 x (A) – 0.000612 x (WP)+ 0.000284 x (H) – 0.000505 x (HP) + 0.000331 (CHP)

Musculoskeletal mass

Lee's equation.
Sample: 324 (244 non-obese and 80 obese). Valid for male and female.
MME (kg) = H x (0.00744 x AGC 2 + 0.00088 x MTC^2 + 0.00441 x CGC^2) + (2.4 x Sex) -0.048 x Age + Race + 7.8.
% MME: MME(kg) x 100/body weight(kg)
AGC= Relax arm girth - (3.1416 x (triceps skinfold/10)).
MTC= Mid-thigh girth - (3.1416 x (MTS /10)).
CGC= Calf girth - (3.1416 x (CS/10)).

TS: Triceps skinfold; SBS: Subescapular skinfold; SPS: Supraspinale skinfold; AS: Abdominal skinfold; MTS: Mid-thigh skinfold; CS: Calf skinfold mm; BD: Body density; IS: Ileocrestal skinfold; CHS: Chest skinfold; MAS: Mid-axila skinfold; AP: Abdominal girth; FP: Forearm girth; NP: Neck girth; S-M P: Supramalleolar girth; WP: Waist girth; HP: Hip girth; CHP: Chest *mesoesternal* girth; H: Height (cm); A: Age (years); ∑7S: Sum of 7 skinfolds (TS + SBS + IS + AS + MTS + CHS + MAS); AGC: Relax arm girth corrected; MTC: Mid-thigh girth corrected; CGC: Calf girth corrected; Sex: Female=0; Male =1; Age (years); Race: Asian= -2; Afro-Americans= 1.1; Caucasian and Hispanic=0; Girth in cm; and skinfolds in mm.

In the same way, the different compartments of the somatotype are calculated (Table II), which is defined as the study of the morphology of the individuals[12].

The different values of fat mass, musculoskeletal mass and somatotype can be compared with references values by sport category or the values of previous assessments of the same athlete to guide nutrition decision or training[12].

Energy expenditure assessment

To give proper nutritional counselling, energy needs of the athlete must be known. Apart from self-reported and objective measurements (see Ara et al, and Aparicio-Ugarriza et al. also included in this supplement), there are tables including theoretically established energy requirements of different sports by different procedures[13], as well prediction equations, MET, or metabolic equivalent-based tables.

Energy expenditure (EE) prediction equations (Table III)

EE estimation is based on the use of predictive equations for calculating the resting metabolic rate (RMR) and daily physical activity energy expenditure[14]. Mostly used in athletes is the:

MET or metabolic equivalent

The most used and recommended method is the registration of 24 hours MET[15]. One MET is defined

Table II
Equations for predicting somatotype components

Component	*Equation*
Endomorphy*	-0.7182 + 0.1451 x X – 0.00068 x X2 + 0.0000014 x X3
Mesomorphy**	(0.858 x HB + 0.601 x FB + 0.188 x AGR + 0.161 x CGC)- (Height x 0.131) + 4.5
Ectomorphy***	-If HRW ≥ 40.75 → = (0.732 x HRW) -28.58. -If HRW between 38.25-40.75 → = (0.463 x HRW)-17.63. -If HRW ≤ 38.25 → = 0.1.

*X= sum of triceps, subscapular and supraspinale skinfold (mm) x (170.18/Height (cm)).
**HB= Humerus breadth (cm); FB= Femur breadth (cm); AGC: Relax arm girth corrected; CGC: Calf girth corrected; Height in cm.
***Requires the calculation of the height (cm) divided by cube root of body mass (kg) (HWR).

Table III
The resting metabolic rate (RMR) prediction equations commonly used in athletes

Institute of Medicine, 2000:
Men= 662 – 9.53 + PA x [15.91 x body mass (kg) + 539.6 x height (m)]
Women= 354 – 6,91 + PA x [9,36 x body mass (kg) + 726 x height (m)]
PA (Physical activity):
1.0-1.39: sedentary and daily activities as walking, house keeping, etc.
1.4-1.56: low activity, daily tasks and 30-60 minutes / day of moderate activity as walking 5-7 km/hour.
1.6-1.89: active and daily activities, more 60 minutes / day of moderate activity.
1.9-2.5: very active, daily activities, with 60 minutes / day of moderate activity more 60 minutes / day of vigorous activity or 120 minutes / day of moderate activity.

Cunningham, 1980:
RMR= 500 + 22 x lean mass (kg)
Greater prediction of RMR in athletes of both sexes who perform resistance training, as based on lean mass (fat-free).

De Lorenzo, 1999:
RMR men= -857 + 9.0 x body mass (kg) + 11.7 x (-height (cm)).
51 men athletes involved in intensive training of water polo, judo and karate.

as the number of calories consumed per minute on an activity, related to basal metabolic rate (1 MET = 1 kcal/kg/h = 3.5 ml/kg/min of O_2). Data obtained by METs are valid for adults 40-64 years. However, in elderly they should be lower, while in young they are higher[16].

The limitation of calculating energy expenditure caused by physical activity by this method is the great individual variability in relation to the level of fitness, skill, coordination, efficiency, environmental conditions, intensity or nature of the effort[15].

Dietary and nutritional evaluation

Dietary assessment is an important tool for assessing the nutritional status of the athlete especially when referring to sports performance and health[17]. We have to assume that a state of balanced eating is an integral part of any sports program[17]. Therefore, information about food consumption and nutrient intake to establish the relationship between diet and health status[18] and athlete's performance is needed.

A study revealed that 80% of survey assessment related to both knowledge and food intake had no supervision by a nutritionist-dietitian[17]. Performing a good dietary assessment is not without difficulty, since it depends on:

- The memory of the athlete.
- The difficulty of the athlete estimating portions size.
- The possible under- or overestimation of food intake.
- The possible bias induced by the dietitian who interviews the athlete.
- The conversion of foods to energy and nutrients and the use of food composition tables.

However, there are strategies to reduce the implicit error in dietary assessment, including:

- Use a combination of quantitative and qualitative methods (dietary history, 24-hour recall, frequency of food consumption).
- Handle methods and techniques with dietary history, asking about some related general aspects that help the patient to recall a more detailed way, all food consumed in a day to reduce the error (24-hour recall multiple steps).
- Use photos or models of foods that help the athlete to estimate the consumed portions.

After obtaining the records, data must be transferred to a database for calculating energy, macro- and micronutrients from which to compare references regarding energy intake and carbohydrates, protein, lipids, water and micronutrients[19].

Due to the heterogeneity of methods used to assess food intake in athletes and the general population, it is difficult to perform a meta-analysis indicating the effectiveness of these methods of nutritional assessment[20], so combining different methodologies[21], is what gives us greater precision when evaluating food intake, in addition to the use of certain online tools that today allow to validate the intake of nutrients[22].

Body water and liquids intake assessment

An adequate hydration status in athletes, young and old, is essential to maintain physical and mental performance during athletic activities[19]; dehydration can cause harmful effects on athletes' health. Hence the knowledge of fluid intake by the athlete is a matter of the utmost importance.

Hydration and Dehydration in exercise

Normal hydration, often called euhydration, is important for health and wellbeing. Even small losses of body water can have a negative effect on muscle strength, endurance and maximal oxygen uptake. Normal hydration status is the condition of healthy individuals who maintain water balance that depends on the difference between water gain and water loss[23].

Under normal conditions, water entry into the organism proceeds from fluid intake (around 2300 mL/day) as well as the production of water from reactions of cellular metabolism (200 mL/day). Concerning water output sources, the main output are in form of urine (1500 mL/day), followed by cutaneous perspiration (350 mL/day), pulmonary ventilation (350 mL/day), sweat (150 mL/day) and faeces (150 mL/day)[23]. During exercise, as fluid losses by sweat increase, fluid intake should also increase[2].

A slight state of dehydration, a water loss of only 1% - 2% of body weight, will negatively affect both physical and mental performance. Dehydration produces a negative effect on the cardiovascular system, thermoregulation, besides compromising metabolic, endocrine and excretory systems, resulting in decreased physical performance and also cognitive function.

During exercise, an increased rate of metabolic heat production and body temperature will rise if heat loss is not increased accordingly. There is a risk to health as a consequence of thermal and fluid balance homeostasis and exercise performance may be reduced in the heat. Therefore, athletes must be concerned to drink accordingly in order to reduce this performance loss. When intense exercise is combined with high temperature or restricted heat loss, core temperature may rise by 2-3 ºC and this may result in exertional heat illness[24].

Sweat loss is composed by water (99%), electrolytes (mainly sodium and chloride), nitrogen and nutrients. During exercise, small amounts of magnesium, calcium, iron, copper and zinc can be lost too. The mean concentration of salt in sweat is 2.6g (45 mEq) for each 1-1.45 L of sweat produced during exercise. During exercise, an excessive sweating can decrease levels of sodium and chloride by 5-7% and potassium by 1%, therefore it must be replaced in order to prevent a deficit.

The sweat rate depends on several factors such the environmental conditions (temperature, humidity); genetics, and the athletic conditioning of the athlete. Moreover, there is a large inter-individual variation in sweating even when the same or similar exercise is carried out in the same conditions or when the individuals are exposed to the same heat stress[24].

The sweat rate can be calculated by:

1. Weight lost: Total body mass after exercise (kg) - Total body weight after exercise (kg).
2. Sweating: Weight lost + total amount of liquid consumed during workout + total urine produced during exercise (mL).
3. Sweat rate: (Sweating/exercise duration).

Fluid replacement by providing water, specific drinks and liquids based on solutes, mainly carbohydrates and electrolytes, helps to maintain hydration and therefore health and performance in athletes. Water commonly represents the fluid chosen by many athletes who exercise regularly, its effect helps to counteract many of the negative effects of dehydration; however, over the past 50 years, investigations have confirmed the benefits of specific sport drinks.

An adequate sport drink must fulfill the following functions: have good palatability, replace fluids and electrolytes, enhance absorption, provide energetic substrates, and ability to maintain blood volume.

Composition and characteristics of sports drinks[2]:

Carbohydrate concentration (5-8%). An intake of CH in proper concentration has shown benefits in order to maintain intensity during high-intensity exercise lasting an hour or more, allowing maintaining adequate blood glucose and delaying the point of fatigue.

- Beverage temperature: 10 °C to 15 °C.
- Osmolarity (180-400 mEq / L).
- Mineral content (especially Na +) (20 to 30 mEq / L).
- Taste: must have a pleasant taste to encourage voluntary hydration and rehydration.

It is important to achieve an appropriate balance between fluid intake and fluid losses in athletes or what is the same optimal state of hydration before, during and after exercise.

It is well known that athletes should not begin competition in a state of deficit of fluid[24] as a fluid deficit can increase physiological stress and reduce performance. It is necessary not only to maintain adequate hydration status after starting the activity, but also before the start of the activity. There are several protocols which allow to achieve or approach as far as possible an euhydration status before, during and after activity

Hydration assessments methods

There is no universal agreement upon the optimal method to measure hydration status that could be universally applied. Over the last years, various options to assess hydration status have been described in detail by many authors[24].

Hydration status can be determined through a variety of methods but many of them have potential limitations. However, there are some authors who suggest that the "gold standard" is the combination of various factors.

Body changes

Body mass changes, rather than any measure of body water change, is typically used in research studies to quantify a change in hydration status[25]. In most athletic settings, the use of body mass measurements in combination with some measure of urine concentration at the first urination of the morning allows large sensitivity for detecting daily deviations from normal hydration. The methods are simple, inexpensive, accurately distinguish euhydration from dehydration, and can therefore be used as a sole source for assessment.

Measurements should be made with subjects' nude, or in light and dry clothes, being the clothes identical before and after exercise for both measurements. The weight test will be collected before and after exercise. It may be convenient that subjects urinate and defecate before weighing[26].

Bioelectrical impedance analysis (BIA)

Total body water content can be estimated by BIA method. Over the last years this noninvasive technique has attracted much attention; however, the lack of precision and the factors that can influence the results as skin temperature, posture and other factors do not recommend its use for monitoring hydration[16].

Blood

Changes in blood volume and composition reflect changes in hydration status (Table IV). Blood volume and plasma osmolality are the primary variables homeostatically regulated, but both are very sensitive to variation by exercise, food ingestion, fluid intake, posture change and several factors. Blood tests for hydration will tend to include hemoglobin concentration, hematocrit, sodium concentration and osmolality. Otherwise it appears that changes in plasma osmolality that stimulate endocrine regulation of the reabsorption of renal water and electrolytes are delayed at the kidney when acute changes in body water occur[27].

Urine

Urine samples for assessment of hydration status may be collected at the first urination of the morning or may be collected immediately before training or competition[26]. The collection time can be affected by several factors and this should be considered in the interpretation of the results. Urine tests for hydration can include:

Osmolality: Measurement of osmolality requires use of an expensive instrument and technical competence. It is most commonly measured be freezing point depression but equipment using vapor pressure analysis is also used. Values of urine osmolality of > 900 mOsmol/Kg reflect a body water deficit of about 2% of body mass[23]. The American College of Sports Medicine[23] suggests a good index of hydration as a urine osmolality ≤700 mOsmol/Kg or a Urine specific gravity of <1020 g/mL.

Urine specific gravity (USG): USG is an accurate and rapid indicator of hydration status. Normal ranges are from 1.013–1.029; a USG of ≥1.030 suggests dehydration and 1.001–1.012 may indicate over-hydration. USG is more indicative of recent fluid consumption versus overall chronic hydration status [28].

Color: Urine color is determined by the amount of uro-chrome, resulting from the breakdown of hemoglobin in the sample. Research has identified linear relationships between urine color and specific gravity, and between urine color and conductivity. Therefore, urine color is an acceptable way to estimate hydration status in athletic or research settings when a high precision may not be needed or where self-assessment may be

Table IV
Serum markers and reference ranges of euhydratation

Serum marker	*Reference ranges*
Haemoglobin:	
Men	14.0-17.0 g/dL
Women	11.5-16.0 g/dL
Haematocrit:	
Men	42-54%
Women	38-46%
Serum sodium	132-142 mmol/L
Serum osmolality	280-300 mOsmol/kg

required. Armstrong et al. (1998) have investigated the linear relationship between urine color and specific gravity and conductivity, and have developed a scale of eight colors. A lighter color indicates adequate hydration, while darker colors indicate the need for fluid consumption. However, diet, supplements, and medications can affect body weight and urine color, thus these factors must be considered when using this method. This method is universally accepted to be used in athletic or other fields to estimate hydration status when high precision may not be needed[29].

Saliva

Saliva osmolality rises in cases of acute dehydration (4% loss of body mass) induced by exercise in the heat, but there is a large variability in how individuals respond. Saliva osmolality can also be affected by a brief mouth rinse with water which makes it an unreliable marker of hydration status.

Questionnaires

Questionnaires are a qualitative tool that can provide important information about amount and types of ingested fluids, which can be rapidly administered to get information of the athlete. The food frequency questionnaire is a tool that is commonly used for assessing intake of foods and drinks; however, water is not contained as a beverage in several of them.

Although there are several measures to estimate hydration status, all have limitations. At present, there is no consensus for using any method over another in an athletic setting, although plasma osmolality and total body water are currently the best hydration assessment measures in the scientific field of fluid needs[24]. Usually the use of body changes combined with some parameter of urine concentration as specific gravity or osmolality, in a sample collected during the first urine of the morning allows a good sensitivity for detecting significant changes in fluid balance (> 2% body mass) for training and competing athletes[30].

Conclusion

Due to high caloric output and intense physical activity, which affects physiological, metabolic and nutritional aspects and body composition, athletes differ from the general population. Assessment of nutritional status in athletes must consider specific aspects like the type of sport, specialty or playing position, training schedule and competition calendar, category, and other specific objectives. Due its complexity, there is consensus that the combination of different methods assures an effective data collection which will be useful to proceed in dietary and nutritional intervention. Combining biochemical assessment, sport kinanthropometry, dietary and hydration status assessment in athletes is essential to obtain reliable data.

Acknowledgements

The EXERNET Study Group (Research Network on Exercise and Health in Special Populations) has been supported by the Ministerio de Educacion y Ciencia (DEP2005-00046/ACTI).

References

1. Driskell JA, Wolinsky I. *Nutritional Assessment of Athletes*. Boca Raton, Fla: CRC Press, 2011.
2. González Gross M. Implicaciones nutricionales en el ejercicio. In: Chicharro JL, Fernández-Vaquero A eds. Fisiología Del Ejercicio. Madrid: Editorial Panamericana, 2006; 240-78.
3. Burke L, Maughan R, Shirreffs S. The 2007 IAAF consensus conference on nutrition for athletics. 2007.
4. Wolinsky I, Driskell JA. *Sports Nutrition: Vitamins and Trace Elements*. CRC Press, 2005.
5. Monsen ER. Dietary reference intakes for the antioxidant nutrients: Vitamin C, vitamin E, selenium, and carotenoids. *J Am Diet Assoc* 2000; 100: 637-40.
6. Paschalis V, Theodorou AA, Kyparos A et al. Low vitamin C values are linked with decreased physical performance and increased oxidative stress: Reversal by vitamin C supplementation. *Eur J Nutr* 2014.
7. Paulsen G, Hamarsland H, Cumming KT et al. Vitamin C and E supplementation alters protein signalling after a strength training session, but not muscle growth during 10 weeks of training. *J Physiol*. 2014; 592: 5391-408.
8. Mielgo-Ayuso J, Urdampilleta A, Martínez-Sanz JM et al. [Dietary iron intake and deficiency in elite women volleyball players]. Ingesta dietética de hierro y su deficiencia en las jugadoras de voleibol femenino de élite. *Nutr Hosp*. 2012; 27: 1592-7.
9. Ahmadi A, Enayatizadeh N, Akbarzadeh M et al. Iron status in female athletes participating in team ball-sports. *Pak J Biol Sci* 2010; 13: 93-6.
10. Lukaski HC. Vitamin and mineral status: Effects on physical performance. *Nutrition* 2004; 20: 632-44.
11. Döker S, Hazar M, Uslu M et al. Influence of training frequency on serum concentrations of some essential trace elements and electrolytes in male swimmers. *Biol Trace Elem Res* 2014; 158: 15-21.
12. Norton K, Olds T. *Anthropometrica: A Textbook of Body Measurement for Sports and Health Courses* Sidney: University of New South Wales, 2004.
13. Burke L. *Nutrición En El Deporte: Un Enfoque Práctico* Madrid: Médica panamericana, 2009.
14. Manore M, Thompson J. *Sport Nutrition for Health and Performance* Champaign, IL: Human Kinetics, 2000.
15. Ainsworth BE, Haskell WL, Whitt MC et al. Compendium of physical activities: An update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; 32: S498-504.
16. Institute of Medicine. *Food and Nutrition Board. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington DC: National Academies Press, 2005.
17. Wierniuk A, Wlodarek D. Assessment of physical activity, energy expenditure and energy intakes of young men practicing aerobic sports. *Rocz Panstw Zakl Hig* 2014; 65: 353-7.
18. Martínez JA, Portillo Baquedano MdP, Navas Carretero S. *Fundamentos De Nutrición Y Dietética: Bases Metodológicas Y Aplicaciones*. Madrid etc.: Médica Panamericana, 2011.

19. González-Gross M, Gutiérrez A, Mesa JL et al. [Nutrition in the sport practice: Adaptation of the food guide pyramid to the characteristics of athletes diet]. La nutrición en la práctica deportiva: Adaptación de la pirámide nutricional a las características de la dieta del deportista *Arch Latinoam Nutr* 2001; 51: 321-31.
20. Spronk I, Kullen C, Burdon C et al. Relationship between nutrition knowledge and dietary intake. *Br J Nutr* 2014; 111: 1713-26.
21. Rumbold P, St Clair Gibson A, Stevenson E et al. Agreement between two methods of dietary data collection in female adolescent netball players. *Appetite* 2011; 57: 443-7.
22. Forster H, Fallaize R, Gallagher C et al. Online dietary intake estimation: The Food4Me food frequency questionnaire. *J Med Internet Res* 2014; 16: e150.
23. Institute of Medicine. Water. In: Anonymous Dietary Reference Intakes for Water, Sodium, Cholride, Potassium and Sulfate. Washington, D.C: National Academy Press, 2005; 73-185.
24. American College of Sports Medicine, Sawka MN, Burke LM et al. American College of sports medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc* 2007; 39: 377-90.
25. Shirreffs S. Hydration in sport and exercise: Water, sports drinks and other drinks. *Nutr Bull* 2009; 34: 374-9.
26. Maughan R, Shirreffs S. Development of hydration strategies to optimize performance for athletes in high-intensity sports and in sports with repeated intense efforts. *Scand J Med Sci Sports* 2010; 20: 59-69.
27. Popowski LA, Oppliger RA, Patrick Lambert G et al. Blood and urinary measures of hydration status during progressive acute dehydration. *Med Sci Sports Exerc* 2001; 33: 747-53.
28. Cheuvront SN, Sawka MN. Sports science exchange 97 VOLUME 18 (2005) number 2 hydration assessment of athletes. *Sports Science* 2005; 18: 97.
29. Armstrong LE, Soto JA, Hacker FT,Jr et al. Urinary indices during dehydration, exercise, and rehydration. *Int J Sport Nutr* 1998; 8: 345-55.
30. Riebl SK, Davy BM. The hydration equation: Update on water balance and cognitive performance. *ACSM's Health & Fitness Journal* 2013; 17: 21-8.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):237-244
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Biomarkers of physical activity and exercise

Gonzalo Palacios [1,2], Raquel Pedrero-Chamizo[1], Nieves Palacios[3], Beatriz Maroto-Sánchez[1], Susana Aznar[4] and Marcela González-Gross[1,2] on behalf of EXERNET Study Group

[1]ImFINE Research Group. Technical University of Madrid. Spain. [2]CIBERobn (Fisiopatología de la Obesidad y la Nutrición CB12/03/30038), Instituto de Salud Carlos III, Spain. [3]Sport Medicine Center. High Sports Council. Spain. [4]PAFS Research Group. University of Castilla-La Mancha. Spain.

Abstract

Traditionally, biomarkers have been of interest in sports in order to measure performance, progress in training and for identifying overtraining. During the last years, growing interest is set on biomarkers aiming at evaluating health-related aspects which can be modulated by regular physical activity and sport. The value or concentration of a biomarker depends on many factors, as the training status of the subject, the degree of fatigue and the type, intensity and duration of exercise, apart from age and sex. Most of the biomarkers are measured in blood, urine and saliva. One of the main limitations for biochemical biomarkers is that reference values for blood concentration of biomarkers specifically adapted to physically active people and athletes are lacking. Concentrations can differ widely from normal reference ranges. Therefore, it is important to adapt reference values as much as possible and to control each subject regularly, in order to establish his/her own reference scale.

Other useful biomarkers are body composition (specifically muscle mass, fat mass, weight), physical fitness (cardiovascular capacity, strength, agility, flexibility), heart rate and blood pressure. Depending on the aim, one or several biomarkers should be measured. It may differ if it is for research purpose, for the follow up of training or to prevent risks. For this review, we will get deeper into the biomarkers used to identify the degree of physical fitness, chronic stress, overtraining, cardiovascular risk, oxidative stress and inflammation.

(*Nutr Hosp* 2015;31(Supl. 3):237-244)

DOI:10.3305/nh.2015.31.sup3.8771

Key words: *Physical fitness. Health. Performance. Biomarker. Cortisol.*

Correspondence: Marcela González-Gross.
ImFINE Research Group.
Department of Health and Human Performance.
Facultad de Ciencias de la Actividad Física y del Deporte-INEF.
Universidad Politécnica de Madrid.
C/ Martín Fierro 7. E.
28040 Madrid.
E-mail: marcela.gonzalez.gross@upm.es

BIOMARCADORES DE LA ACTIVIDAD FÍSICA Y DEL DEPORTE

Resumen

Tradicionalmente, los biomarcadores han sido de interés en las ciencias del deporte para medir el rendimiento, el progreso en el entrenamiento y para identificar el sobreentrenamiento. Durante los últimos años, cada vez hay mayor interés en evaluar los efectos relacionados con la salud que se producen en el organismo debidos a una actividad física regular y al deporte. El valor o la concentración de un biomarcador depende de muchos factores, como el grado de entrenamiento, el grado de fatiga y del tipo, la intensidad y la duración del ejercicio, aparte de la edad y del sexo. La mayor parte de los biomarcadores se miden en sangre, orina y saliva. Una de las principales limitaciones que presentan los biomarcadores bioquímicos es la falta de valores de referencia adaptados específicamente para deportistas y personas físicamente activas. Las concentraciones pueden variar considerablemente de los valores de referencia normales. Por lo tanto, es importante adaptar los valores de referencia siempre y cuando sea posible y controlar a cada sujeto regularmente, con el fin de establecer su propia escala de referencia.

Otros biomarcadores útiles son la composición corporal (específicamente masa muscular, masa grasa, peso), la condición física (capacidad cardiorrespiratoria, fuerza, agilidad, flexibilidad), frecuencia cardíaca y presión arterial. Dependiendo de la finalidad, será conveniente analizar uno o varios biomarcadores. Para esta revisión, profundizaremos en los biomarcadores que se emplean para evaluar condición física, fatiga crónica, sobreentrenamiento, riesgo cardiovascular, estrés oxidativo e inflamación.

(*Nutr Hosp* 2015;31(Supl. 3):237-244)

DOI:10.3305/nh.2015.31.sup3.8771

Palabras clave: *Condición física. Salud. Rendimiento. Biomarcador. Cortisol.*

Background

A biomarker (biological marker) is a measurable product or substance used as an indicator of the biological state, to objectively determine the body's physiological or pathological processes. In sport, biomarkers are key parameters to assess the impact of exercise on different systems, tissues and organs[1]. Therefore, we

can estimate parameters for assessing the degree of fitness, muscle damage, hydration/dehydration, inflammation, oxidative damage, fatigue, overtraining, etc, which facilitate the evaluation of the response of the human body at the different levels of physical activity or training being carried out. Biomarkers can be used to measure the impact of training on the long term or the acute effect of exercise. The value or concentration of a biomarker depends on many factors, as the training status of the subject, the degree of fatigue and the type and duration of exercise, apart from age and gender, among others. Climate can also play a role, mainly temperature, humidity and wind speed. Exercise can be classified according to the duration as the following: around 20s (demand for anaerobic energy up to 90%), exercise lasting 20s to 1 min (aerobic and anaerobic energy) or exercises that extend over 1 min (aerobic energy more than 50%). Intensity is also an influencing factor on biomarker concentration. Most of the biomarkers are measured in blood, urine and saliva. In elite sports, non-invasive samples like urine and saliva have a preference. Other useful biomarkers are body composition (specifically muscle mass, fat mass, weight), physical fitness (cardiovascular capacity, strength, agility, flexibility), heart rate and blood pressure.

Depending on the aim, one or several biomarkers should be measured. It may differ if it is for research purpose or for the follow up of training.

Interest

Traditionally, biomarkers have been of interest in sports in order to measure performance, progress in training and for identifying overtraining[2]. During the last years, growing interest is set on biomarkers aiming at evaluating health-related aspects which can be modulated by regular physical activity and sport[3]. Additionally, as promotion of physical activity is supported by most of public health authorities, the evaluation of the biological response to exercise is also a need in the amateur athlete. For this review, we will get deeper into the biomarkers used to identify the degree of physical fitness, chronic stress, overtraining, cardiovascular risk, oxidative stress and inflammation.

Controversy

Controversy exists regarding if biochemical biomarkers are really useful for the monitoring of training progress and adaptation, and some trainers do not include biomarkers in their season planning[2]. Less controversy exists in regard to identifying risk situation, like overtraining, nutrient deficiencies, etc. Unfortunately, there is no gold standard for monitoring most of the processes; therefore, the analysis of several biomarkers is recommended.

Limitations

Reference values for blood concentration of biomarkers specifically adapted to physically active people and athletes are lacking. Therefore, for most of the biomarkers measured routinely in the laboratory, reagent manufactures' reference values are used. In the authors' opinion, this can lead to misclassification or wrong interpretation of the results. Our research group is currently working on reference values specifically adapted to athletes of different sports (E. Diaz, non-published data). It is important to bear in mind that highly trained people can have concentrations of biomarkers which would be pathological in non-trained people, even in routine hematology and biochemistry parameter. Therefore, it is important to adapt reference values as much as possible and to control each subject regularly, in order to establish his/her own reference scale.

Current state and perspective

Markers of Physical fitness

Physical fitness is a set of attributes that people have or achieve and it is referred to the capacity of a person to meet the varied physical demands of their activities of daily living and/or sport practice without experimenting fatigue. Physical fitness is not only a predictor of morbidity and mortality for cardiovascular disease[4]. It is nowadays considered one of the most important health markers because it integrates most of the body functions (skeletomuscular, cardiorespiratory, hematocirculatory, psychoneurological and endocrine-metabolic) involved in the performance of daily physical activity and/or physical exercise[3]. Accordingly, when physical fitness is tested, the functional status of all these systems is actually being checked. Physical fitness is in part genetically determined, but it can also be greatly influenced by environmental factors, such as physical exercise, sedentary habits, harmful lifestyles, etc.

Physical fitness components can be differentiated between a health-related and a performance-related approach that pertain more to athletic ability, being the health-related components more important to public health than are the components related to athletic ability[5]. According to Bouchard et al.[1], the health-related fitness components of a person include a cardiorespiratory component (e.g. maximal aerobic power or heart function); a muscular component (e.g. strength, power or muscular endurance); a motor component (e.g. agility, balance and co-ordination); a morphological component (e.g. body composition, bone density or flexibility); and a metabolic component (e.g. glucose tolerance, lipid and lipoprotein metabolism and substrate oxidation characteristics)[6]. There are numerous tests for measuring physical fitness, ranging from self-assessment techniques over simple field test to

more sophisticated laboratory tests. One may choose to employ a different measure depending on the specific objectives of the investigation and cost constraints.

The World Health Organization (WHO), considered the maximal oxygen consumption (VO2max) as the single best indicator of cardiorespiratory fitness[7] and it can be estimated using a maximal or sub-maximal test (e.g. treadmill or bicycle tests, 2 km. walk test, 20-m shuttle run, 6 min. walk test). According to muscular component, the handgrip strength test is one of the most used tests for assessing muscular fitness being a strong predictor of morbidity and mortality[8]. For assessing power strength or muscular endurance jump, dynamic sit-up and bent-arm hand tests have been used with young, adult and older people. Agility, balance, speed or co-ordination is included in the motor component. Agility is a combination of speed, balance, power and coordination[3]. Some tests used to measure motor component are 30-m sprint test and 4 x 10-m shuttle run test for young people and 30-m walk test and 8-foot-and-go, for older adults. For measuring static balance, single leg balance, with or without open eyes, is a good alternative test. Flexibility is a morphological component; chair sit-and-reach test and back scratch test are two validated tests for measuring this capacity (Fig. 1).

Test item	Assessment category	Description
One leg [] 	Static balance	Number of seconds during which the participant kept balance on one leg. The maximum time allowed for the test was 60 s.
Chair stand 	Lower body s strength	Number of full stands in 30 seconds with arms folded across chest.
Arm curl 	Upper body strength	Number of biceps curls in 30 seconds holding hand weight.
Chair sit -and -reach 	Lower body flexibility	From sitting position at front of chair, with leg extended and hands reaching toward toes, number of centimetres from extended fingers to tip of toe.
Back scratch 	Upper body flexibility	With one hand reaching over shoulder and one up middle of back, number of centimetres between extended middle fingers.
8 -foot -and -go 	Agility/Dynamic balance	Number of seconds required to rise from seated position, walk 2.45 metres, turn, and return to seated position on chair.
30 -m walk 	Walking speed	Number of seconds required to walk 30 metres.
6 -minute walk 	Aerobic capacity	Number of meters that can be walked in 6 minutes around a 46 meters course.

Fig. 1.—Some tests used for the evaluation of physical fitness in elderly (modified from 9).

For use in clinical practice, reference values for men and women in all age groups are needed. Some of the most important studies that have provided reference values are AVENA and HELENA[3] studies, for Spanish and European adolescents, respectively, and the senior fitness test by Rikli & Jones and the EXERNET study[9], for Americans and Spanish elderly people, respectively.

Markers of chronic stress and fatigue

Cortisol

Cortisol is a steroid hormone synthesized from cholesterol by enzymes of the cytochrome P450 located at adrenal cortex. It's expressed following a circadian rhythm: at midnight, cortisol blood levels are very low (sometimes even undetectable) and they increase overnight to reach a peak in the morning. This rhythm is regulated by the main circadian oscillator in the suprachiasmatic nucleus which is located in the hypothalamus[10]. Cortisol counters insulin effect by promoting high blood glucose levels via stimulation of gluconeogenesis, the metabolic pathway that synthesizes glucose from oxaloacetate. The presence of cortisol triggers the expression of enzymes critical for gluconeogenesis, facilitating this increase in glucose production. Conversely, it also stimulates glycogen synthesis in the liver, which decreases net blood sugar levels. Thus, cortisol carefully regulates the level of glucose circulating through the bloodstream: when blood glucose has been depleted (for example during fasting), cortisol ensures a glucose basal concentration by activating gluconeogenesis[11].

Cortisol shows other metabolic functions. Among others, it allows a correct pH regulation of extracellular liquid: when cells loose too much sodium, it accelerates the rate of potassium excretion. Therefore, cortisol regulates the action of cellular sodium-potassium pumps to reach an ion equilibrium after a destabilizing event[11]. Cortisol's weakening effects on the immune response have also been well documented. T-lymphocyte cells (T-cells) are activated by cytokine molecules (interleukins) via a signaling pathway. Cortisol prevents specific T-cells receptors to recognize interleukin signals and reducing proliferation of T-cells, which provokes a decrease of inflammation course. In the same way, it reduces inflammation due to inhibition of histamine secretion. Cortisol's ability to prevent the immune response can render people who suffer from chronic stress highly vulnerable to infection[12].

While it is important for adrenal glands to secret more cortisol in response to psychological or physical stress, it is also fundamental that cortisol levels return to normal values following a stressful event. Unfortunately, in some athletes the stress response to an intensive exercise is activated so often that the metabolic pathways do not always have a chance to return to a normal situation. This can lead to health problems, resulting, among others, in chronic stress and fatigue.

Training load as measured by the session-RPE (Rating of Perceived Exertion) is a subjective method of quantifying the load placed on an athlete. Measured session-RPE in 8 young elite middle-distance runners for 8 weeks, showed that this indicator of training load was able to detect states of overreaching[13]. In another way, measurement of the countermovement jump (CMJ) score can be used as an indicator of neuromuscular performance and therefore it has been used to assess fatigue in different kinds of athletes. Finally, salivary cortisol correlates with both physical magnitudes[14]. Thus, the measurement of session-RPE, CMJ score and salivary cortisol is used to monitor the training process in different kinds of athletes. Post-exercise salivary cortisol responses were significantly different depending on the intensity. For example, immediately after a high intensity acute resistance exercise, salivary cortisol showed a significant elevation of 97% from baseline values, while there was no difference when the intensity of exercise was very low[15]. In addition to the intensity, another factor that may affect the salivary cortisol response is the training status of the subjects[16]. Highly-trained strength athletes show an inverse and significant correlation with neuromuscular performance. Kraemer et al. [17] through their study on cortisol and performance of a group of highly-trained soccer players throughout a season, concluded that athletes starting the season with elevated cortisol values may experience significant reductions on performance during the season. Similar results have been obtained with middle and long distance runners[18]. Individuals presenting higher long-term salivary cortisol levels showed a significant tendency to be those with lower CMJ scores throughout the season. However, when correlation was studied in a shorter period of time, a significant positive trend was observed between runners with higher weekly salivary cortisol concentrations with higher CMJ scores. Further studies are needed to explain these opposite tendencies depending of measure time.

Testosterone

This steroid hormone belonging to the group of androgens in the body facilitates increased muscle mass and strength, increased combativeness and aggression of athletes and allows greater reduction of muscle fat. Reference ranges are 300 - 1000 ng/dL for men and 15-70 ng/dL for women. A disproportionate rise in the physiological stress response induces an increase in cortisol secretion which could in turn inhibit the synthesis of testosterone. The cortisol/testosterone ratio is an index used to measure chronic fatigue in athletes[16].

Markers of overtraining

Lactate

Muscles always produce lactate, even at rest (0.8 – 1.5 mmol/L), but lactate increases incrementally with

exercise intensity. At a certain intensity lactate increases exponentially, this is called the lactate threshold, which occurs on average at a blood lactate concentration of 4.0 mmol/L. Fatigue onset appears fast above the lactate threshold limit, while efforts just below this limit can be sustained for hours when athletes are well trained. This training allows also raising the lactate threshold to the highest genetic potential of each subject. However, to perform too much training at or above the lactate threshold can result in overtraining. Thus, blood lactate measurement is used to determine not only the lactate threshold, but also the correct intensity of the exercise and the time needed for recovery. Lactate testing is used all over the world by researchers and athletic coaches. It can be considered as the current gold standard for determining exercise intensity and for determining whether or not training is producing the desired physiological effect. Briefly, muscle contraction starts on an electrical impulse from the brain, which is transmitted to muscle cells by means of the acetylcholine liberated at the motor neuron synapses. This produces a change in the membrane potential due to the leak out of potassium ions to the extracellular space, allowing calcium ions to be released from the endoplasmic reticulum and finally to trigger contraction of the muscle fiber. But during high-intensity or long-time exercises, potassium ions continuously leak out of the muscle cell into the extracellular space, causing a depolarizing effect in the membrane, as the charge difference between inside and outside cell decreases. As a consequence, electrical currents have a harder time getting in and muscle contractions become weaker. Recent studies have shown that far from causing fatigue in the exercising muscle, lactate production actually prevents fatigue by counteracting the effects of depolarization produced by the potassium ions outflow[19].

Creatine (phospho) kinase (CK or CPK)

CK is used as a marker of muscle fiber damage. Blood concentrations increase with increasing exercise intensity and duration. There is an adaptation due to training, enabling the levels in trained people to rise less than in sedentary people. Elevated baseline values indicate trauma or overtraining and its concentration can be used to monitor activity around athletes who have got a muscle injury[20] (Table I).

Table I
Training status depending on creatine kinase concentrations

CK concentration	*Interpretation*
200UI	Training adaptation
200-250UI	Elevated training levels
>300UI	Possible overtraining and muscle damage

Creatinine

This metabolite is an end product of muscle metabolism. It originates from muscle creatine degradation which in turn is produced by hydrolysis of creatine phosphate, by the action of creatine phosphate kinase (CPK). Creatinine clearance in the human body occurs almost exclusively by glomerular filtration, which is an important indicator of renal function. Renal excretion, unlike urea, does not depend on diuresis. Concentrations are substantially constant in each individual independent of diet, muscle mass being the main determinant. Commonly, creatinine is measured to assess whether renal function is adequate or not. In sports medicine, creatinine is typically used to assess the overall health of the athlete but normal values based on the normal population are not adequate for athletes. Normal references range from 0.7-1.3 mg/dl in adult men. In athletes, levels are usually high, depending on training, time of the season, which can induce changes in creatinine levels due to changes in the homeostasis of the body, which can lead to errors in biochemical and hematological parameters[2]. No specific references have been defined for athletes. Therefore, most commonly elevated creatinine is an indicator of a high degree of training or overtraining rather than a case of renal pathology. Creatinine concentration should be taken with caution, as it can be up to 1.4 mg/dl without suffering from renal disease. The interpretation of creatinine values should be done individually, taking into account gender, age and weight of the athlete.

Ammonia

In athletes, the accumulation of ammonia in the blood is dependant on the effort intensity. During physical exercise, the two main mechanisms by which ammonia accumulates are resynthesis of ATP from the breakdown of phosphocreatine (PC) and the deamination of amino acids. Rising ammonia is related to fast twitch muscle fibers. Therefore, the analysis of the values of ammonia can serve both as a marker for this type of exercise and as a marker of intense muscular effort fibers. The normal range of ammonia is 15 to 45 μg/dL. Elevated blood ammonia levels indicate a physiological response in sprinters (purely anaerobic metabolism), while lower rates correspond to medium or long distance runners (predominantly aerobic metabolism)[21].

Lactate dehydrogenase (LDH)

LDH is a catalytic enzyme found in most tissues of the body, and specifically in heart, liver, kidneys, muscles, blood cells, brain and lungs. LDH plays an important role in anaerobic energy metabolism, redu-

cing pyruvate to lactate at the end of the glycolysis. When there is muscle damage or muscle fiber destruction, LDH serum levels are significantly increased. In addition, LDH has a variety of isoenzymes, which are specific to different tissues, which provide additional information on the origin of muscle damage[20].

Uric acid

Uric acid is the end product of purine metabolism, which increases after intense exercise. Its concentration should be stable during the competition season. Elevated levels may be due to intense training, to high energy demands and small muscle damage as a result of overtraining. The increase may also be related to intake of purine-rich foods and food supplements, and body weight changes in athletes[2].

Urea

Urea is mostly formed in the liver as the waste product from the breakdown of proteins (amino acids). Normal blood urea concentrations for optimum training loads are 5-7 mmol/L. Very long training sessions cause an increase in the urea concentration in blood, liver, skeletal muscles, urine and sweat. It is used as a marker of protein catabolism. Thus, the measurement of urea allows to evaluate the degree of protein utilization as an energy substrate, the degree of effort in a competitive test session in particular, and the level of athlete's overtraining[21].

Markers of cardiovascular risk

Homocysteine

Homocysteine (Hcy) is an intermediate sulfhydryl-containing amino acid derived from methionine. In the methionine cycle, methionine converses to S-adenosyl methionine and to Hcy. Hyperhomocysteinemia (high Hcy blood levels) can be classified depending of total serum plasma Hcy concentration in three stages: moderate (for concentrations between 16 and 30 μM/L), intermediate (31–100 μM/L), and severe (for concentrations higher than 100 μM/L). Hyperhomocysteinemia can be the result of disturbed Hcy metabolism, principally when deficiencies in folic acid, vitamin B6, or vitamin B12 are present, as these vitamins are coenzymes of several regulating enzymes[22]. Hyperhomocysteinemia can be also caused by other factors independent of diet like genetic disorders in methionine and homocysteine metabolism, including mutations in cystathione b-synthase, methionine synthase and methylenetetrahydrofolate reductase (MTHFR)[21]. Increased Hcy levels are associated with several disorders, like cardio and cerebrovascular diseases[22] and neurodegenerative diseases that affect the central nervous system, such as epilepsy, stroke, Alzheimer's disease and dementia[23].

There are several proposed mechanisms to explain the toxicity of Hcy. For this review, we will only describe the two main ones. The first one is related to oxidative stress. Oxidation of the thiol terminal group of Hcy, when Hcy binds proteins (by forming a disulphide bridge), low-molecular plasma thiols or a second Hcy molecule, produce an increase of production of reactive species. Those free radicals induce the subsequent oxidation of proteins, lipids and nucleic acids[24] and can lead to the endothelial dysfunction and damage to the vessel wall, followed by platelet activation and thrombus formation. Homocysteinylation represent the second main mechanism of Hcy toxicity and it consists on modification of protein structure due to disulphide bond. Degree of the protein homocysteinylation increases with increased plasma Hcy and causes immune activation, autoimmune inflammatory response, cellular toxicity, cell death and enhanced protein degradation[22].

Because physical activity contributes to reduce cardiovascular risk factors and Hcy is one of such factors, theoretically Hcy could be used as biomarker of cardiovascular health when physical activity is performed. However, results obtained from several studies are contradictory and sometimes inconclusive, may be due to different kind of exercise, intensities, duration, with or without prior training, etc. A recent study carried-out by Iglesias-Gutierrez et al.[25] about serum Hcy concentration during an acute bout of exercise showed an increase at the beginning of exercise and a subsequent decrease at the end, the basal value being recovered 19 hours post-exercise. Due to this long period to reach again the initial Hcy levels, differences in timing of post-exercise sample collection could explain these discrepancies on Hcy levels variations after exercise described in the literature. An important point to be considered is the maximum Hcy concentration reached during exercise and how long high Hcy concentration persists in blood. In this study, authors did not observed any concentration above 15 μmol/L, the upper limit of Hcy normal range, beyond which it falls in hyperhomocysteinemia. However, this does not mean that the transient increase observed in Hcy is lacking of physiological relevance. A meta-analysis has shown that an average Hcy increase of 1.9 μmol/L was associated to a 16% higher risk of isquemic heart disease[26]. Nevertheless, this increase in cardiovascular disease risk observed by Wald et al.[26] refers to a sustained elevation of Hcy throughout lifespan, while Iglesias-Gutierrez et al.[25] refers to an elevation as response of an acute exercise.

In a recent review on effects of physical activity on Hcy levels, authors underscored that a high daily physical activity can help to control Hcy levels and thus reducing cardiovascular disease risk[27]. However,

an intensive and acute exercise tends to increase Hcy blood levels[28]. The effect of aerobic training is more controversial: resistance training seems to reduce Hcy levels while intensive training increases them. Authors suggest to carry-out further studies to study changes in homocysteine induced by combined exercise programs (i.e., aerobic and resistance).

Cardiac troponin

Cardiac troponin consists of two protein complexes *(cTnI and cTnT)* which regulate muscle contractile function. They are present in skeletal and cardiac muscle. Increased concentration of the cardiac isoforms (TnI and TnT) indicates that there has been muscular heart damage. Therefore, both markers are useful parameters to assess a cardiac event. However, the increase after intense or prolonged exercise in the absence of cardiac symptoms, suggests muscle lesions, due to adaptation of training.

Markers of oxidative stress

Malondialdehyde (MDA) and protein carbonyls (PC)

Malondialdehyde (MDA) is a marker of oxidative degradation of the cell membrane caused by lipid peroxidation of unsaturated fatty acids. Protein carbonyls (PC) come from the oxidation of albumin or other serum proteins and are used as a marker of oxidative damage of proteins. Reference limits for PC are 0.30 to 0.36 nmol/mg[29]. PC and MDA are lower in trained individuals. An increase can be due to stress caused by increasing training loads. However, after adaptation to training, concentrations decrease and return to normal values.

Superoxide dismutase (SOD) and glutathione peroxidase (GSH)

These are antioxidant enzymes modulated by physical activity. Resistance training increases moderately enzymes activity[29].

Reactive oxygen species (ROS)

There is growing evidence that the continued presence of high concentrations of free radicals is capable of inducing antioxidant enzymes and other defense mechanisms. In this context, free radicals can be viewed as beneficial rather than as harmful, since they act as signals to improve the defenses when cells are exposed to high levels of ROS. This is mainly due to the regulation of endogenous antioxidant enzymes such as glutathione peroxidase, manganese superoxide dismutase (MnSOD), and γ-glutamylcysteine synthetase. Therefore, we could state that training increases the expression of antioxidant enzymes that in turn keep decreasing ROS levels. The stimulated high levels of ROS create more antioxidant enzymes, which do not contribute to the oxidation of the body's cells[29].

Markers of inflammation

C-reactive protein

C-reactive protein (CRP) originates in the liver. There are many stimuli that can cause an increase in CRP concentrations, such as infection, trauma, surgery, chronic inflammatory conditions, etc. In the field of sports, intense physical activity can cause an increase in CRP. However, continuous training causes a reduction of CRP levels compared to baseline. This is due to different mechanisms and processes taking place while the body is adapting to training (improved endothelial function, reduced inflammatory cytokine production, antioxidant effects, increased insulin sensitivity, etc). A higher CRP level after training indicates lack of adaptation or overtraining, probably due to oxidative stress (inflammation). However, after adaptation to training, values are normalized[30].

Interleukin-6

Interleukin-6 (IL-6) is considered an anti-inflammatory cytokine that regulates acute inflammatory response. Receptors are located in adipose tissue, skeletal muscle and liver. IL-6 increases lipolysis in adipose tissue and improves insulin sensitivity in the liver, increases glycogenolysis in skeletal muscle. Intense exercise training increases plasma concentrations of IL-6 up to 100 times, indicating the beneficial effect of physical exercise[30].

Leukocytes

The white blood cells are part of the immune system, produced in the bone marrow and lymphoid tissue. After being synthesized they are transported by the blood to the different parts of the body. The fundamental value of leukocytes is that they are specifically transported into areas where there is inflammation, to provide rapid and vigorous defense against any possible infectious agent. Exercise causes a transient leukocytosis, which magnitude is directly related to the intensity of the exercise: it is more pronounced in response to maximal exercise, and in untrained or poorly trained individuals. An increased leukocyte value due to exercise reaches again normal values within 24 hours.

Conclusions

Biomarkers are useful tools for assessing and monitoring health, training status and performance. As there is some controversy in the literature, depending on the process to be monitored, a combination of biomarkers could be useful. However, controversy exists regarding which parameters are most relevant for monitoring fatigue. The most researched and applied to muscle fatigue are cortisol, lactate and IL-6. Also gaining increasingly more importance is the measurement of ammonia, leukocytes and oxidative stress parameters. The biomarkers of muscle fatigue could be a prognostic tool to identifying subjects who are at increased risk of poor adaptation to training. Exercise, in particular, has a major influence on the most widely used inflammatory biomarkers, including C-reactive protein and interleukin-6. Additionally to biochemical biomarkers, the measurement of physical fitness components should be included in order to monitor progress and adaptation to training, as fitness is considered one of the most important markers of health.

Acknowledgements

The EXERNET Study Group (Research Network on Exercise and Health in Special Populations) has been supported by the Ministerio de Educacion y Ciencia (DEP2005-00046/ACTI).

References

1. Bouchard C, Shephard RJ, Stephens T. Physical activity; fitness and health: International proceedings and consensus statement. Champaign III: Human Kinetics; 1994.
2. Calderón Montero FJ, Benito Peinado PJ, Melendez Ortega A, González-Gross M. Control biológico del entrenamiento de resistencia. *Rev Int Cienc Deporte* 2006; 2: 65-87.
3. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)* 2008 Jan;32(1):1-11.
4. Dhoble A, Lahr BD, Allison TG, Kopecky SL. Cardiopulmonary fitness and heart rate recovery as predictors of mortality in a referral population. *J Am Heart Assoc* 2014 Mar 24;3(2).
5. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep* 1985 Mar-Apr; 100(2): 126-131.
6. Vanhees L, Lefevre J, Philippaerts R, Martens M, Huygens W, Troosters T, Beunen G. How to assess physical activity? How to assess physical fitness? *Eur J Cardiovasc Prev Rehabil* 2005 Apr;12(2):102-14.
7. Shephard RJ, Allen C, Benade AJ, Davies CT, Di Prampero PE, Hedman R, et al. The maximum oxygen intake. An international reference standard of cardio-respiratory fitness. *Bull World Health Organ* 1968; 38(5): 757-764.
8. Stenholm S, Mehta NK, Elo IT, Heliövaara M, Koskinen S, Aromaa A. Obesity and muscle strength as long-term determinants of all-cause mortality--a 33-year follow-up of the Mini-Finland Health Examination Survey. *Int J Obes (Lond)* 2014 Aug;38(8):1126-32.
9. Pedrero-Chamizo R, Gómez-Cabello A, Delgado S, Rodríguez-Llarena S, Rodríguez-Marroyo JA, Cabanillas E, Meléndez A, Vicente-Rodríguez G, Aznar S, Villa G, Espino L, Gusi N, Casajus JA, Ara I, González-Gross M; on behalf of EXERNET Study Group. Physical fitness levels among independent non-institutionalized Spanish elderly: The elderly EXERNET multi-center study. *Arch Gerontol Geriatr* 2012; 55(2):406-16.
10. Chan S, Debono M. Replication of cortisol circadian rhythm: new advances in hydrocortisone replacement therapy. *Ther Adv Endocrinol Metab* 2010; 1: 129-138.
11. Giordano R, Guaraldi F, Berardelli R, Karamouzis I, D'Angelo V, Marinazzo E et al. Glucose metabolism in patients with subclinical Cushing's syndrome. *Endocrine* 2012; 41: 415-23.
12. Patterson S, Moran P, Epel E, Sinclair E, Kemeny ME, Deeks SG et al. Cortisol patterns are associated with T cell activation in HIV. *PLoS One* 2013; 26: 8:e63429.
13. Garcin M, Fleury A, Billat V. The ratio HLa:RPE as a tool to appreciate overreaching in young high-level middle-distance runners. *Int J Sport Med* 2002; 23: 16-21.
14. Gorostiaga EM, Grandados C, Ibanez J, Gonzalez-Badillo JJ, Izquierdo M. Effects of an entire season on physical fitness changes in elite male handball players. *Med Sci Sports Exercise* 2006; 38: 357-66.
15. McGuigan MR, Egan AD, Foster C. Salivary cortisol responses and perceived exertion during high intensity and low intensity bouts of resistance exercise. *J Sports Sci Med* 2004; 3: 8-15.
16. Fry AC, Kraemer WJ, Stone MH, Koziris LP,Thrush JT, Fleck SJ. Relationships between serum testosterone, cortisol and weightlifting performance. *J Strength Cond Res* 2000; 14, 338-43.
17. Kraemer WJ, French DN, Paxton NJ, Häkkinen K, Volek JS, et al. Changes in exercise performance and hormonal concentrations over a big ten soccer season in starters and nonstarters. *J Strength Cond Res* 2004; 18: 121-128.
18. Balsalobre-Fernández C, Tejero-González CM, del Campo-Vecino J. Relationships between training load, salivary cortisol responses and performance during season training in middle and long distance runners. *PLoS One* 2014; 9(8).
19. Overgaard K, Højfeldt GW, Nielsen OB. Effects of acidification and increased extracellular potassium on dynamic muscle contractions in isolated rat muscles. J Physiol 2010; 588: 5065-76.
20. Martín García. Estudio de marcadores bioquímicos de interés en el diagnóstico y pronóstico del síndrome coronario agudo. Doctoral Thesis 2010. Ed: Universidad Complutense de Madrid. ISBN: 978-84-693-4105-6.
21. Testai FD, Gorelick PD. Inherited metabolic disorders and stroke part 2: homocystinuria, organic acidurias, and urea cycle disorders. *Arch Neurol* 2010; 67: 148-53.
22. González-Gross M, Sola R, Castillo MJ, Pietrzik K. Homocisteina y riesgo cardiovascular. *Investigación Clínica* 5:219-226, 2002.
23. González-Gross M, Marcos A, Pietrzik K. Nutrition and cognitive impairment. *Br J Nutr 86* (3):313-321, 2001.
24. Zou CG, Banerjee R. Homocysteine and redox signaling. *Antioxid Redox Signal* 2005; 7: 547-59.
25. Iglesias-Gutiérrez E, Egan B, Díaz-Martínez AE, Peñalvo JL, González-Medina A et al. Transient increase in homocysteine but not hyperhomocysteinemia during acute exercise at different intensities in sedentary individuals. *PLoS One* 2012; 7:1-8.
26. Wald DS, Morris JK, Wald NJ. Reconciling the evidence on serum homocysteine and ischaemic heart disease: a meta-analysis. *PLoS One* 2011;6: e164473.
27. de Souza e Silva A, Gonçalves da Mota MP. Effects of physical activity and training programs on plasma homocysteine levels: a systematic review. *Amino Acids* 2014; 46:1795-1804.
28. Maroto-Sánchez B, Valtueña J, Albers U, Benito PJ, González-Gross M. El ejercicio agudo aumenta las concentraciones de homocisteína en varones físicamente activos. *Nutr Hosp* 2013; Mar-Abr; 28(2):325-332.
29. Shi M, Wang X, Yamanaka T, Ogita F, Nakatani K, Takeuchi T. Effects of Anaerobic Exercise and Aerobic Exercise on Biomarkers of Oxidative Stress. Environ. *Health Prev Med* 2007; 12: 202-08.)
30. Pedersen BK, Steensberg A, Fischer C, Keller C, Ostrowski K, Schjerling P. Exercise and cytokines with particular focus on muscle-derived IL-6. *Exerc Immunol Rev* 2001; 7:18-31.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):245-254
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Resting energy expenditure; assessment methods and applications

Raquel Blasco Redondo

Specialist of Internal Medicine. Regional Medicine Sport Center of Castilla-León. Valladolid. School of Medicine. University of Valladolid. Spain.

Abstract

The energetic expense daily total of an individual (EEDT) represents the energy that the organism consumes. It is constituted by the sum of: metabolic basal rate (MBR), termogenesis endogenous (TE) and energetic expense linked to the physical activity (EEPA).

The determination of the EEDT considering the physical activity and the state of health of a person, it is very important to fit the calculation of the nutritional need for every individual.

The MBR is the minimal quantity of energy that an organism needs to be alive. It constitutes a from 60 to 70 % of the EEPA in the majority of the sedentary adults, while, in the physically very active individuals it is of approximately 50 %. It changes depending on the corporal composition, specially on the corporal lean mass.

The basal metabolism expressed as MRB, it is different from the metabolic rate in rest (MRR) or *Resting energy expenditure* (REE); the latter is obtained when the determination is done in rest and in the conditions described for the MRB but not in fasting, including therefore the energy used for the biological utilization of the food.

Habitually, the REE decides by means of different technologies as the indirect calorimetry, the electrical bioimpedancy, the doubly marked water, the predictive equations, between others. These methods are used in the clinical practice and in scientific studies. Nevertheless, due to the inconsistency of the results of these researches, still there is no a consensus with regard to his applicability though the evidence indicates that the measurement of the consumption of oxygen, it is the method of major precision.

***Aims:* This review has as aim expose the components of the energetic expense in rest, as well as the technologies for its determination and estimation, indicating its advantages, limitations and practical applications.**

***Results:* Part of the technologies of evaluation of the energetic expense described in this review, they remain relegated, for its complexity and cost to the area of the investigation. For a long time the indirect calorimetry, she remained also restricted to this field. Nevertheless, the technological advances have allowed the development of precise light and attainable equipments that allow that**

GASTO ENERGÉTICO EN REPOSO; MÉTODOS DE EVALUACIÓN Y APLICACIONES

Resumen

El gasto energético total diario de un individuo (GETD) representa la energía que el organismo consume. Está constituido por la suma de: tasa metabólica basal (TMB), termogénesis endógena (TE) y gasto energético ligado a la actividad física (GEAF).

La determinación del GETD considerando la actividad física y el estado de salud de una persona, es muy importante para ajustar el cálculo de la necesidad nutricional para cada individuo.

La TMB es la mínima cantidad de energía que un organismo requiere para estar vivo. Constituye del 60 al 70% del GETD en la mayoría de los adultos sedentarios, en tanto, en los individuos físicamente muy activos es de aproximadamente el 50%. Varía dependiendo de la composición corporal, especialmente de la masa corporal magra.

El metabolismo basal expresado como TMB, es diferente a la tasa metabólica en reposo (TMR) o Gasto Energético en Reposo (GER); este último se obtiene cuando la determinación se hace en reposo y en las condiciones descritas para la TMB *pero no en ayuno,* incluyendo por tanto la energía utilizada para el aprovechamiento biológico de los alimentos.

Habitualmente, el GER se determina por medio de diferentes técnicas como la calorimetría indirecta, la bioimpedancia eléctrica, el agua doblemente marcada, las ecuaciones predictivas, entre otras. Estos métodos son utilizados en la práctica clínica y en estudios científicos. Sin embargo, debido a la inconsistencia de los resultados de estas investigaciones, todavía no hay un consenso respecto a su aplicabilidad aunque la evidencia señala que la medición del consumo de oxígeno, es el método de mayor precisión.

***Objetivos:* Esta revisión tiene como objetivo exponer los componentes del gasto energético en reposo, así como las técnicas para su determinación y estimación, señalando sus ventajas, limitaciones y aplicaciones prácticas.**

***Resultados:* Parte de las técnicas de evaluación del gasto energético descritas en esta revisión, quedan relegadas, por su complejidad y coste al ámbito de la investigación. Durante mucho tiempo la calorimetría indirecta, quedó también restringida a este campo. Sin embargo, los avances tecnológicos han permitido el desarrollo de equipos precisos ligeros y asequibles que permiten que en la actualidad sea un**

Correspondence: Raquel Blasco Redondo.
Centro Regional de Medicina Deportiva
de la Junta de Castilla y León.
Avenida Real de Burgos s/n.
47071 Valladolid.
E-mail: raquelblasco92@hotmail.com

at present it should be a very useful method in the clinical space of the determination of the REE.

(*Nutr Hosp* 2015;31(Supl. 3):245-254)

DOI:10.3305/nh.2015.31.sup3.8772

Key words: *Resting energy expenditure. Methods. Equations. Indirect calorimetry. Applications.*

método muy útil en el espacio clínico de la determinación del GER.

(*Nutr Hosp* 2015;31(Supl. 3):245-254)

DOI:10.3305/nh.2015.31.sup3.8772

Palabras clave: *Gasto energético en reposo. Métodos. Ecuaciones. Calorimetría indirecta. Aplicaciones.*

Abbreviations

EEDT: Energetic Expense Daily Total.
REE: Resting Energy Expenditure.
MBR: Metabolic Basal Rate.
ET: Endogenous Thermogenesis.
TEF : Thermal Effect of the food.
EEPA: Energetic Expense linked to the physical activity.
MFF: Mass Free of Fat.
DEXA: Absorciometry of double radiological energy.
CTW: Corporal Total Water.
BIA: Impedance bioelectrica.
EE: Energetic Expense.
PA: Physical Activity.
PAL: Physical Activity Level.
RQ: Respiratory Quotient.
IC: Indirect calorimetry.
DC: Direct Calorimetry.
CF: Cardiac frequency.
VO2: Consumption of Oxygen.
PE: Predictive Equations.

Introduction

In all the aspects of the physiology the balance is looked, the homeostasis. In the field of the energy balance it could not be otherwise.

When we speak about the caloric balance assessment of an organism, this one answers to the dynamic balance between both ends of the following equation:

Energetic contribution =	Energetic expense Total Daily (EETD) +Energy Excreted +Energy stored as tissue

In this contribution we are going to speak about Energetic Expense in Rest, (EER) but before beginning we must define a series of terms:

The energetic expense daily total of an individual (EETD) represents the energy that the organism(organization) consumes; it is constituted by the sum of:

1. The metabolic basal rate (MBR) (that is the resultant one of the sum of the energetic expense of the dream (EE of the dream) and the energetic cost of the maintenance of the wake.
2. The endogenous termogenesis (ET) (that includes the thermal effect of the food (TEF).
3. And finally the energetic expense linked to the physical activity (EEPA) (sum of the physical spontaneous activity and of the physical voluntary not restricted activity)

Habitually, the energetic expense in rest (EER) decides by means of predictive equations, but the evidence indicates that the measurement of the consumption of oxygen, it is the method of major precision[1,2].

Another determinant of the EER, it is the corporal composition, specially the mass free of fat (MFF); different methods exist (BIA) determines, between them the densitometry, the absorciometry of double radiological energy - DEXA-, the tomography, the measurement of the corporal total water (CTW), the anthropometry and the impedance bioelectrical. The use of the latter has spread so it is not invasive, presents a rapid application, under cost, and safety. Nevertheless, in the practice, the method most used to determine the corporal composition, for its facility of application, under cost, and high precision is the anthropometry, which has been widely validated by others of major precision as the isotopic ones and the densitometrics.

Finally, the endogenous termogénesis (ET) represents near 10% of the EETD and the EEPA represents between 25-75% of the EETD (wide range depending on the physical activity of the individual).

Energetic expense in rest. Definition. Relation with EETD, ET and EEPA

Energetic Expense in Rest. Relation with the energetic expense daily total

Since already we have seen before, the energetic expense total daily (EETD), it includes) the energetic basal expense (EBE), also named metabolic basal rate (MBR), the EETD and ET.

The World Health Organization (WHO), defines the EETD as "the necessary level of energy to support the balance between the consumption and the energetic expense, when the individual presents weight, corporal composition and physical activity compatible with a good state of health, adjustments must be done for individuals by different physiological conditions as growth, gestation, lactation and aging"[3].

Energetic Expense in Rest. Relation with the metabolic basal rate

The EER is the minimal quantity of energy that an organism needs to be alive and to represent of 60-70% of the total of the energetic expense (EE), in the majority of the sedentary adults, (though along the exhibition we will clarifying these terms).

The EER represents, therefore the integration of the minimal activity of all the fabrics of the body in conditions of balance, expresses as production of heat or consumption of oxygen for unit of corporal size. (MET).

A MET is the energetic consumption of an individual in condition(state) of rest, which is equivalent approximately to 1 kcal for kg of weight and hour, that is to say, 4,184 kJ for kg of weight and hour[2].

Mitchell, defined the EER as the "minimal rate of energetic expense compatible with the life". He constitutes a from 60 to 70% of the daily EE in the majority of the sedentary adults, while, in the physically very active individuals it is of approximately 50%; it changes depending on the corporal composition, specially on the corporal lean mass[1,4].

Margus-Levy in 1899 introduced the termbasal metabolism and established that its measurement should carry out in the following conditions:

Patient hold totally rested before and during the measurements, put to bed, in state of wake, in fasting of 10-12 hours, in conditions controlled of temperature (22-26 C °), in absence of infection and free of emotional stress[5,6].

The basal metabolism expressed as MBR, it is different from the metabolic rate in rest (MRR) or from the EER; the latter is obtained when the determination is done in rest and in the conditions described for the MBR but not in fasting, including therefore the energy used for the biological utilization of the food.

Therefore the EER is the taken MBR NOT FASTING

These measurements, they differ in less than 10% and both terms are tended to use indistinctly, though at present there is in use more EER's name[7].

There exist several physiological characteristics that do that the EER changes from a few persons to others, principal it are the size, the corporal composition, the age, the sex and the production of hormones[8].

Energetic expense in Rest. Relation with the Endogenous Thermogenesis (ET) and the thermal effect of the food (TEF)

The energetic cost inherent in the aptitude to regulate the corporal temperature and to keep it stable in environmental unfavorable it represents, in general a small fraction of the energetic total expense. Nevertheless, joined it have to be considered to be also the thermogenesis produced during the processes of digestion, absorption, transport, metabolism and storage of the macronutrients.

The thermal effect of the food (TEF) refers to the increase of the energetic expense (EE) produced after the food consumption, and correspondsto the energy necessary for the digestion, absorption, transport, metabolism and storage of the macronutrients.

The intensity and the duration of TEF are determined by the quantity and composition of the emaciated food.

The increase in the EE changes of 5-10% for carbohydrates, 0-5% for fats, and of 20-30% for proteins. The consumption of a mixed diet produces an increase in the EE equivalent to 10% of the energy contained in the food[9].

Both components of TEF are the obligatory thermogenesis and the physician. The first one is modulated by factors as the activity of the nervous sympathetic system and the tolerance to the glucose; it represents both third parts of the thermal effect of the food.

The optional component TEF corresponds to the third part of and is related to the cephalic phases and postprandial of the (food); In fact has been suggested the need to distinguish between the effects in the short and long term of the (food), choosing the term of thermogenesis postprandial to refer at the hours following the food ingestion and reserving the term "thermogénesis induced by the (food)" only to designate the long-term component, which depends on the effect supported of the level ingestion above or below the energetic needs.

This optional component presents a major activity in some tissues as the skeletal muscle due to the activation of the nervous sympathetic system and of the recipients Beta adrenergic receptors, which stimulate the cellular metabolism[10,11].

III Energetic Expense in Rest. Relation with the EEPA

The Expense tied to the physical activity (EEPA) can subdivide in turn in:

- An energetic expense destined to support the physical spontaneous needs that it seems to be a notably family feature.
- An expense derived from the physical voluntary activity, determined principally by the intensity and the duration of the realized activity and by the own corporal weight of the individual.

In fact, this classification is in conformity with the realized one for The FAO-WHO-UNU (2001[12]) who consider two types of physical activity (PA): the obligatory activities related to the work, the study and the attention of the home and the discretionary activities referred to the physical regular activity, the recreation and the social interaction, considered important because they support the health, provide well-being and improve the quality of life.

The EEPA changes between 25 and 75% of the EEDT. The period of the life of major sudden decrease of the EEPA is between the adolescence and the young adult. During this stage, the total activity (minutes/week) and the time of recreative habitual activity (MET/ week) it diminishes strongly in men (31%) and in women (83%). The studies of EEPA and of EEDT during this period reflect important changes in the habits of life, demographic, social and biological, factors that can be associated with an increase of the risk of obesity and of comorbilities[13].

The EEPA is very variable between individuals and can change day after day. In sedentary persons, near two third parts of the EEDT they use in the basal metabolism, whereas only a third part becomes exhausted in EEPA. In very active individuals, the EEDT can rise up to the double of the MBR; the expense can be still major in some athletes and in whom they realize heavy duty.

The level of physical activity (PAL Physical Activity Level) is described as the proportion between the EEDT and the MBR and is used to determine the quantity and intensity of the habitual PA of an individual[13].

Until a few years ago the EEDT it was the expense most difficult to determine. At present, the utilization of stable isotopes allows to study the energetic daily expense in habitual living conditions and during long periods of time, from which and in combination with other methods, it is possible to deduce the compartment tied to the physical activity.

If they do not arrange of these analytical methods, there exist diverse tables that allow to estimate a value of energetic expense for different physical activities[12].

Energetic expense in Rest. Measurement. Conditions

The GER can be estimated or measured; the measurement is more precise than the estimation, always and when there are controlled the factors that can introduce modifications, since it are the energy induced by the (food), the consumption of alcohol, the use of nicotine, the PA, the environmental temperature, the position of the individual during the test and the time of measurement.

The recommendations established by the Dietitians' American Association to improve the precision of this measurement appear in the table I (taken of[14]).

Energetic expense in Rest. Technologies(skills) and methods of Measurement

The components of the EE, that is to say the basal metabolism and the expense that any PA needs, can decide for calorimetry, which can be direct or indirect[7]. Besides the calorimetry, other methods exist to determine the EER and the requirement of energy: the predictive equations, the impedance bioelectrical and the doubly marked water[1].

The following ones are the most used methods:

Direct Calorimetry

The EETD can decide for the measurement of the heat quantity produced by the organism. This procedu-

Table I

Criterion	*Healthy adults*
Fasting	Minimum from 4 to 5 hours(o'clock) after a ligth food, in whom a long fasting is not recomended
Ingestion of alcohol	Minimal Abstention of 2 hours
Use of nicotine	Minimal Abstention of 2 hours
Ingestion of caffeine	Minimal Abstention of 4 hours
Period of rest	10-20 minutes before the test
Restriction of physical activity	Abstention of aerobic moderate exercise or of anaerobic exercise minimal 2 hours before the test and of 14 hours, in persons who practise vigorous exercise of resistance
Environmental conditions	Temperature between 20 to 25°C, Comfortable conditions
Devices for the compilation	Rigorous adherence to anticipate leaks of the gases
State of balance (Steady-state)	To reject 5 initial minutes; then to reach a period of 5 minutes with conditions and intervals? 10% CV for the production of oxygen (VO_2) and of dioxide of carbon (VCO_2)
Number measurements/24 hours	The ideal thing is the condition(state) of balance reaches in a measurement, if it is not possible, 2 or 3 not consecutive measurements improve the precision
Variation in the repetition	3-5% in the realized ones in the first 24 hours and about 10% of measurement after weeks or months
Respiratory quotient (RQ)	RQ 0.7 o> 1.0 suggests breach of the protocol or imprecision in the gas measurement

re is realized in hermetic cameras by insulating walls, where it is confined in the subject and the stored heat is registered and lost by radiation, convection and evaporation; is needed a minimum of six hours to stabilize the system; the most known method is Atwater's camera, in which the produced heat is absorbed by the water that passes across this one and quantified by means of thermalsensors or thermometers that register the temperature at the entry and to the exit in a certain time.

Since it is possible to deduce, it is a method complex and difficult to realize in the practice, therefore its use has been of aims of research or to value indirect methods[7].

Indirect Calorimetry

Under the supposition of which the chemical energy of a substratum is obtained in the organism(organization) after its complete oxidation by the consequent consumption of oxygen and liberation of carbon dioxide and water, it is possible to estimate the quantity of total heat produced in the organism from the determination of the volume of both gases.

Nevertheless, though this supposition is true for the carbohydrates and the fats, it is not fulfilled for the proteins.

During the processes of multifaceted oxidation the nitrogenous fraction does not oxidize completely being eliminated partly in the shape of nitrogen ureico still energetically. Thinking that the nitrogen corresponds(fits) to 16% of a theoretical pool of proteins, is admitted that the urinary loss of 1 gr of nitrogen corresponds(fits) to the energy produced during the oxidation of 6,25 grs of protein.

Therefore, from the measures of the gases emaciated and liberated during the oxidatives processes , there can be estimated the energetic basal expense or of rest, in these terms these stocks the indirect calorimetry (IC).

The IC since it is a not invasive method that allows to estimate the production of energy equivalent to the MBR[15] and the rate of oxidation of the energetic substrata. The name of hint indicates that the metabolic expense decides by means of the caloric equivalents of the oxygen ($O_{2)}$ emaciated and of the carbon dioxide (CO_2) produced, whose quantities differ according to the energetic substratum that is being used.

The production of energy corresponds to the conversion of the chemical energy contained in the nutrients in chemical energy stored as ATP and, in the energy removed as heat, during the process of oxidation. If is admitted that the whole emaciated O2 is in use for oxidizing the energetic substrata (proteins, carbohydrates and lipids) and, that the whole produced CO2 eliminates for the breathing, is possible to calculate the total energy produced by the nutrients[1].

The IC is based on the principle of the gas exchange; the breathing in a calorimeter produces deplection of O_2 and accumulation of CO_2 in the air camera.

The quantity of O_2 consumed and of CO_2 produced it decides multiplying the frequency of ventilation, typically of 1 L/seg, by the change in the concentration of the gas. The EE is calculated using the consumption of O_2, production of CO_2.

The respiratory quotient is an important component in the determination of the IC and is defined as the relation that exists between (among) the production of CO_2 and consumption of O_2; it has a value of 1,0 for the oxidation of carbohydrates, of 0.81 for the protein and of 0.71 for the fat[16].

At present, there are commercialized two types of indirect calorimeters which difference takes root in the method of obtaining and storage of the breathed air: The based ones on systems of closed circuit and on systems of opened circuit.

IC in closed circuit

This method is specially adapted at present for the study of small animals, it is not useful in the human study, since in spite of not needing analyzers of oxygen not of carbon dioxide, it does not allow periods of monitoring superior to 20 minutes.

IC in opened circuit

This method consists of the air traffic of flow and composition known (O_2 14,978%, CO_2: 5,004% and N2 79,987%) and in the determination of the decline of oxygen and increase of CO_2 in the air exhaled by the patient. In this system the produced CO_2 is absorbed inside the system, and is added O_2 to keep the volume of the gas constant.

In spite of the high cost of the infrared systems and for magnetic necessary for the breathing of the exhaled gases and of the possible escapes that can take place during its withdrawal, the most used calorimeters are based on this system, since they offer a high precision and allow to realize it measured metabolic medium-term.

IC's different methods exist opened depending on the system of withdrawal of the exhaled air. Between them the stock exchange of Douglas, Oxilog, drafty bonnet, calorimeter of canopy and of entire body.

In the method with mask, the patient connects to a mouth mask, whereas in the method of camera of entire body, it needs a much more complex infrastructure.

There exist few studies that compare calorimetry with opened and closed circuit, nevertheless, there is mentioned that the closed circuit overestimates the EER[5].

I am interested in emphasizing here a series of limitations of the technology that must be considered in the estimation of the expense. Apart from the variability of the precision of the own systems of measure incorporated into the equipments, all the physiological

situations capable of altering in some sense the gaseous exchange of the organism, can alter the estimation of the metabolic expense. For example: changes in the balance acid - base, condition of hiper or hipoventilation, modifications in the pool of CO_2, owed to cutaneous losses (use of vasodilator) or even own reactions of the intermediary metabolism have to of be considering in the moment to evaluate the metabolic condition of the individual.

Impedance bioeléctrica (BIA)

It is a method that estimates the corporal compartments, included the quantity of liquid in the spaces intra and extracelulars. This technology is based on the resistance to the step of the alternating current. The lean fabric is highly conductive due to the great quantity of water and electrolytes that it contains, therefore it offers low resistance; on the contrary the fat, the skin(leather) and the bone are means of low conductivity and therefor of high resistance. At present it arranges of scales that have the equations incorporated in its software to determine the MBR[1,2].

Nevertheless the dispersion of the results is important.

Methods of NOT REST

In spite of the fact that we are talking about the measurement of the EER. Methods of evaluation exist of not rest that they us can turn out to be useful for it.

IC in corporal total camera

In that the individual can remain for days in conditions of semirest. This one is a theoretically very simple, but very specialized technology, needs a complex structure and the use of costly instruments of measurement. With everything, the great limitation takes root in that it presents an artificial environment and therefore, not comparablly with the conditions of free life.

Direct calorimetry CD

A crucial difference between this method and the CI camera is that in this case is needed to calculate all the heat that enters or goes out of the camera, which complicates methodologically the technology. It is potentially the most precise method, in strictly controlled conditions, which turns it into one of the methods of reference to validate other methods of measurement of the EETD and of the EER. Nevertheless, the enormous economic cost and the complex structure that it needs relegate it to the field of the (research).

Record of the cardiac frequency

This technology bases the fact that the cardiac frequency (CF) increases with the physical activity and that this increase relates narrowly with it consumption of oxygen inside a reasonable interval

The placement of a system of constant record of the CF, it would allow, at least theoretically, the estimation of the energetic expense from the consumption of oxygen, during periods habitual long of time, in which the individual might realize its activities.

For it, it is necessary to establish individually the straight line of existing regression between CF and VO_2 This first estimation would be done determining simultaneously the CF and the VO_2 by means of CI in rest and also during the accomplishment of exercises of variable intensity.

The basic problem is that the linear relation of both variables, gets lost with FC's low levels (in which there are in the habit of being the majority of the individuals who realize moderate activities) to this point where the linearity gets lost, it is named CFFlex.

For it, instead of predicting the average of the energetic expense from the average of the CF, there are preferred systems of CF's compilation minute to minute.

From here the EETD it is calculated supposing the EEB.

Water doubly marked

Administration oral route of a dose of water doubly marked with two stable isotopes deuterium and O_2 and posterior quantification for spectomethry of masses of the isotopic enrichment of any fluids (saliva, urin, dregs…) gathered in a time superior to seven days.

The Deuterium is distributed exclusively by the water, but Or by the water and the bicarbonates. The different elimination of both isotopes does not allow to find the elimination of the CO_2 and therefor to estimate the EETD. The precision is superior to that of IC in camera in 4%[17].

But the high cost and the difficulty in the interpretation of the results relegate it use, at the moment to the research.

Method of dilution of the bicarbonate

Similar to the previous one but across the previous infusion with marked bicarbonate. This method needs diverse suppositions and corrections, and provided that for the final determination it refers to the production of CO_2 and VO_2, it is necessary to consider the respiratory average quotient, similar to the previous technology.

JUDGING methods

Predictive equations. La determination of the need of energy is a basic component in the approach of the food due to the fact that the balance assessment between consumption and EE has important implications for the health. In the practice, it is common to use equations of reference to estimate the EEB and to apply the method factorial to determine the energetic daily requirement.

The predictive equations (PE) usually have been developed by healthy persons and are based on analysis of regression that includes weight, height, sex and age as independent variables and in the measurement of the EER for IC as variable dependent; for example, the equation of the FAO/WHO/UNU 1985 are in mind the sex, the groups of age and the weight. Other authors bear in mind the index of corporal mass (BMI)[18].

The principal PE that have been elaborated for the estimation of the EER are:

Equation of Harris and Benedict

The original publication dates back of 1919, the studies realized by these authors were based on BMI's measurements of 136 men and 103 women on the Laboratory of Carnegie's Nutrition on Boston; there were used statistical rigorous methods that gave like proved the following equations[19]:

Men EER =
66.4730 + 13.7516 x W + 5.0033 x T-6.7759 x A

Women EER =
665.0955 + 9.5634 x W + 1.8496 x T - 4.6756 x A

W = I weigh in Kg, **T** = it deals in cm, **A** = age in years.

Quenouille's Equation

Quenouille and cols in 1951fueron the first ones in elaborating a study with base in determinations of the TMB; the information of Quenouille there included persons who were living in the tropic and they orientated to examine the role of the ethnicity and of the climate on the TMB, nevertheless, the equation has not been very used.

This information was included later in the bases of information of Shofield and Oxford[20].

EER (Kcal/day) = 2.975 x T + 8.90 x W + 11.7 x CS + 3.0 h - 4.0 t + 293.8

T = height in centimeters, **W** = Weigh in kilograms, **CS** = DuBois's corporal surface, **h** = Dampness and **t** = temperature.

Shofield's Equations (FAO/WHO/UNU) 1985

The Experts' Committee of the FAO/WHO/UNU in 1985, developed a series of PE to estimate the energetic requirement with base in some premises: the energetic requirement must be based on the measurement of the GE and not on the ingestion; the organism has the aptitude to adapt to low unexploits and, the requirement refers to groups and not to individuals.

This Committee adopted the method factorial and proposed the application of multiple of the TMB; in the equations. They considered age, sex and corporal weight.

They were in use as base principally the information of Shofield's studies, nevertheless, these were presenting such limitations as: little information on breast-fed babies, teenagers and major adults; lack of information of persons from developing countries; few ethnic and geographical variability (there was included a disproportionate number of Italians, 47%) and it lowers incorporation of individuals of tropical regions[21].

PA's levels and the factors that were considered to calculate the EET were: Genre) and activity[21,22].

Genre	*Slight Activity*	*Moderate Activity*	*Heavy Activity*
Man	1.55	1.76	2.10
Woman	1.56	1.64	1.82

Equations of Oxford

Between 1980 and 2000, one group of experts selected studies of measurement of the GE that included the following aspects:

Age, weight and genre; description of the experimental conditions and of the equipment used for the measurement of the MBR; measurements in healthy subjects, in condition postabsortion and without previous PA and, description of the etnia and of the geographical location. From the database they were excluded to all the Italian subjects of Shofield's studies and there was included information of inhabitants of the tropics. From these variables there was generated a database called of Oxford, which bore in mind 10552 MBR's values.

With the equations developed (Table II) the values of the TMB, in major of 18 years they were lower than the obtained ones with the equations of the FAO/WHO/UNU of 1985[5].

The comparison between the equations of Oxford bearing the corporal weight in mind and those of the FAO/WHO/UNU 1985 for MBR's estimation shows itself in the table III.

FAO/WHO/UNU's Equations (2001)

They developed from Shofield's database used in the estimation of the MRB (1985); they were conside-

Table II
Equations of Oxford to estimate Metabolic Basal Rate (MBR) according to age and with incorporation of variables of weight and height

Gender	*Age / years*	*MBR (Kcal/day)*
Men	10-18	15.6 x W + 266 x T + 299
	18-30	14.4 x W + 313 x T + 113
	30-60	11.4 x W + 541 x T – 137
	> 60	11.4 x W+ 541 x T – 256
Women	10-18	9.40 x W + 249 x T + 462
	18-30	10.4 x W + 615 x T – 282
	30-60	8.18 x W + 502 x T- 11.6

red to be three AF's levels and it was chosen for ranges for every category; in addition, there was adopted the term(end) of way of life more than that of labor occupation to define PA's level[23,24]:

Sedentary or way of life with slight activity:	1.40-1.69
Active or way of life moderately active:	1.70-1.79
Vigorous or vigorously active way of life:	2.0-2.4

Historically, the nutritionists dietitians have used the PE to estimate the EER, but the studies of validation have thought that these equations can overestimate or underestimate the energetic requirement; in some, the reported mistake is 20% and in others, the imprecision is of the order of 200 Kcal, which though it weighs anchor, is important, since it can promote the profit of weight in adults

Cunningham's Equation

In which (whom) the variable that is used is the weight of the free mass of fat (before obtained by someone of the methods of measurement of the corporal composition preferably for Kineantropometry):

Metabolic basal expense (kcal/día) = free Mass of fat (grs) x 21,6+370

The equation of Harris and Benedict is the the most ancient and most used; the studies suggest that this equation overestimates the MBR between 10 and 15%, specially in persons of low weight;

That of the FAO/WHO/UNU, validated by Muller (2004) also it overestimates the BMR in some communities.

Schofield's equation and that of the FAO/WHO/UNU does not bear the height in mind because they think that it does not contribute to the estimation of the EER in healthy individuals (less than 0.1% of the value of the pre-established EER), is based only on the weight. Nevertheless, the Institute of Medicine of the United States affirms that the incorporation of this variable can reduce slightly the mistake of prediction[18].

Nowadays, it thinks that the climate is a determining variable, because it can influence the BMR; the persons who live in hot climate tend to have a BMR lower than those who live in cold climate, still(yet) after fitting for size and corporal composition; therefore, it is possible that the climate change and the migrations other geographical zones concern, at least partially, the BMR

Clinical and practical application

Report of the technologies of evaluation of the energetic expense described previously, they remain relegated, by its complexity and cost to the area of the research. For a long time the indirect calorimetry, she remained also restricted to this field, whereas in the clinic there were preferred equations of prediction based on simple measurements as the weight and the height.

Nevertheless, the technological advances have allowed the development of precise light and attainable equipments that they have been finding it to go well together in the clinical space

Table III
Comparison between(among) the equations of Oxford and those of the FAO/WHO/UNU 1985 for estimation of MBR W: Weigh in kg. Source [5]: Henry CJK. Basal metabolic rate studies in humans: measurement and development of new equations Public Health Nutrition 2005; 8 (7A): 1133-1152

Gender	*Age / years*	*Oxford MRB (Kcal /día)*	*FAO/WHO/UNU 1985 MRB (Kcal/day)*
Men	10-18	18.4 x W + 581	17.686 x W + 658.2
	18-30	16.0 x W + 545	15.057 x W + 692.2
	30-60	14.2 x W + 593	11.472 x W + 873.1
	> 60	13.5 x W + 514	11.711 x W + 587.7
Mujeres	10-18	11.1 x W + 761	13.384 x W + 692.6
	18-30	13.1 x W + 558	14.818 x W + 486.6
	30-60	9.74 x W + 694	8.126 x W + 845.6

The indirect calorimetry has an undeniable practical interest in the study of numerous clinical situations as the obesity, the malnutrición, traumatism, sepsis, renal and hepatic failure, cancer, multiorganic failure, serious infections as the HIV, the calculation of energetic requirements of critical patients and, in the field that occupies me, of persons with an intense physical wear and athletes of different sports modalities

Summary

Report of the technologies of evaluation of the energetic expense described in this review, they remain relegated, for its complexity and cost to the area of the research. For a long time the indirect calorimetry, she remained also restricted to this field. Nevertheless, the technological advances have allowed the development of precise light and attainable equipments that allow that at present it should be a very useful method in the clinical space of the determination of the GER, in wide groups of population, it recovers, with different types of pathology and also submitted to an intense physical wear as the athletes of different sports modalities

References

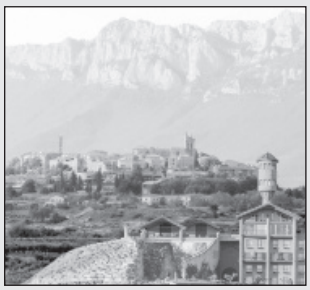
1. Esteves de Oliveira FC, de Mello Cruz AC, GonçalvesOliveira C, Rodrigues Ferreira Cruz AC, Mayumi Nakajima V, Bressan J. Gasto energético de adultos brasileños saludables: una comparación de métodos. *Nutr Hosp* 2008; 23:554-61.
2. Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, et al. Compendium of physical activities: energy costs of human movement. *Med Sci Sports Exerc* 1993;25:71-80.
3. World Health Organization (WHO). Obesity: preventing and managing the global epidemic. Geneva: World Health Organization. 1998.
4. Levine JA. Measurement of energy expediture. *Public Health Nutr* 2005; 8:1123-32.
5. Henry CJK. Basal metabolic rate studies in humans: measurement and development of new equations. *Public Health Nutr* 2005; 8:1133-52.
6. Aleman-Mateo H, Salazar G, Hernández-Triana M, Valencia ME. Total energy expenditure, resting metabolic rate and physical activity level in free-living rural elderly men and women from Cuba, Chile and Mexico. *Eur J Clin Nutr* 2006; 60:1258-65.
7. Mataix J, Martínez JA. Balance de energía corporal. En: Nutrición y alimentación humana. Mataix J Ed. Oceano/Ergon. Barcelona. 2006:703-22.
8. Mahan LK, Escott-Stump S. Dietoterapia de Krause.Edit. Elsevier Masson. 12 a. ed. Barcelona 2009: 22-37.
9. *Eur J of Clin Nutr* 2006; 60:538-44. Food and Nutrition Board. Institute of Medicine. Dietary Reference Intakes for Energy, Carbohidrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids (Macronutrients). Washington: National Academy Press; 2005. (Reporte en Internet) (Consultado en Octubre 2010). Disponible en: http://www.nap.edu/catalog/10490.htlm
10. Stob NR, Bell C,Baak MA, Seal DR. Thermic effect of food and -adrenergic thermogenic responsiveness in habitually exercising and sedentary healthy adult humans. *J Appl Physiol* 2007; 103:616-22.
11. Watanabe T, Nomura M, Nakayasu K, Kawano T, Ito S, Nakaya Y. Relations between thermic effect of food, insulin resistance and autonomic nervous activity. *J Med Invest* 2006;53:153-58.
12. FAO/WHO/UNU Energy and proteins requeriments. WHO Tech. Rep. Ser 724. Gèneve: World Health organization. 1985
13. Wickel EE, Eisenmann JC. Within- and betwennindividual variability in estimated energy expenditure and habitual physical activity among young adults. *Eur J of Clin Nutr* 2006;60:538-44.
14. Compher C, Frankenfield D, Keim N, Roth-Yousey L. Best Practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. *Am J Diet Assoc* 2006;106:881-903.
15. Lawrence C, Ugrasbul F Prediction of daily energy expenditure during a feeding trial using measurements of resting energy expenditure, fat-free mass, or Harris-Benedict equations. *Am J Clin Nutr* 2004; 80:876-80.
16. Patiño JF Determinación del gasto energético en el paciente quirúrgico. En: Metabolismo Nutrición y Schock. Ed Panamericana. Bogotá. 2006:181-93.
17. Ravussin E, Rising R Daily Energy expenditure in humans: Measurements in a respiratory chamber and by doubly labelled water. En: Kinney JM, Tucker HN eds Energy metabolism: Tissue determinants and cellular corollaries. NY Raven Press, 1992; 81-96.
18. Weijs PJM, Kruizenga HM, Dijk AE, Meij BS, Langius JAE, Knol DL, Strack RJM et al. Validation of predictive equations for resting energy expediture in adult outpatients and inpatients. *Clin Nutr* 2008; 27:150-57.
19. Harris JA, Benedict FG. A Biometric Study of the Basal Metabolism in Man. Washington, DC: Carnegie Institution of Washington; 1919. Publication No. 279.
20. Melzer K, Karsegard VL, Genton L, Kossovsky MP, Kayser B, Pichard C. Comparison of equations for estimating resting metabolic rate in healthy subjects over 70 years of age. *Clin Nutr* 2007; 26:498-505.
21. Lorenzo DA, Tagliabue A, Andreoli A, Testolin G, Comelli M, Deurenberg P. Measured and predicted resting metabolic rate in Italian males and females, aged 18 ± 59 y. *European Journal of Clinical Nutrition* 2001; 55: 208-214.
22. Ferro-Luzzi A. The conceptual framework for estimating food energy Requirement. *Public Health Nutrition* 2005; 8:940-52.
23. FAO/WHO/UNU. Energy and protein requirements.1985. 220 p.
24. FAO/WHO/UNU. Human energy requirements. 2005. 96 p.

FOOD SECURITY AND ADDITIONAL ISSUES IN NUTRITION STUDIES

SEGURIDAD ALIMENTARIA Y ASPECTOS COMPLEMENTARIOS EN LOS ESTUDIOS NUTRICIONALES

"Consensus Meeting on the Methodology of Dietary Surveys, Classification of Physical Activity and Healthy Lifestyles"

"Reunión de Consenso sobre la Metodología de las Encuestas Alimentarias, Tipificación de la Actividad Física y Estilos de Vida Saludables"



Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):257-264
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Methodology for the estimation of use of tobacco, alcohol and other drugs

Susana Belmonte Cortés, Carmen Serrano Zarceño and Susana Granado de la Orden

Subdirección General de Promoción de la Salud y Prevención. Dirección General de Atención Primaria. Consejería de Sanidad de la Comunidad de Madrid. Spain.

Abstract

The objective of this article is to revise the methods used for the assessment of the use of tobacco, alcohol and other drugs. Analysing the advantages of using one method or the other, as well as the most frequent methodological difficulties and problems in medication and classification of each one of these indicators.

The main sources of information available from European, National and Madrid Autonomous Community levels have been consulted to estimate the most relevant aspects of these forms of substance abuse.

(*Nutr Hosp* 2015;31(Supl. 3):257-264)

DOI:10.3305/nh.2015.31.sup3.8773

Key words: *Alcohol drinking. Tobacco use. Substance abuse. Questionnaire.*

METODOLOGÍA PARA LA ESTIMACIÓN DEL CONSUMO DE TABACO, ALCOHOL Y OTRAS DROGAS

Resumen

El objetivo de este trabajo es revisar los métodos utilizados para la estimación del consumo de tabaco, alcohol y otras drogas. Analizar las ventajas de utilizar unos u otros métodos, así como las dificultades y problemas metodológicos más frecuentes en la medición y clasificación de cada uno de estos indicadores.

Se recogen las principales fuentes de información disponibles a nivel Europeo, Nacional y en la Comunidad de Madrid para estimar los aspectos más relevantes del consumo de este tipo de sustancias.

(*Nutr Hosp* 2015;31(Supl. 3):257-264)

DOI:10.3305/nh.2015.31.sup3.8773

Palabras clave: *Consumo de alcohol. Consumo de tabaco. Uso de drogas. Cuestionarios.*

Abreviaturas

SIVFRENT: Surveillance System for Non-transmissible Diseases Risk Factors.

FAO: United Nation Food and Agriculture Organization.

WHO: World Health Organisation.

NIS: National Institute of Statistics.

Q/F: Quantity Frequency Indexes.

EESE: European Survey of Health in Spain.

DGSANCO: Directorate General of Health and Consumer Protection of the European Commission.

NHS: National Health Survey.

EDADES: Household survey on alcohol and drugs in Spain.

ESTUDES: State survey on the use of drugs by students in secondary school.

ESO: Obligatory Secondary education.

Correspondence: Susana Belmonte Cortés.
Subdirección General de Promoción de la Salud y Prevención.
Dirección General de Atención Primaria.
Consejería de Sanidad de la Comunidad de Madrid. Spain.
E-mail: susana.belmonte@salud.madrid.org

Introducción

One of the crucial elements for planning and adopting Public Health measures is having precise information available about the health status of the population and about the indicators of greatest influence regarding this status.

To obtain this information it is possible to have recourse to different sources. Some of these, statistics found in registers that while being comprehensive, do not cover all of the aspects of health and cannot be linked in many cases with sociodemographic variables nor with other health status determinants.

At the European level, a Health Survey is currently used to gather this information. Nonetheless, no uniformity exists in the manner of conducting these surveys and this leads to difficulties in comparing data from the different countries within our sphere which in turn creates difficulties in providing indicators for the planning of common European Union policies[1,2].

As well as relying on different, relatively isolated studies, Spain has at its disposal some national population-based surveys which are systematically applied and conducted over periods of time which allow approaches to situational knowledge. However, each one presents its own characteristics that condition the validity of the data obtained, availability and an interpretation of the results.

Since 1995 the Madrid Region has had the Surveillance System for Non-transmissible Diseases Risk Factors (SIVFRENT) at its disposal as a tool for monitoring the distribution and the evolution of risk factors related to behaviour and preventive practice. This information serves to elaborate public health intervention policies and to evaluate their impact on the population[3,4].

Differences and similarities exist between the three types of substances: alcohol, tobacco and other drugs. As will be shown later, in the case of the legal substances like alcohol and tobacco, production records are available through which, in spite of methodological limitations which will be commented on in each section, an indicator of per cápita use can be obtained. This is not the case with illegal drugs in which these types of records are unavailable.

Tobacco and alcohol use indicators

Health interventions must be based in reality. To monitor conducts which have a strong influence on health (such as diet, tobacco use, alcohol and other drugs) it is necessary to use systematic information sources which provide valid data[1].

Smoking is one of the main public health problems in developed nations and is the main cause of avoidable premature death. Tobacco use not only damages those who consume it but also those exposed to tobacco smoke. For this reason it is interesting not only to know the frequency of tobacco use but also exposure to the smoke itself[5].

The estimation of tobacco use in the population can be achieved by utilizing *per cápita* indicators or indicators obtained through surveys.

With regard to the use of alcoholic beverages we find that it is currently one of the main factors related to individual and public health status. From a public health perspective, having an estimate of quantities of use levels available and their distribution between different population level trends, is one of the main tasks towards planning different intervention strategies[6,7,8].

Indicators related to alcohol use in the population can be classified as direct or indirect. In the first group, those in which the quantity and frequency of use within the study population are directly measured are included, regardless of method[6,9].

On the other hand, indirect indicators are all those directed towards estimating aspects related to, in greater or lesser degree, with alcohol use, but which in no case are aimed at observing the quantity/frequency of alcohol use by the study population. Some examples of these types of indirect indicators are: alcoholic beverage production, indicators of the impact of alcohol related problems such as fatalities attributed to use, hospital admissions and death by suicide or homicide[6].

Per cápita use

Tobacco

An estimation of per cápita tobacco use when tax and sales statistics are exact can reflect how a society consumes tobacco[10].

Data on sales of cigarette packs can be obtained from the Tobacco Market Commission[11] and data on the Spanish population ages 15 to 16 from the National Institute of Statistics. In this way the number of cigarettes consumed by person and day can be estimated[12].

At the international level the population aged 15 or older is used as a denominator because it is assumed that minors below this age consume little of the available tobacco.

This indicator can show trends over time, that is to say, increases and decreases in global rates of use. However, it provides no information regarding consumer habits of different population groups. In this way, the indicator can remain stable if, for example, the number of male consumers decreases proportionally to an increase in the number of female consumers. It could also show a decreasing trend in spite of the fact that the index of adolescent smokers shows a significant increase[10] (Table I).

A limitation of per cápita tobacco use is that it does not include illegal sales, for example, sales to tourists or tobacco smuggling. However it is a less costly method than surveys being that it is updated routinely with available statistics.

Alcohol

With regards to alcohol, annual (*per cápita*) use per person is a very direct population indicator for comparing geographical and/or temporal differences in morbidity and mortality, performing international comparisons, studying temporal series or carrying out ecological studies, thereby allowing for an approximation of its magnitude and evolution[6, 7, 9, 13,14].

Sufficient epidemiological evidence exists to affirm that this indicator is strongly related to the distribution of alcoholic beverages throughout the population and spe-

Table I
Advantages and inconveniences in estimating per cápita use of tobacco and alcohol

Advantages	*Inconveniences*
Less costly	Does not measure: Illegal trade and home-made production Tourist consumption Smuggling
Indicator of use at a national level.	
Shows trends	
	Does not identify risk groups Problems related to excessive use Does not identify use patterns

cifically with the proportion of heavy drinkers that exist within it as well as with the frequency of problems related to alcohol. For this reason, the monitoring of global per cápita alcohol use trends over time is a useful tool for finding out the proportion of high-risk drinkers within the population[6, 9,13].

Per cápita use calculation is based on information about production, importation, exportation and sales of alcoholic beverages made available from governmental statistics (taxes or fees), alcoholic beverage production data and estimates from the United Nation Food and Agriculture Organization (FAO) [7].

It is expressed in litres of pure ethanol (overall or broken down by beverage type) assigning a standard alcoholic content for each type. Generally an estimation is performed on 3 groups of beverages: beer, wine and spirits, assuming average alcohol content. A fourth group of high grade wines can be added. Once the volumes of pure alcohol consumed have been obtained, the average quantity consumed during the year by each individual is calculated. This exact estimate takes the denominator of the legal drinking age population into consideration, eliminating the fraction of non- drinkers[6,7].

However for international comparisons the 15 year or older population is usually used as a denominator taking into account data limitations.

Per cápita alcohol use is an indicator with many advantages, although there are also limitations (Table I). Regarding the advantages, it costs less with respect to survey methods, being that it is based on information regularly collected from many countries with a similar methodology, and therefore, it is used as an indicator of alcohol use at a national level[6].

The inconveniences of this indicator can be classified in two categories: what they do not measure and what they cannot measure. Regarding the first, per cápita alcohol use estimates are generally derived from sales, manufacturing, commerce information and alcoholic beverage taxes. As such, neither illegal nor home-made alcohol production nor tourist use or alcohol smuggling are taken into account.

As for the second category, this type of indicator assumes that all of the alcohol available is consumed by the target population in the period of time being studied (usually a year). Therefore it does not allow for the identification of high risk groups in the population, problems related to excessive use nor does it identify population use patterns[6, 7,13].

At the international level, the World Health Organisation (WHO) annually publishes the per cápita use of multiple countries. In Spain, other sources of information are available such as the Food Use Panel which has published data on alcoholic beverage purchases in probability samples of households, eating establishments and institutions (quantity, price and expense).The National Institute of Statistics (NIS) annually performs the Family Budget Survey ,which includes information about alcoholic beverages consumed in households (litres and cost), and the Industrial Product Survey on national production of alcoholic beverages. All of these measure total litres of beverages that must be converted to pure ethanol to estimate per cápita use[15, 16,17].

Population health surveys

Tobacco

Questionnaires are the most commonly used method for monitoring the prevalence of tobacco use and the number of cigarettes smoked by the general population.

To study the consequences of the tobacco habit, it can be useful to understand its utilization. For this reason, the questionnaire must include questions which collect information about the different ways in which tobacco is consumed (cigarettes, cigars, pipe tobacco, roll tobacco).

In the identification of tobacco use patterns, the most common indicators are the frequency and the quantity consumed. The World Health Organization (1998)[10] proposes the following categories of tobacco use patterns: *non-smokers, ex-smokers and current smokers*, in agreement with the following definitions shown in figure 1.

What is more, when low incidence populations or group populations are studied it is advisable to separate smokers that are in an experimental stage, that is to say, those who have still not smoked more than 100 cigarettes.

It is also important to know the number of cigarettes that are being smoked or were smoked in the past and the exposure time to tobacco. What is more, the additional category of the passive smoker, those individuals exposed to tobacco smoke in their environment, must be taken into account. All of these factors allow for the evaluation of health risk problems[10].

Although questionnaires are commonly used and present relative validity they are not free of problems such as an incorrect statement (deliberate or not) on the part of the person being interviewed and the following mistaken cigarrettes use classification. Moreover, the low social tolerance towards non healthy habits like tobacco use, is a possible factor of under reporting in health surveys.

Some surveys show a certain variation in the use of cigarettes smoked according to health surveys and that shown by data on tobacco sales, which shows an under- reporting of the number of cigarettes smoked given in health surveys in comparison with official sales figures[12].

Alcohol

It is internationally admitted that the best way of approaching an understanding of alcoholic beverage

Nonsmokers	People who have never smoked
Ex-smokers	
Occasional	People that smoked more than 100 cigarettes in the past but not on a daily basis
Daily	People that smoked more than 100 in the past during their lifetime and on a daily basis
Occasional smokers	
Reduced smokers	People that smoked on a daily basis but do not now
Experimental	Smokers that have smoked more than 100 cigarettes during their lifetime and currently smoke occasionally
Continual smokers	People that never smoked on a daily basis, that have smoked at least 100 cigarettes during their lifetime and currently smoke occasionally
Daily smoker	People that smoke everyday

Fuente: Medina-More, 2003

Fig. 1.—Tobacco use patterns.

use and its determining factors in the population are through surveys. These provide disaggregated information on alcohol use in a sample population, factoring indicators such as starting age, frequency of alcohol use, proportion between drinkers and non-drinkers, average use or alcohol intake patterns[7, 9].

Surveys allow for the detection of risk population groups and establish more solid associations between drink patterns, social-demographic factors and effects on health. Carried out periodically, they are also useful for planning and evaluating the effectiveness of implemented health policies[7].

Survey methods have advantages and inconveniences. Amongst the advantages of surveys are the fact that they indicate who drinkers are. Intake data per cápita does not report the number of people that completely abstain from alcohol, and therefore does not distinguish between changes resulting from increases or decreases in the proportion of abstainers from those that reflect varying volumes of use in drinkers (Table II).

A second advantage of survey data is that it allows for the comparison of use amongst diverse sub populations of interest. Moreover, a survey, being that it is conducted by an individual, gathers information of a social-demographic character that's use can be of great assistance in the detection of high risk groups or groups of special interest for intervention thus serving as an instrument of great utility for planning and evaluating sanitary policies[6,13].

A third advantage of survey data is that it allows for the exploration of multiple aspects related to alcohol use, describing not only drinking habits (frequency and quantity of use, place of use, beverage type) but also attitudes and knowledge about alcohol and its consequences or problems related to excessive use. A person that has one drink a day has the same ingested volume as one who drinks seven in a row once a week; however the consequences of these two drinking models can be very different[6,13].

Moreover, surveys carried out on a regular basis can be an extraordinarily useful instruments for the supervision and monitoring of alcohol use in the population.

Among the inconveniences are found limitations related fundamentally with methodology.

In the first place the difficulty exists of selecting population samples that are representative of the general population from the existing sample. Another problem is that of defining the minimum age within the target population in which alcohol use is going to be studied, being that the legal age limit for alcohol sales could be a reference being that use among the young is ever more frequent[6].

A second methodological difficulty is the choice of a good measuring tool that is sufficiently precise enough for estimating alcohol intake. Indicators for characterising types of use are equally necessary and therefore it is important to establish consensual definitions for classifying these different forms[7, 18].

Another difficulty in surveys are the important resources needed for their execution. To this can be added the problem of the studying a habit that is very rooted socially but that has important negative connotations that make obtaining valid information on alcohol use, frequently underestimated, even more complex[6,7,18].

In surveys for determining alcohol use, there exist two strong methods for collecting information by individual self-declaration: asking about characteristics of habitual use or asking that the respondent report daily use during a recent period of time.

With regards to the first method, two questions must be asked to the respondent: *How frequently do you consume alcoholic beverages?* and *What is the quantity*

Table II
Advantages and inconveniences in population surveys for estimating alcohol use

Advantages	*Inconveniences*
Identifies alcohol consumers Allows for comparisons between population subgroups Detects high risk groups Useful in planning and evaluation Health policies Describes habits, attitudes y knowledge Instrument of surveillance and monitoring	Methodological difficulties: simple selection, choice of measuring tool and indicators Needs important resources for implementation

you usually consume? This data, when properly dealt with, provides an average of the volume of alcohol habitually consumed[6,9].

This type of measurement tool, denominated Quantity Frequency Indexes (Q/F) give information on the two dimensions of use. Frequency and quantity, it being necessary to bear in mind both when studying use patterns Q/F indexes serve as a global measurement of individual use. Their use is limited to those situations in which very limited space is available in a national survey on more general topics[6,13].

Another mode of questioning called the graduated frequency and quantity questionnaire exists. In this case, subjects are asked about the frequency with which they consume specific quantities of alcoholic beverages in a single day, beginning generally with larger quantities and reducing to lesser quantities to encourage complete information. This is an efficient method regarding costs and the greater part of the essential information can be retrieved with 8 questions.

With the second method of self-declared alcohol use (daily use over a period of time) the respondents must state on a daily basis their use over a specific and concrete period of time, showing the quantity of alcoholic beverages consumed on each one of the last days[6,9 ,13].

A quite generalised opinion exists that the measurement of alcohol use via surveys produces an underestimation of levels of use, although other studies detect the opposite phenomenon. Some reasons given to explain said underestimation have been a certain under representation of heavy drinkers in the samples studied, being that marginalised and institutionalised populations are generally excluded, or an over representation of drinkers in households, where use seems to be less likely to be remembered than that done in other places. Other commonly referred to reasons have been the well-known memory lapse and a certain deliberate underestimation[6].

With regards to the ingested alcohol measurement unit, volumes ingested by the individual are usually measured by "drinks" being that this unit of measurement is easier to understand amongst consumers. To this end, investigators should define "drink" for the different beverage types, based on the quantity of grams of alcohol that they contain[9].

The diverse typology and presentation of drinks that contain alcohol and the irregularity of consumer patterns over time, demand the use of very extensive questionnaires to estimate weekly ingestment, even more so during adolescence. The truth is that no common methodology is available that assures that the measurement of ingestion are comparable and sufficiently valid, a problem repeatedly pointed out by different authors that invoke the necessity of better standardization for measuring alcohol use[1].

Types of interviews

With regards to the ways in which information is collected, the most common are telephone interviews, personal interviews and self-administered questionnaire

The advantage of using self-administrated questionnaires is that information about aspects which people may feel embarrassed to tell an interviewer is obtained. The disadvantage is that it is necessary to have a high level of education. One option that seems quite interesting is a combination between them all, where the interviews have self-administered sections for the most conflictive parts[9].

When it comes to the interview modal, this can be carried out face to face or by telephone. The telephone interview is an option only in those countries in which practically every household has a telephone. In those cases, the cost of a telephone interview is substantially lower than those of personal interviews[4,13].

At times a self-administered section is included in a personal interview so that the interviewer can collect information that the respondent possible would find uncomfortable giving verbally. This option requires a relatively high level of literacy in all of the population sectors included in the survey sample. However it appears that confidential questionnaires provide more extensive information on alcoholic behavior than personal interviews[13].

The use of telephone surveys has increased notably in the last few decades owing, above all, to the good price-efficiency ratio and the possibility of quickly having collected information available.

Different studies have compared telephone interviews with those performed face to face and, in general, the results have shown very similar estimations, with a tendency towards a reduction in differences between both methods in the most recent work.

In a study conducted in the Madrid Region, it was shown that the prevalence of diverse health risk factors related to behavior and preventative practices is similar when the data is obtained by home telephone interview as well as in household face to face interviews**.** However the reduction in the economic cost, as well as the greater flexibility in speed of execution, made this first methodology an efficient technique for utilization in monitoring systems in geographic areas with high telephone coverage, obtaining as well, a good questionnaire reproducibility, with consistently high estimations in the prevalence of groups when repeatedly applied to the same individuals, and also describe a good individual conformity. These results agree with those observed in other studies, which also utilize continual survey methods based on telephone methodology as a source of information in monitoring systems based on these factors[3,4].

Indicatores of use of other drugs

Surveys are the best way of estimating illegal drug use.

In the case of some substances used prevalently by adolescents ,such as cannabis, it is necessary to have indicators available which permit the differentiation of use levels which show greater risk or reflect the existence of a disorder (such as harmful use, abuse or dependency)[1].

In the case of other drugs, the low prevalence that are generally observed in population studies require a search for more significant indicators, this being the case of the indicator: *number of times the drug has been used*. Through the use of this indicator, it is possible to distinguish experimental users (those that have only tried the drug 1 to 5 times without continuing use upon having experienced the effects), regular users (those that have used the drug more than 5 times) and heavy users (those that have used each substance on more than 50 occasions)[10].

Some available sources of information

Some of the sources of available information for the three types of substances (alcohol, tobacco and other drugs) at the European level, Spanish level and Madrid Region level will be set out below, as well as methodological criteria that is used.

At european levels

European Survey of Health in Spain (EESE)

This survey is promoted by the Directorate General of Health and Consumer Protection of the European Commission (DGSANCO) and coordinated by the European Statistics Office (Eurostat). The first edition took place in 2009 and since then take places every five years. It is carried out in 18 EU countries using a common European questionnaire about 16 year olds. Its main objective is to obtain data about health status, lifestyles and the use of health services in a harmonic fashion which is comparable at a European level. This information permits planning and evaluation of European and national performance in health matters[2, 7].

The questionnaire consists of five modules. In one of them, a self-administered part is included in which the respondent report their tobacco, alcohol and drug use habits.

At Spanish levels

In Spain, the Ministry of Health periodically carries out diverse population studies. One of these is the National Health Survey (NHS) which has been conducted since 1987 and takes place with irregular frequency in the 15 year and older population. The Government Delegation for the National Plan on Drugs carries out the Home Survey on Drugs and Alcohol in Spain on the population between the ages of 15 and 64 and the State Survey on Drug Use in Secondary Education on the population between 14 and 18 years of age. Both are published have been biannually since 1997 and 1994 respectively, allowing for an assessment of the evolution of alcohol use[19, 20, 21].

National Health Survey (NHS)

The National Health Survey is an investigation directed towards the general population of 15 and older which allows us to obtain information about the health status of the Spanish population, and compare morbidity life styles and the use of health services with each other and with certain socio demographic and geographic characteristics[19].

Information collected through personal interviews made to adults (individuals 16 and over) through interviews with the mother, father or tutor in the case of children (individuals from 0 to 15 years old)

Questions that are related to the smoking habit and alcohol use are placed in the section about habits and lifestyles but only in the questionnaire directed to the adult population sample (population 16 and older) and do not appear in the child sample (population 0-15 years). The method of collection is a personal interview via computer.

Household survey on alcohol and drugs in Spain (EDADES)

This survey is directed towards the general population ages 15-64. The questionnaire is conducted in the

person's household. The first part is given in a face to face interview and a second part dealing with questions about drug use are self-completed by the respondent with the object of facilitating the confidentiality of the answers. The questions lead to a better understanding of drug availability, the inherent risk of different forms of use, ways of obtaining drugs, preferred and utilized information to do so, as well popular opinion about the importance of the drug problem and ways of reducing it[20].

State survey on the use of drugs by students in secondary school (ESTUDES)

This survey is directed to students between the ages of 14 and 18 with the objective of knowing the situation and trends of drug use, patterns of usage, associated factors and the opinions and attitudes of this population group towards drugs.

Self-completed questionnaires are used and the confidentiality of the respondents is guaranteed[21].

AT Madrid Region level

The Surveillance System for Non-transmissible Diseases Risk Factors (SIVFRENT) was put into practice in 1995 for adults in (SIVFRENT-A) and in 1996 for young people (SIVFRENT-J) [22, 23].

With this system an attempt is made to learn about the distribution and the evolution of risk factors related to behavior and preventive practices. Information serves to elaborate public health intervention policies and evaluate their impact on the population.

Sivfrent A

Results are based on a telephone survey conducted annually to a sample of 2000 people from ages 18 to 64 residing in the Madrid Region. The questionnaire consists of a central core questions that remain the same over a period of time so as to be able to make comparisons, grouped together in the following sections: physical activity, nourishment, anthropometry, tobacco use, alcohol use, prevention practices, road safety and accident rates (Table III).

Sivfrent J

This is directed to the young population between the ages of 15 and 16 and measures the prevalence, distribution and characteristics of the major risk factors related to behavior. It is based on annual serialized surveys undertaken with a sample of approximately 2000 schooled individuals in the 4º course of Obligatory Secondary education (ESO) in The Madrid Region.

Table III
Methodological characteristics and questionnaire sections related to alcohol, tobacco and other drug use, Surveillance system of risk of non-transmittable disease. (SIVFRENT)

	SIVFRENT-A	*SIVFRENT-J*
Starting Date	1995	1996
Target population	Population between the ages of 18-64 residing in the Madrid Region	Population between the ages of 15-16 residing in the Madrid Region
	Sample design	
Sampling frame	Population between the ages of 18-64 residing in the Madrid Region with home telephone line	Schooled population in the 4º year of E.S.O in the Madrid Region
Sampling size	Around 2000 interviews annually (Ej. Year 2013 1944)	Around 2000 interviews annually (Ej. Year 2013 2115: interviews distributed in 89 classrooms in 45 school centers)
	Information collection	
Method	Structured questionnaire composed of a central nucleus and variable modules, conducted by telephone survey via the CATI (Computerized Assisted Telephone Interview)	Structured questionnaire composed of a central nucleus and variable modules self-administered in the classroom.
	Sections of the questionnaire related to use of tobacco, alcohol and other drug	
Alcohol use	Total use, Risk use, *binge drinking*	
Tobacco use	Current and past use, passive smoking, attempts to quit smoking	
Illegally purchased drugs		Unprescribed tranquilizers, hashish, cocaína, heroin, speed o anfetaminas, ectasy and other desiner drugs, halucinagenics

The questionnaire is made up of core questions that remain unchanged over time so as to be able to make comparisons, and a flexible section that is periodically modified according to public health necessities. Aspects of physical activity, nutrition, behavior related to food disorders, overweight and obesity, tobacco use, illegal drug and alcohol sales, sexual relations, accident rates and road safety (Table III).

Conclusion

There are many valuable information sources available to estimate the use of alcohol, tobacco and other drugs based on the method used. It is necessary to have valid and comparable data available on health status and its determinants as a key element of a health policy based on evidence[24].

The survey method provides information not only in relation to use but to other important aspects. Nonetheless, to be able to compare different surveys it is necessary to homogenize the questionnaires considering some methodological aspects like: volume measurement in the case of alcohol, categorization of use, age groups, etc.

References

1. Valoración de las encuestas a adolescentes sobre consumo de tabaco, alcohol y cannabis en España. Joan R Villalbí; Josep M Suelves; Esteve Saltó; Carmen Cabezas. *Adicciones* 2011. Vol. 23 (1): 11-16.
2. Ministerio de Sanidad, Servicios Sociales e Igualdad. Encuesta Europea de Salud en España, 2009. [Consultado 1 de Septiembre de 2014]. Disponible en: http://www.msssi.gob.es/estadEstudios/estadisticas/EncuestaEuropea/.
3. Reproducibilidad de un cuestionario telefónico sobre factores de riesgo asociados al comportamiento y las prácticas preventivas. Iñaki Galán; Fernando Rodríguez-Artalejo y Belén Zorilla. *Gac Sanit* 2004;18(2):118-28.
4. Comparación entre encuestas telefónicas y encuestas «cara a cara» domiciliarias en la estimación de hábitos de salud y prácticas preventivas. Iñaki Galán, Fernando Rodríguez-Artalejo, Belén Zorrilla. *Gac Sanit* 2004; 18(6):440-50.
5. La prevalencia del consumo de tabaco en España. Cristina Infante; Jesús Miguel Rubio-Colavida. *Adicciones* (2004), vol. 16, supl. 2.
6. Indicadores de consumo de alcohol en España. Juan L. Gutiérrez-Fisac. *Med Clin (Barc)* 1995; 104: 544-550.
7. Aspectos metodológicos en la medición del consumo de alcohol: la importancia de los patrones de consumo. José L Valencia Martín, Mª José González, Iñaki Galán. *Rev Esp Salud Pública* 2014; 88:433-446.
8. Patrones de consumo de alcohol en España: un país en transición. Iñaki Galán, Mª José González y José L Valencia-Martín. *Rev Esp Salud Pública* 2014; 88:529-540.
9. Consumo de bebidas alcohólicas: sugerencias para su medición en Cuba. Martha Chang de la Rosa, Mayilée Cañizares Pérez e Isabel Barroso Utra. *Rev Cubana Med Gen Integr* 2005;21(3-4).
10. Diagnóstico del problema: conceptos básicos. Mª Elena Medina-Mora. En: Metodología para la elaboración de estudios epidemiológicos a nivel nacional y local y estudios para grupos especiales relacionados con las adicciones. Consejo Nacional Contra las Adicciones. México 2003. ISBN: 970-721-135-0.
11. Ministerio de Hacienda y Administraciones Públicas. Información sobre el Mercado de Tabacos: ventas de labores de tabaco a expendedurías. (Consultado el 01/09/2014.) Disponible en: http://www.cmtabacos.es/wwwcmt/paginas/ES/mercadoEstadisticas.tmpl.
12. Variabilidad en el consumo de cigarrillos según la fuente de información en España (1993-2009). Jose M. Martínez-Sánchez, Marcela Fu, Silvano Gallus, Xisca Sureda, Carlo La Vecchia y Esteve Fernández. *Gac Sanit* 2013; 27(1):61–63.
13. Guía Internacional para vigilar el consumo de alcohol y sus consecuencias Sanitarias. Organización Mundial de la Salud 2000.
14. Métodos de obtención de información: Encuestas en hogares. Ma. Elena Medina-Mora, Jorge Villatoro, Clara Fleiz y Patricia Cravioto. En: Metodología para la elaboración de estudios epidemiológicos a nivel nacional y local y estudios para grupos especiales relacionados con las adicciones. Consejo Nacional Contra las Adicciones. México 2003. ISBN: 970-721-135-0.
15. Ministerio de Agricultura, Alimentación y Medio Ambiente. Panel de consumo alimentario.[Consultado 1 de Septiembre de 2014]. Disponible en: http://www.magrama.gob.es/es/alimentacion/servi-cios/.
16. Instituto Nacional de Estadística. Encuesta de Presupuestos Familiares. [Consultado 1 de Septiembre de 2014]. Disponible en: http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t25/p458&file=inebase.
17. Instituto Nacional de Estadística. Encuesta Industrial de Productos. [Consultado 1 de Septiembre de 2014]. Disponible en: http://www.ine.es/jaxi/menu.do?type=pcaxis&path=%2Ft05%2Fp049&file=inebase&L=0.
18. Encuesta Nacional de Salud. España 2011/12. Serie Informes monográficos no 1. Consumo de alcohol. Ministerio de Sanidad, Servicios Sociales e Igualdad. Madrid 2013. [Publicación en la Intranet]. Ministerio de Sanidad, Servicios Sociales e Igualdad 2013.NIPO en línea: 680-14-081-9. Disponible en: https://www.msssi.gob.es/estadEstudios/estadisticas/encuestaNacional/encuesta2011.htm.
19. Ministerio de Sanidad, Servicios Sociales e Igualdad. Encuesta Nacional de Salud de España, 2011/12. [Consultado 1 de Septiembre de 2014]. Disponible en: http://www.msssi.gob.es/estadEstudios/estadisticas/encuestaNacional/.
20. Plan Nacional sobre Drogas. Ministerio de Sanidad, Servicios Sociales e Igualdad. Encuesta Domiciliaria sobre Alcohol y Drogas en España (EDADES). [Consultado 1 de Septiembre de 2014]. Disponible en: http://www.pnsd.msc.es/Categoria2/observa/estudios/home.htm.
21. Plan Nacional sobre Drogas. Ministerio de Sanidad, Servicios Sociales e Igualdad. Encuesta Estatal sobre Uso de Drogas en Enseñanzas Secundarias (ESTUDES). [Consultado 1 de Septiembre de 2014]. Disponible en: www.pnsd.msc.es/Categoria2/observa/estudios/home.htm.
22. Hábitos de salud en la población adulta de la Comunidad de Madrid, 2012. Boletín Epidemiológico de la Comunidad de Madrid Nº 7. Volumen 19. Julio 2013.
23. Hábitos de salud en la población juvenil de la Comunidad de Madrid, 2013. Boletín Epidemiológico de la Comunidad de Madrid Nº 4. Volumen 20. Abril 2014.
24. Encuestas de salud en España: situación actual. María Luisa Requena, Mónica Suárez, Óscar Pérez y Grupo Técnico de Encuestas de Salud de la Subcomisión de Sistemas de Información del Consejo Interterritorial del Sistema Nacional de Salud. *Rev Esp Salud Pública* 2013; 87:549-573.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):265-271
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Quality of life, dependency and mental health scales of interest to nutritional studies in the population

Susana Granado de la Orden, Carmen Serrano Zarceño and Susana Belmonte Cortés

Subdirección de Promoción de la Salud y Prevención. Dirección General de Atención Primaria. Consejería de Sanidad. Comunidad de Madrid. Spain.

Abstract

***Quality of life, dependency* and *mental health* are multidimensional constructs that cannot be observed directly yet can be deduced in an indirect manner through indicators or profiles generated from questionnaires. These questionnaires are based on the validity of information transmitted by the respondents about perceptions, feelings and attitudes. For this reason, the information is difficult to contrast with and translate to a measuring system.**

The use of questionnaires or rapid quality of life and mental health evaluation scales involve a process directed towards an early identification of specific problems so as to establish medical treatment.

This work will review the most commonly used scales or questionnaires in determining these variables and their relationship with the nutritional status of the population.

(*Nutr Hosp* 2015;31(Supl. 3):265-271)

DOI:10.3305/nh.2015.31.sup3.8774

Key words: *Quality of life. Questionnaires. Personal autonomy. Mental health, nutritional status.*

ESCALAS DE CALIDAD DE VIDA, DEPENDENCIA Y SALUD MENTAL DE INTERÉS EN ESTUDIOS NUTRICIONALES DE CARÁCTER POBLACIONAL

Resumen

***Calidad de vida, dependencia y salud mental* son constructos multidimensionales no observables directamente pero que pueden ser deducidos de manera indirecta a través de indicadores o perfiles generados a partir de cuestionarios. Estos cuestionarios se basan en la validez de la información de percepciones, sentimientos y actitudes que trasmite el encuestado. Por esta razón, esta información es difícil de contrastar y traducir a un sistema de medida.**

El empleo de cuestionarios o escalas de valoración rápida de la calidad de vida, dependencia y salud mental, conlleva un proceso dirigido a identificar precozmente a sujetos con problemas específicos para poder instaurar programas de intervención.

Este trabajo revisa las escalas o cuestionarios más empleados en la determinación de estas variables y su relación con el estado nutricional de la población.

(*Nutr Hosp* 2015;31(Supl. 3):265-271)

DOI:10.3305/nh.2015.31.sup3.8774

Palabras clave: *Calidad de vida. Cuestionarios. Dependencia. Salud mental. Estado nutricional.*

Abbreviation

HRQOL: Health-Related Quality of Life.
WHO: World Health Organization.
ADL: Activities of Daily Living.
ICF: International Classification of Funcioning, Disability, and Health.

Introduction

Technological advances along with an augmentation in longevity have produced a change in health care in such a way that lethal illnesses have become chronic illnesses. Situations have also increased in which health intervention is directed towards alleviating symptoms and preventing complications in recuperation, and/or maintaining quality of life.

Quality of life, dependency and mental health are multidimensional constructs which are not directly observable, but which can be deduced in an indirect manner through indicators or profiles generated using questionnaires. These questionnaires are based on the validity of information from perceptions, feelings and attitudes that the respondent transmits, however this information is difficult to contrast and translate to a system of measurement.

When speaking of questionnaires we often speak of Evaluation scales which are the tools that permit cumulative scaling of items by giving a global rating at the end of the evaluation. This is what differentiates them from data recollection questionnaires.

Correspondence: Carmen Serrano Zarceño.
Subdirección General de Promoción de la Salud y Prevención.
Dirección General de Atención Primaria.
Consejería de Sanidad de la Comunidad de Madrid. Spain.
E-mail: cserranoz@salud.madrid.org

Questionnaires require a series of psychometric properties that guarantee reliability and validity and must allow for an adequate rating of the scaling of the phenomenal object of measurement as well as for the quality of measurement, especially when the purpose is to extrapolate results obtained from the population. Therefore questionnaires must fulfil the following series of characteristics:[1-2]

1. Validity of content: Both the questionnaire and the items must be adequate for measuring that which is to be measured. For this reason the questionnaire should be submitted to evaluation by investigators and experts.
2. Components and dimensions must be clearly defined so that each one contributes to the scale total in an independent way.
3. Reliability and precision: questionnaires must be capable of providing true and constant results when used under similar conditions in repeated situations.
4. Sensibility to change: They must be capable of detecting differences in the magnitude of construct, which are the changes in different individuals, and the answers given by the same individual over time.
5. They must be accepted by the agents involved: interviewer, respondent, investigator, etc. in those aspects such as the time needed to conduct the questionnaire and the level of reading and understanding necessary to answer the questions.

Health-Related Quality of Life (HRQOL)

The definitions found in the bibliography related to the HRQOL derive from the definitions for health and quality of life given by the World Health Organization (WHO), which in 1948 defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity[3]." Subsequently, in 1994 it described quality of life as "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns[4]". Therefore, the evaluation of Health- Related Quality of Life concerns the way in which illness, as a producer of pain, physical dysfunctions and discomfort, causes limitations or alterations in the everyday conduct, social activities, psychological well-being and other aspects of daily life in individuals. (Fig. 1)[5-6]

Quality of Life evaluation is of great interest. However it is a difficult concept to quantify objectively. It concerns the measurement of results centred on the patient and the impact that illness and subsequent treatment have on the patient's perception of their own satisfaction and physical, psychological, social and spiritual well-being[7]. The importance of the HRQOL has continued to grow in recent years, becoming a central objective in health care and a measurement of results in patient-cantered health care.

To evaluate the HRQOL, instruments must be used which asses the effects of health status on the normal life of an individual. Difficulty exists in trying to evaluate the effects on the quality of life of a defined population group with specific pathologies.

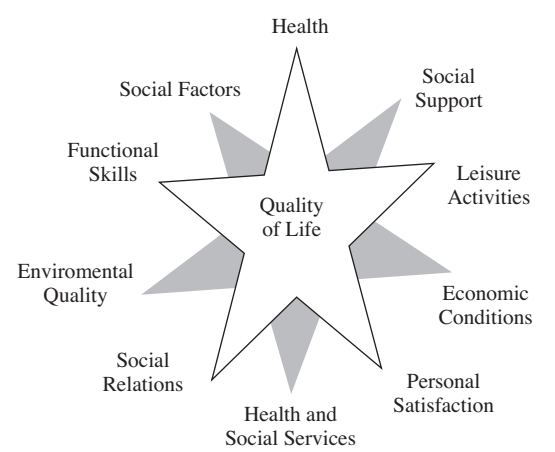
The instruments that measure the HRQOL are utilized more and more to evaluate clinical procedures and the quality of the care given. There are different criteria for classifying HRQOL measuring instruments, although the most accepted is that proposed by Guyatt et al[8] which distinguishes between generic tools and specific tools for an illness.

Generic tools can be used on different types of patients or populations with the advantage that they allow us to compare the impact of different illnesses on the HRQOL and determine the effects of treatment on different aspects of the HRQOL. They are applicable to a great variety of conditions being that they cover a wide spectrum of dimensions of the HRQOL. Generic dimensions such as physical, mental, and social status are included in these health profiles.

However one disadvantage is that by not including specific aspects for the evaluation of a particular condition, they can be less sensitive to change. The most utilised are the SF-36 and the EuroQol-5D.

Specific instruments focus on particular aspects of an illness or concrete syndromes and have the advantage of being more sensitive to quality of live aspects determined by the effects of a specific illness.

In general terms, specific questionnaires for measuring HRQOL are more adequate than generic ones for measuring changes in the evolution of a patient, especially those changes caused by treatments, given that generally specific tools include questions about signs and symptoms that a patient with a particular



Source. Fernández-Ballesteros, R; Zamarrón, M.D. y Maciá, A. Different contexts of Quality of Life in the Aged. Madrid-Spain: Inational Institute of Social Services. 1996.

Fig. 1.—Factors which make up quality of life.

illness suffers from in different degrees. The majority of experts in HRQOL evaluation recommend the use of specific instruments for each illness, together with the administration of some generic tool. The main disadvantage is that this does not allow for comparisons between different conditions[9].

Alterations in nutritional status have effects which condition an individual's quality of life in an important way, impeding, or at the very least complicating physical, psychological and social development. Nonetheless, it is not easy to find any approximations to measure the impact that these nutritional alterations can have on quality of life, unless it be those made from generic questionnaires.

The revision of tools utilized with the objective of measuring the impact of nutritional status on quality of life makes clear the difficulty involved in developing a tool which can measure the quality of life of malnourished patients as well as provide information about how said quality of life is affected by malnutrition status. There exists the need to have a tool available, which together with other classic parameters, signals the proper moment to initiate or terminate a nutritional intervention, as well as giving information as to whether said intervention is positive.

In scientific bibliographies we find how a specific medical intervention increases the patient's quality of life. However in few cases do we find that this is authenticated by a measurement of this quality of life[10].

The absence of specific tools to register effects on the HRQOL, together with the necessity of knowing the impact of concrete problems such as nutritional status, forces the use of various instruments concomitantly which in turn leads to a lack of operational ability and a vision most likely contaminated by other modifying variables of effects present in the patient's pathological context which the generic questionnaires collect in a prevalent way[11].

The ideal would be to have an instrument available that together with other classic parameters would indicate the most adequate moment to incite and terminate nutritional intervention as well as giving information on whether said intervention has been valid. In a revision performed on Quality of life related to nutritional status[12], all of the studies included in the revision and other publications, demonstrated the need to study this relationship in greater detail.

For this reason *CaVEN* (Quality of life questionnaire related to nutritional status) was created. This is a constructed and validated questionnaire which measures quality of life in relation to nutritional status[13].

In the elaboration of this specific tool to measure quality of life in relation to nutritional status, 14 experts on nutrition were interviewed and 6 focal groups were formed 17 judges, experts in clinical nutrition, questionnaire validation and other areas of knowledge, participated in the evaluation of the different versions of the questionnaire. After eliminating or restating the items which were ambiguous, incomprehensible, redundant or inconsistent from a theoretical point of view, there remained a questionnaire made up of 26 items referring to 6 dimensions of health: Perception of General Health (8 items), Physical Activity (4 items), Work Activity (2 items), Mood (6 items), Family and Social Relationships (3 items), Pain and Physical Discomfort (3items).

CaVEN was designed to be a self-administered questionnaire and was edited so that subjects could directly express their sensations and perceptions about their quality of life during the previous month in accordance with a 1-6 Likert type scale.

CaVEN showed how it was possible to put together the adequate psychometric characteristics so as to fulfil the proposed task as well as measure the perceived quality of life of patients with different nutritional status. It can be used not only to identify the level of affectation that provokes the different degrees of malnutrition on quality of life, but also to evaluate the impact of the different interventions directed to modify the nutritional status on quality of life[14].

The CaVEN questionnaire expounds its capacity to measure the affectation of the quality of life of the subjects. Compared with other questionnaires utilized as references or *Gold Standard*, the CaVEN has been shown to perform as a valid and trustworthy tool for measuring the Quality of life related to nutritional status questionnaire.

Dependency

To establish what dependency is and how it deals with a concept that is closely related to that of personal autonomy it is necessary that both concepts be previously defined according to the definitions as established in the Act on the Promotion of Personal Autonomy and Care for Dependent Persons[15] (39/2006) in which it is indicated that:

1. ***Dependency****: the permanent state in which persons that for reasons derived from age, illness or disability and linked to the lack or loss of physical, mental, intellectual or sensorial autonomy require the care of another person/other people or significant help in order to perform basic activities of daily living.*
2. ***Personal Autonomy****:" ability of one's own initiative to control, deal with and make personal decisions about how to live in keeping with the regulations and personal preferences as well as carrying out the basic activities in their daily life.*
3. ***Activities of Daily Living (ADL)****: those that allow a person to cope with a minimum level of autonomy and independence, such as: taking care of themselves, basic domestic chores, essential getting about, recognising people and objects, knowing where they are, understanding and carrying out orders or simple tasks.*

On the basis of these definitions we can deduce two clear phenomenon. On the one hand autonomy and dependency are two concepts that are closely related; the loss of personal autonomy implies dependency being that as a consequence of limitations in the development of personal autonomous and social skills, a person has greater difficulty adapting to their environment and, as a result, need support to compensate for these limitations (Fig. 2).On the other hand, being that age is a key variable, there exists an indubitable relationship between old age and dependency. Disabilities during old age result in a loss of personal autonomy in performing daily activities such as shopping, food preparation and feeding oneself with the resulting lack of daily nutritional needs and state of malnutrition[16]. It is beyond doubt that there exists an important relationship between the conservation of these skills, the degree of dependency and nutrition. The lack of personal autonomy in the development of the ADL can significantly affect the patient's nutritional status.

The phenomenon of dependency, which at the same time linked to another concept which is that of disability, is a subject of worldwide importance, being especially relevant to developed countries as they are also the highest in ageing populations[17].

Based on the Disabilities, Independence and Dependency Situations Survey of 2008[18], the disability rate in Spain was 89.7 disabled for every 1000 inhabitants. This data gives us an idea of the enormous economic impact of dependency which supposes an important problem for the Public Health System which must rate itself from two points of view: Health, given that disability is the consequence of an illness or alteration in health, and require medical assistance; and Rehabilitation, with a focus centred on social integration of these persons provided by health care professionals[19].

Disability or dependency assessment needs to be centred on the studies of those activities in which one person needs the assistance of another for their realisation, without losing sight of corporal deficiencies or context[20].Therefore, to the extent to which we want to obtain greater sensitivity and/or specificity in rating dependency, we shall have to differentiate and measuring the three components: deficiency, activities and assistance, without sacrificing any of them.

Measurement of dependency is measured through the use of Scales of Dependency. There exist a multitude of scales which allow adjustment of the degrees of dependency and for this the WHO, conscience of the difficulties of Dependency evaluation and scaling, have spent many years developing a valid, reliable and international instrument which will facilitate assessment. Thus, the World Health Assembly of May 22, 2001 approved the International Classification of Functioning, Disability, and Health (ICF)[21] presenting a generic scale for adjusting dependency in 5 iso groups based on severity.

Table I shows the scales of greatest interest for adjusting dependency in the performance of daily activities just as other scales allow us to obtain detailed information about diverse aspects intimately related to dependency. The use of these scales could be useful for exploring other components of dependency such as the "Interacting context".

No scale specifically relating dependency with a person's nutritional status has been found and for this reason it is necessary to design and validate an instrument that evaluates nutritional status in relation to dependency.

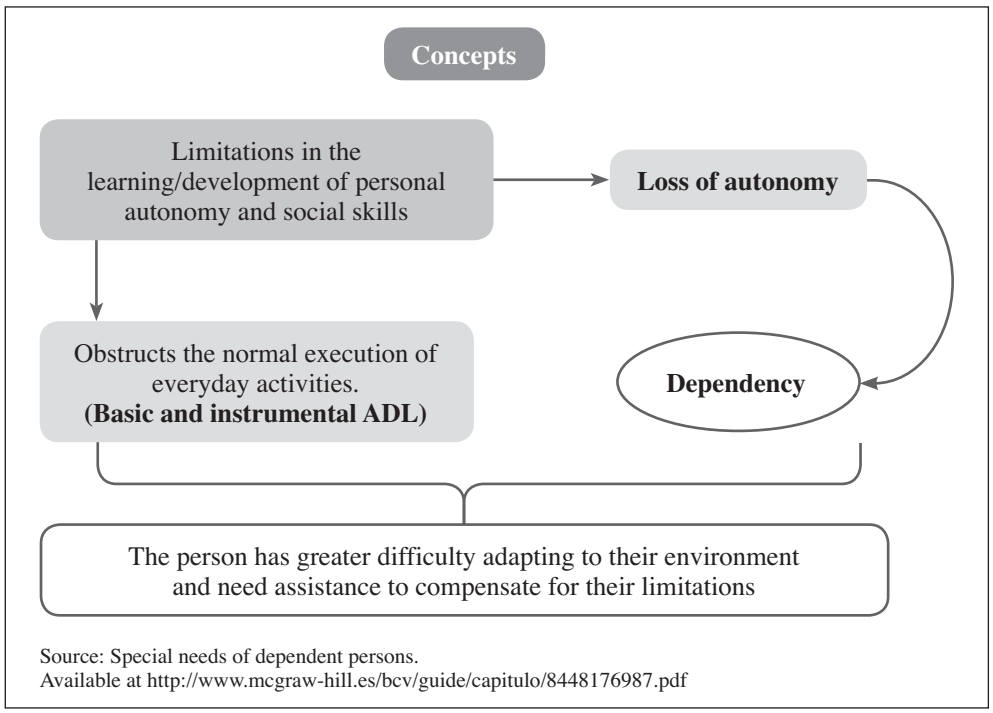


Fig. 2.—Diagram showing the relationship between the concepts of personal autonomy and dependency.

Table I
Dependency rating scales

Dependency Scales	*Objective*	*Use*	*Nutritional Ranking*
Barthel Index[a]	Evaluates the capacity to carry out basic daily activities	Rehabilitation, geriatric and patients in resident homes	No
Katz Index[b]	Evaluates the capacity to carry out basic daily activities	Rehabilitation, geriatric	No
Lawton Index[c]	Evaluates the capacity to carry out basic daily activities	Rehabilitation, geriatric and patients in resident homes	No
Mini Nutritional Assessment MNA[d]	Evaluation of nutritional status	Geriatric	Yes
Norton Scale[e]	Evaluates the risk of bedsores	General hospitalised patients	No

[a]Mahoney FI, Barthel D. Functional evaluation: The Barthel Index. Maryland State Medical Journal 1965; 14: 56-61.
[b]Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The index of ADL: a standardized measure of biological and psychosocial function JAMA. 1963; 185: 914-9.
[c]Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontologist. 1969; 9: 179-186.
[d]Guigoz Y. The Mini Nutritional Assessment (MNA(R)) Review of the Literature - What Does It Tell Us? J Nutr Health Aging. 2006; 10: 466-87.
[e]Norton D, McLaren R, Exton-Smith AN. An Investigation of Geriatric Nursing Problems in Hospital. London: Churchill Livingstone; 1962:193-224. Norton D. Calculating the risk: reflections on the Norton Scale. Decubitus 1989; 2:24-31 (erratum 1989;2:10).

Mental Health

The positive dimension of mental health makes reference to the concept of welfare and the skills for adapting to adversity. It includes self-esteem, self-control, optimism and a sense of coherence. Mental health is the basis of welfare and the proper functioning of an individual and community is much more than the absence of pain, being that it has value in itself[22]. The degree of mental health is related with the capacity to confront and overcome life's adversities with losing emotional balance.

In Spain, according to the Disabilities, Independence and Dependency Situations Survey (DIDSS 2008) 18, disabilities attributed to dementia, mental disorders and reduced intellectual capacity affects 719,000 people over the age of 6; 19% of all people with disabilities.

During the aging process deterioration of cognitive functions is observed. This can emerge from its lightest form (as a simple non progressive memory deficiency) to the severest form of dementia with irreversible and progressive effects on occupational and social activities which can affect the individual's feeding capacity. Therefore, cognitive deterioration has a direct relationship with diet and can result in a state of malnutrition, a fact which especially aggravates the ageing process[23].

The noted increase in the prevalence of cognitive deterioration in the elderly population and its impact on the level of independence and quality of life of the institutionalised elderly justifies the need for early detection of such alterations so as to initiate, as soon as possible, intervention programs directed at delaying dependency, maximizing capabilities and improving quality of life.

During clinical evaluation of cognitive degeneration, the use of neuropsychological tests and screening instruments is recommended. Currently, is assumed that at least a part of those persons that will suffer dementia in the future can be detected by means of neuropsychological testing.

There exist different test forms for evaluating the cognitive function[24] (Table II). None of them alone are capable of diagnosing dementia and cannot be considered independently apart from clinical evaluation.

It would be desirable to have an instrument available for the evaluation of the nutritional status of mental health patients with the objective of knowing how the nutritional status is modified on the basis of their cognitive status.

Conclusions

In issues related to nourishment it is necessary to distinguish between two different facets: nutrition, directly related to the necessary contributions for maintaining or improving health status, and food, as a cultural and socialising element respectful towards traditions and cultures, generator of welfare. Both aspects merge with and influence people's quality of life in a direct manner, especially when they are older.

Quality of life depends as much on physical well-being as on psychological, and both factors can be influenced by nutritional status. A growing knowledge that poor nutritional status has a negative impact on quality of life exists. It must not be forgotten that nutritional status is one of the most important and potentially modifiable disability risk factors.

In spite of the fact that, on the one hand, difficulties exist at the moment of being able to measure quality of life and, on the other, a variety of methods are employed to evaluate nutritional status, a close association between malnutrition and worsening in the quality of life has been observed, and as such, both the functional status as well as the cognitive state are intimately

Table II
Mental Evaluation Scales

Evaluation Scales of cognitive function	*Objective*	*Use*	*Items explored*
Mini Mental State(MEC)[a]	Screened for neurodegenerative illnesses that show cognitive degeneration	Adults and Elderly	Orientation, focusing, concentration, calculating, memory, language and construction
Pfeiffer Questionnaire (SPMSQ)[b]	Evaluate degree of cognitive degeneration	Institutionalized or not patients. Very useful in populations with high prevalence of illiteracy.	Short and long term memory, orientation, information about everyday facts and calculating capacity
Yesavage Geriatric Depression Scale (GDS)[c]	Evaluates depression in the Elderly	Elderly	15 items provide information regarding affective state

[a]Folstein MF, Folstein SE, Mchugh PR. Mini Mental State. A practical method for grading the cognitive state of patients for the clinical. J Psychiatr Res 1975;12:189-198. Lobo A, Ezquerra J. El Mini-Mental cognoscitivo: un test sencillo y práctico para detectar alteraciones intelectivas en pacientes médicos. Actas Luso-Esp. Neurol Psyquiatr 1979; 3:149-153.
[b]Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. J Am Geriatr Soc 1975;23:433-441. García-Montalvo JL, Rodríguez L, Ruipérez I. Valoración del cuestionario de Pfeiffer y la escala de incapacidad mental de la Cruz Roja en la detección del deterioro mental en los pacientes externos de un servicio de geriatría. Rev Esp Geriatr Gerontol 1992;27: 129-133.
[c]Pérez E, González MA, Moraleda P, Szuker S, González JA. La escala de depresión geriatrica (GDS) como instrumento para la evaluación de la depresión: bases de la misma. Modificaciones introducidas y adaptación a la realidad psicogeriátrica española. Rev Esp Geriatr Gerontol 1990;25(3):173-180. Yesavage JA, Brink TL, Rose TL, Lum O, Huang V, Aday M, et al. Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res 1982:17:37-49.

related to said quality of live. To sum up, it can be concluded that:

Mental health, quality of life and dependency are increasingly important elements in rating health status.

Without any doubt, healthy nutritional status contributes to improving the functional and mental status of the individual and thus contributes to an improvement in the quality of life itself, something extremely important at the present time being that life-spans have clearly increased.

Public Health works to find a compound measurement which encompasses different objective and subjective dimensions.

General Health Surveys are trying to collect this information in a comprehensive manner.

The specific measurement instruments utilised are disparate and a lack of specific instruments exists which forces the use of different concomitant instruments.

It is necessary to continue working on the development of specific questionnaires for evaluating quality of life, dependency and mental health in relation to the nutritional status of the individual.

Generic scale of dependency severity	
Group 1	No dependency
Group 2	Light dependency
Group 3	Moderate dependency
Group 4	Severe dependency
Group 5	Total dependency
Source: WHO, 2001	

Fig. 3.—Generic scale of severity of dependency.

References

1. Grau G. Metodología para la validación de cuestionarios. *MEDIFAM* 1995; 5(6): 351-359.
2. Martín Arribas MC. Diseño y validación de cuestionarios. *Matronas Profesión* 2004; 5(17): 23-29.
3. World Health Organization. Constitution. En: WHO. Basic Document Geneve WHO 1948.
4. World Health Organization. Quality of life Assessment. An annotated bibliography. Geneva: WHO (MNH/PSF/94.1), 1994.
5. Bergner M. Quality of life, health status and clinical research. *Med Care* 1989; 27 (3 Suppl.): 1485-96.
6. Hörnquist JO. Quality of life: concept and assessment. *Scand J Soc Med* 1989; 18 (1): 68-79.
7. Patrick D, Erickson P. Health Policy, Quality of Life: Health Care Evaluation and Resource Allocation. Oxford University Press; New York, 1993.
8. Guyatt GH, Veldhuyzen Van Zanten SJ, Feeny DH, Patrick DL. Measuring quality of life in clinical trials: a taxonomy and review. *CMAJ* 1989; 140:1441-8.
9. Badía LX, Lizan TL. Estudios de calidad de vida. En: Martín Zurro A, Cano PJF, Atención Primaria. Conceptos, organización y práctica asistencial. 5ªed. España: *Elsevier* p. 250-261.
10. Planas M, Alvarez J, García-Peris PA, de la Cuerda C, de Lucas P, Castellà M et al. Nutritional support and quality of life in stable chronic obstructive pulmonary disease (COPD) patients. *Clin Nutr* 2005; 24 (3): 433-41.
11. Cuerda C, Cambor M, Bretón I, García-Peris P. Seguimiento a largo plazo de la nutrición parenteral domiciliaria en un hospital general: complicaciones y calidad de vida. *Nutr Hosp* 2002; 42 (1): 15-21.
12. Wanden-Berghe C, Sanz- Valero J, Escribà-Agüir V, Castelló-Botia I, Guardiola- Wanden-Berghe R. Evaluación de la Calidad de vida relacionada con el estado nutricional. *British Journal of Nutrition* 2009; 101(7): 950-960

13. Wanden-Berghe C, Martín Rodero H, Guardiola- Wanden-Berghe R, Sanz- Valero J y Galindo-Villardón P. Cuestionario de calidad de vida relacionado con el estado nutricional (CaVEN). *Nutr Hosp* 2012;27(6):1876-1885.
14. Wanden-Berghe C, Muñoz J, Cantó C, Domenech MD, Reyes MD, Pérez Moya C et al. Gastrostomía Endoscópica Percutánea (PEG). Diez años de experiencia. *Nutr Hosp* 2010; 25 (6): 949-53.
15. Ley 39/2006, de 14 de diciembre, de Promoción de la Autonomía Personal y Atención a las Personas en situación de dependencia, BOE número 299 de 15 de diciembre 2006.
16. Dapcich V, Medina R. Factores condicionantes del estado nutricional en el anciano. En: Muñoz M, Aranceta J, Guijarro JL, eds. *Libro blanco de la Alimentación de los mayores*. Madrid: Editorial Médica Panamericana 2004b. p. 23-29.
17. Albarrán Lozano I, Alonso González P. La población dependiente en España: Estimación del número y coste global asociado a su cuidado. *Estudios de economía* 2009; 36(2): 127-163
18. INE (2007). Proyecciones de población: resultados nacionales (período 2002- 2060) y resultados por comunidades autónomas y provincias (período 2002-2017), en http://www.ine.es/inebase/cgi/um?M=%2Ft20%2Fp25 1&O=inebase&N=&L (10/9/07).
19. Jiménez, A. y Huete, A. (2002). Epidemiología de la Discapacidad. Madrid. Real Patronato sobre discapacidad.
20. Querejeta González M. Discapacidad/ dependencia. Unificación de criterios. Madrid: Ministerio de Trabajo y Asuntos Sociales. IMSERSO, 2003
21. Organización Mundial de la Salud (2001). Aprobación de la Clasificación Internacional del Funcionamiento, de la discapacidad y de la Salud (ClF). Resolución 54/21. De la 54 Asamblea Mundial de la Salud realizada en 22/05/01)
22. World Health Organization. Mental Health in Europe, Country Reports from the WHO European Network on Mental Health. Copenhagen: World Health Organization; 2001.
23. Gómez Candela C., Reuss Fernández JM. Malnutrición en el anciano. 1ª edición. 2004. Barcelona. Manual de recomendaciones nutricionales en pacientes geriátricos. Novartis Consumer Health SA.
24. Sociedad Española de Medicina de Familia y Comunitaria. Recomendaciones sobre la demencia. Barcelona: semFYC; 1999.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):272-278
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Household Food Insecurity Access Scale (HFIAS)

Gemma Salvador Castell[1], Carmen Pérez Rodrigo[3,4], Joy Ngo de la Cruz[2] and Javier Aranceta Bartrina[2,5,6]

[1]Agència de Salut Pública de Catalunya. Departament de Salut. Generalitat de Catalunya. Barcelona (Spain). [2]Fundación para la Investigación Nutricional, Parc Científic de Barcelona. [3]Fundación FIDEC. Bilbao. [4]Presidenta de la Sociedad Española de Nutrición Comunitaria, SENC. [5]Departamento de Medicina Preventiva y Salud Pública. Universidad de Navarra. [6]CiberOBN, Instituto de Salud Carlos III, Madrid.

Abstract

In 1996, the World Food Summit reaffirmed the inalienable right that each person across the globe has to access safe, adequate and nutritious food. At that time a goal was established to reduce by half the number of undernourished persons worldwide by 2015, in other words the year that we are now commencing. Different countries and organisations considered the necessity of reaching consensus and developing indicators for measuring household food insecurity. The availability of a simple but evidence-based measurement method to identify nutritionally at-risk population groups constitutes an essential instrument for implementing strategies that effectively address relevant key issues.

(*Nutr Hosp* 2015;31(Supl. 3):272-278)

DOI:10.3305/nh.2015.31.sup3.8775

Key words: *Food security. Food insecurity. Questionnaire. Indexes. Scales.*

ESCALAS DE EVALUACIÓN DE LA INSEGURIDAD ALIMENTARIA EN EL HOGAR

Resumen

En 1996, la Cumbre Mundial sobre la Alimentación reafirmó el derecho inalienable de los habitantes del mundo a tener acceso a una alimentación adecuada, inocua y nutritiva, y se planteó como meta disminuir a la mitad el número de personas subnutridas en el mundo para el año 2015, es decir, este año que iniciamos. Diversos países y organizaciones se plantean la necesidad de consensuar y desarrollar indicadores para la medición de la inseguridad alimentaria en los hogares. Disponer de un método de medición simple pero con base científica para identificar los grupos de población de mayor vulnerabilidad nutricional, se considera una herramienta básica para poder implementar estrategias que permitan afrontar el problema de un forma efectiva.

(*Nutr Hosp* 2015;31(Supl. 3):272-278)

DOI:10.3305/nh.2015.31.sup3.8775

Palabras clave: *Seguridad alimentaria. Inseguridad alimentaria. Cuestionarios.Escalas.*

Abbreviations

ACF International: Action Against Hunger-Acción Contra el Hambre.
CFSSM: Child Food Security Survey Module.
CCHIP: Community Childhood Hunger Identification Project.
FAO: United Nations Food and Agriculture Organization.
FANTA: Food and Nutrition Technical Assistance.
FI: Food insecurity.
FS: Food Security.
EPSA: Food Security Perception Scale.
ELCSA: Latin American and Caribbean Scale.
HFIAS: Household Food Insecurity Access Scale.
HFSSM: Household Food Security Supplemental Module.
HFSS: Household Food Security Scale.
HDDS: Household dietary diversity score.
LIDNS: Low income diet and nutrition survey.
MFP: Main Food Provider.
NHANES: National Health and Nutrition Examination Survey.
SBP: School Breakfast Program.
SENC: Spanish Society of Community Nutrition.
USDA: United States Department of Agriculture.

Correspondence: Gemma Salvador Castell
Dietista-Nutricionista. Agència de Salut Pública de Catalunya.
Departament de Salut. Generalitat de Catalunya.
C/ Roc Boronat, 81-95. 08005 Barcelona, Spain.
E-mail: gemma.salvador@gencat.cat

Introduction

The World Food Summit (FAO 1996) defined food security (FS) as the situation in which "*all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*". Food security can be classified into three main components – availability, access and utilisation[1].

Food availability exists when households have access to sufficient quantities of adequate and necessary foods

obtained through local production, commercial imports or agency donations. Access refers to having necessary resources for the purchase or interchange of goods with the aim of obtaining a variety of foods to comprise a nutritionally adequate diet. Utilisation addresses the safe distribution, storage and preparation of foodstuffs.

Food insecurity (FI) is defined as the limited or uncertain availability of nutritionally adequate and innocuous foods or the limited or uncertain capacity for acquiring adequate foods by socially acceptable means[1].

Low food security occurs when individuals experience a reduction in food quality, variety, or desirability, and at times a reduction in food intake. Very low food security describes disrupted eating patterns and reduced intake because of insufficient resources[2].

In developed countries, among children very low food security has been associated with greater dietary intakes of total calories and percentage of calories from fat and added sugar[3]. A study conducted by Action Against Hunger-Acción Contra el Hambre (ACF International) in collaboration with the Spanish Society of Community Nutrition (SENC) in the Region of Madrid (Spain) reported less frequent consumption of fruits, vegetables, meat, fish and dairy products in low food security or food insecure families compared to food secure households. Additionally, Food Diversity Scores among children decreased as household food security decreased[4]. Food insecure women in the USA have been found to have a higher body mass index (BMI) and prevalence of overweight and obesity. There is also evidence from studies conducted in the UK, USA, Canada and Australia that adults who are food insecure consume lower amounts of fruit and vegetables.

Studies in the USA and Canada have also shown that women who were food insecure had lower intakes of a number of nutrients thus increasing the risk of nutrient deficiencies[5].

Food insecurity (FI) among young children is often invisible, because although young children who experience FI may experience negative health and developmental outcomes, their growth is often unaffected[6]. A direct link has been established between inadequate food quality and quantity and poor mental and physical health, psychosocial, behavioral, learning, family stress, and academic outcomes[7-10].

Children's Health Watch found that children younger than 3 years who live in food-insecure households have 90% greater adjusted odds of being in fair/poor health, 31% greater adjusted odds of being hospitalized since birth, and 76% greater adjusted odds of being at increased developmental risk compared with food-secure families[7].

In 2011, in the USA 17.9 million households were identified as food insecure. Among them, 9.2% experienced low food security while 5.7% had very low food security. Very low food security arises when at least one household member experiences "*multiple indications of disrupted eating patterns and reduced food intake*". In 2011, food insecurity at the child level was present in 10% of U.S. households with children under 18 years of age. Of households with food insecurity experienced by children, 9% had low food security among children and 1% of households had at least one child with very low food security[11].

The high prevalence of food insecurity, especially in developing countries, has also reached countries in the European Union (Greece, Portugal, Spain) as a consequence of the severe economic crisis occurring in the last few years (2009-2014)[12].

Environmental and household conditioning factors influence food insecurity. Social risk factors, including employment, economic and relational dimensions, can be mentioned among the environmental factors; household resources and capacity to confront and adapt to food insecurity are among the household factors. In the present global financial crisis unemployment and poor living conditions are important drivers for food insecurity and most vulnerable people are particularly affected by price changes and financial shock, while current economic policies in many European countries have deteriorated welfare systems and are unable to provide adequate protection to increasing numbers of affected people.

In 2010, 185 million meals were served by food banks and 740,000 people visited these organizations in France, compared to 663,000 in 2008. Furthermore, a study conducted in 2011 in the Paris metropolitan area reported 6.30% of households had experienced FI, 3.90% low FS and 2.40% very low FS; i.e. an estimated 326,000 adults were living in food-insecure households, with 124,200 of them living in households with very low FS[13]. The study conducted by ACF-International in Madrid in 2014 reported 5.7% food insecure households and a further 12.8% low food security households[4]. UNICEF reported a 10% increase in 2012-2013 of children at risk of poverty in Spain.

The availability of a simple but evidence-based measurement method that has demonstrated validity and reliability to identify these phenomena, scope and degree of severity, is essential for the detection of nutritionally vulnerable population groups and the implementation of effective strategies addressing these issues. As such, diverse countries and organisations have set out to reach consensus and develop indicators for measuring household food insecurity[14-16]. There are multiple effects of household food insecurity, and are principally related to risks of malnutrition/undernutrition and disease; risks of social and political conflict and instability and reduced productivity and the community's economic capacity.

A conceptual framework of Food Insecurity

Figure 1 depicts a conceptual framework about the onset and process of household food insecurity. In the

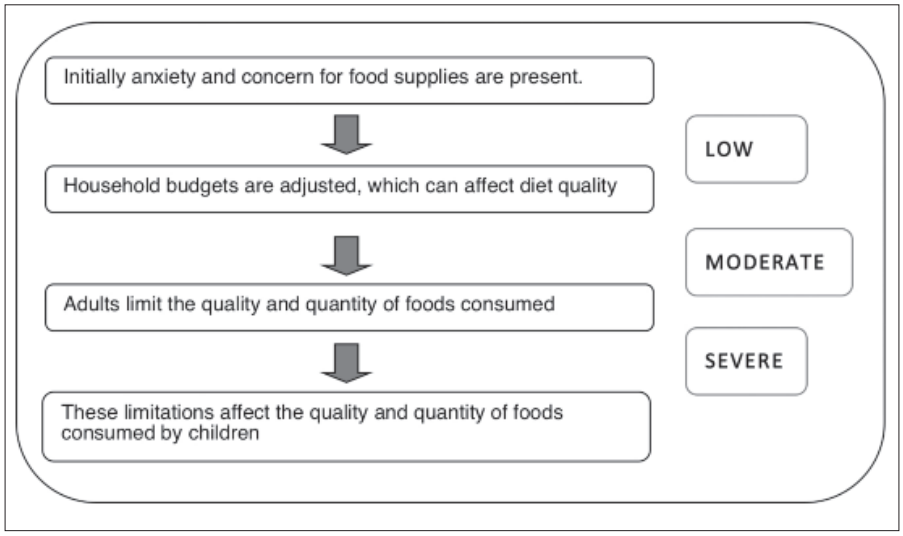
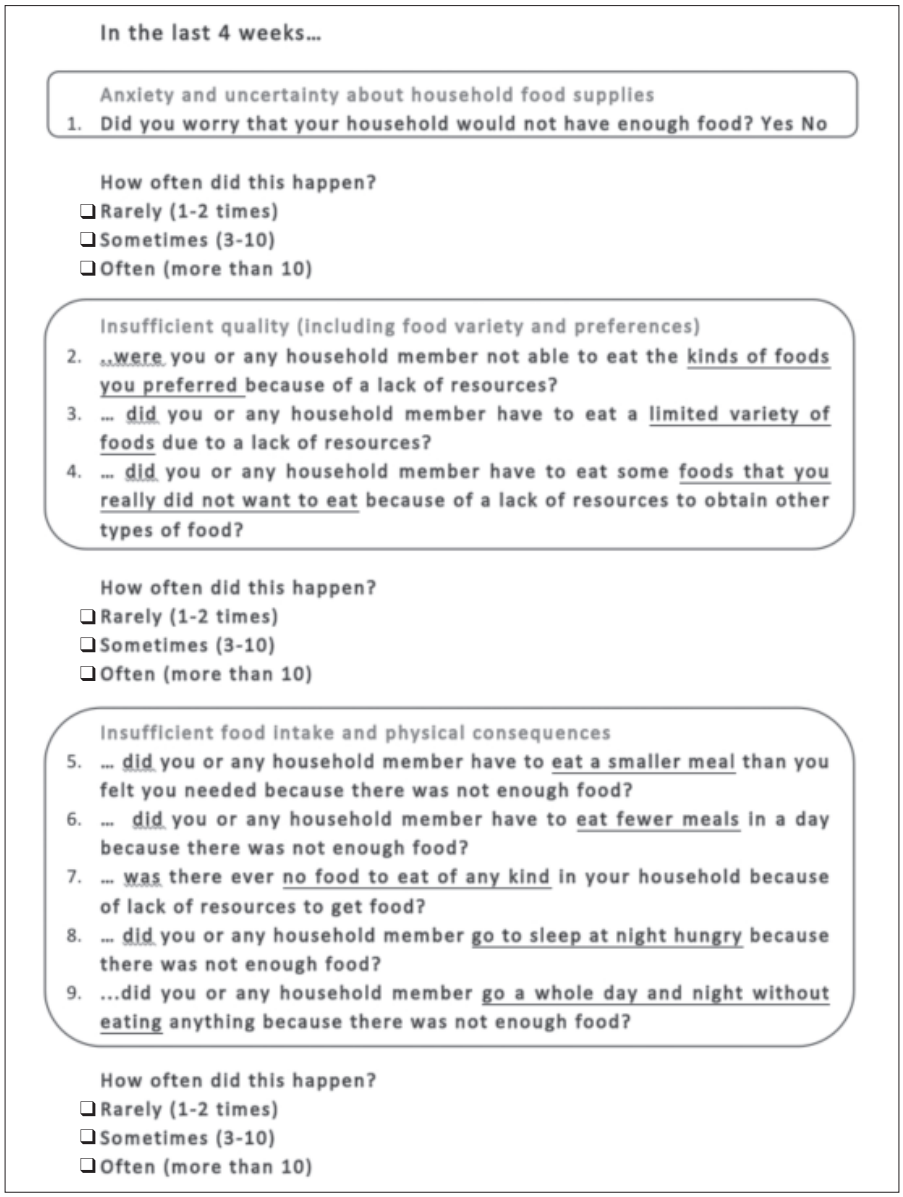


Fig. 1.—Onset and process of household food insecurity[4,5].



In the last 4 weeks…

Anxiety and uncertainty about household food supplies

1. Did you worry that your household would not have enough food? Yes No

How often did this happen?

- ❑ Rarely (1-2 times)
- ❑ Sometimes (3-10)
- ❑ Often (more than 10)

Insufficient quality (including food variety and preferences)

2. ..were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?
3. … did you or any household member have to eat a limited variety of foods due to a lack of resources?
4. … did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?

How often did this happen?

- ❑ Rarely (1-2 times)
- ❑ Sometimes (3-10)
- ❑ Often (more than 10)

Insufficient food intake and physical consequences

5. … did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?
6. … did you or any household member have to eat fewer meals in a day because there was not enough food?
7. … was there ever no food to eat of any kind in your household because of lack of resources to get food?
8. … did you or any household member go to sleep at night hungry because there was not enough food?
9. …did you or any household member go a whole day and night without eating anything because there was not enough food?

How often did this happen?

- ❑ Rarely (1-2 times)
- ❑ Sometimes (3-10)
- ❑ Often (more than 10)

Fig. 2.—Household Food Insecurity Access Scale (HFIAS) generic questions Food and Nutrition Technical Assistance III Project (FANTA)[5].

development of household food insecurity a gradient occurs that begins with the uncertainty and concern about accessing food. Next, adjustments are made in the family budget on food spending, reducing food quality and variety. As food insecurity progresses further adjustments are made that begin to affect not only the quality but also the quantity of food consumption. Food portions are reduced and some meals are omitted. In the next stage where food insecurity becomes more severe, hunger appears, initially appearing in adults and finally affecting children[15].

Methods of measuring food insecurity

Each one of the following methods provides information that may be complementary. However it's worth noting that the first four methods are extensive, long, costly and rather than directly measuring the problem, they inform us of the consequences of food insecurity: 1) Food balance sheets; 2) Household budget and spending surveys; 3) Individual food intake surveys; 4) Anthropometric and biochemical assessment and 5) Measurement of the perception of household food security/insecurity.

Food Insecurity questionnaires usually employ a series of 9 to 15 questions that detect the level of concern and the lack of access to, variety and/or quantity of food. The questions retrospectively refer to a period between 4 weeks to 3 months. They reflect 3 different domains of food insecurity: 1) Anxiety or uncertainty; 2) Insufficient quality and 3) Insufficient quantity.

Each of one of the questions shown in figure 2 refers to a previous period of four weeks (30 days). The subject interviewed is first asked about the occurrence of food insecurity, in other words if the condition reflected in the question took place in the last four weeks (yes or no). If the subject answers affirmatively to this type of question, another question is asked about the frequency to determine if the condition has occurred a few times (once or twice), sometimes (between three to ten times) or frequently (more than 10 times) in the last four weeks.

In the 1980s, the Community Childhood Hunger Identification Project (CCHIP) developed a series of 4 questions about children's food conditions as part of a survey module to assess hunger conditions in households[17]. Radimer et al. developed a methodology for measuring food insecurity that included assessments of the adequacy of food quality and quantity at household, adult, and child levels, and of food anxiety at the household level[18].

In the early 1990s, the USDA and the U.S. Department of Health and Human Services initiated the. U.S. Food Security Measurement project. The project included child-referenced questions as well as household- and adult referenced questions adapted from previous research. In 1995 the United States administered a questionnaire to identify indicators of household food insecurity (Household Food Security Supplemental Module, HFSSM) as part of NHANES (National Health and Nutrition Examination Survey). The instrument consists of 18 items.

Since 1999, NHANES has included the U.S. Household Food Security Survey Module in its household-level questionnaire. Additionally, since 2001 NHANES also collects information about the food security of sampled individuals (except for adolescents aged 12–15 y). Adults and adolescents ≥16 y of age were asked the 7 most severe adult-referenced questions in the HFSSM, adapted to refer specifically to conditions experienced by the respondent[18].

The food security status of older children (≥12 y of age) can be assessed using a self-administered survey tool, the Child Food Security Survey Module (CFSSM), developed by adapting questions from the Household Food Security Survey Module for direct administration to children after cognitive testing.

In 2005, NHANES began using 5 slightly adapted questions from the CFSSM to provide individually referenced food security information for children 12–15 y of age[18-21]. HFSSM is considered as a robust measure and a source of information that is useful for orienting policies and for identifying vulnerable populations or regions. A review published in 2008 presents data on the experience of utilizing these types of questionnaires in more than 20 countries[22].

The HFSSM includes three questions referring to the household, seven for adults, and eight questions that determine food insecurity at the child level. One weakness of the 18- item Household Food Security Survey Module is that it identifies food insecurity at the aggregate level, and is not able to discern intra-household differences in food security among individual adults and children.

In the Low income diet and nutrition survey (LIDNS)[5] conducted in the UK, food security was measured using a scale based on15 questions, 10 for adults and 5 for children. Each question asked whether the condition or behaviour occurred at any time during the previous 12 months due to a lack of money or other resources to obtain food. Questions were directed to the Main Food Provider (MFP) for the household and responses were applied to all individuals within the household. The scale included four constructs: a) Uncertainty, anxiety or perceptions that the household food budget or supply was inadequate or insufficient to meet basic needs; b) Perceptions that the food eaten by adults was inadequate in quality; c) Reported instances or consequences of reduced food intake, such as hunger or weight loss for adults and d) Reported instances of reduced food intake or its consequences, such as hunger for children[5].

The scale used in the study conducted in Madrid by ACF-International was adapted from the US FIS. Included four domains: anxiety for the provision of food; quality of food; use of social support and welfare networks; d) Reduced or insufficient food intake[4].

It has been reported that parent proxy reports of children's food security may be inaccurate or incomplete. All household members may not experience food insecurity in the same capacity. Mothers may not be fully aware of children's experiences or actions taken to reduce the severity of food insecurity. Researchers that have investigated whether or not children could reliably report on their own experiences concluded that children ages 6-16y can do so[17,22-24].

Connell and colleagues identified quantity, quality, psychological, and social components of children's perceptions of household food insecurity. Previous studies investigating the relationship between self-report and reports by others concluded that, even controlling for issues such us measurement error or poor design, the discrepancy in reports remains high. Therefore, discordance is likely due to the fact that children's experiences and perceptions may differ from those of adults[21,23,24].

Children reported more frequently than mothers on reducing portion sizes, skipping meals, or being hungry. Mothers' responses may also be influenced in part by social desirability. Recent research revealed that among a sample of 5–11 year old children and their parents, discordance may be a result of different reasoning methods and response styles[23].

Although the HFSS is widely used, it is time-consuming to administer and has a complex scoring algorithm. Several shortened questionnaires have been published, including the HFSS Short Form (a 6-item version with excellent sensitivity and good specificity). More recently, a single-item screen for hunger has been developed. However, the exclusive focus on hunger may miss food-insecure families that experience stress related to uncertain access to enough food but not the physiologic sensation of hunger. The authors defined adult hunger by responding 'sometimes true' or 'often true' to the statement: "I am hungry but don't eat because I can't afford enough food." Child hunger was defined by responding that the following statement was 'sometimes true' or 'often true': "I know my child(ren) is (are) hungry sometimes, but I just can't afford more food."[25]

A 2-item FI screen for identifying families at risk for FI was developed and demonstrated sensitivity, specificity, and convergent validity. The FI screen quickly identifies households with young children at risk for FI, which enables providers to target services to ameliorate the health and developmental consequences associated with FI. The questions asked are 1) "Within the past 12 months we worried whether our food would run out before we got money to buy more" and 2) "Within the past 12 months the food we bought just didn't last and we didn't have money to get more."[3,6].

Other authors have used a household food insecurity and access scale developed by Food and Nutrition Technical Assistance (FANTA) Program of the U.S. Agency for International Development[6,26]. The scale is similar to the household food security scale, except that it reflects the past four weeks. There are nine "occurrence" questions; if the household endorses any one of those questions, then there is a frequency question. There is one question on anxiety, three questions on quality, and five questions on food intake and consequences. Sometimes the last three questions are used as a household hunger set.

The Food Security Perception Scale (EPSA) and the Latin American and Caribbean Scale (ELCSA) are based on the principles developed by Wehler in 1992 and are used in Latin American and Caribbean Countries, such as Mexico, Colombia or Venezuela[4].

The household dietary diversity score (HDDS) developed within FANTA is meant to reflect the economic ability of a household to access a variety of foods. Studies have shown that an increase in dietary diversity is associated with socio-economic status and household food security (household energy availability)[27]. More recently a food insecurity experience scale has been developed in the context of FANTA as a global standard for monitoring hunger worldwide[28].

HFIAS risk factors

The principle causes of food insecurity are social injustice, inequity and the lack of guarantees for the population to be able to access economic, social, cultural and environmental rights as well as the right to food. Food insecurity is more common in households located in rural areas, with children, in single parent families (single mothers caring for a number of children), immigrant groups, displaced persons, refugees, the elderly, among others[4,29-31].

Studies carried out in the UK, USA, Canada and Australia have shown the prevalence of food insecurity to be associated with factors such as income, lower educational attainment, whether or not children were present in the household, past homelessness, poorer health, lack of home ownership and living alone[5].

For low-income families in the USA, the School Breakfast Program (SBP) is an important component of the safety net for children and has been linked to improved nutrient intake[11]. According to the study conducted in Madrid in 2014, participating in school meals was associated with food security. Conversely, not using that service was associated with poor food security or food insecurity. 5 out of 10 children in food secure households participated in school meals, as compared to only 3 out of 10 children in food insecure households[4].

Conclusion

Food insecurity continues to be a problem that affects millions of people worldwide. The Committee on World Food Security in the 2012 Global Strategic Framework

for Food Security and Nutrition identified five principles that Food Security and Monitoring Systems should meet: a) They should be human-rights based, with particular reference to the progressive realization of the right to adequate food; b) They should make it possible for decision-makers to be accountable; c) They should be participatory and include assessments that involve all stakeholders and beneficiaries, including the most vulnerable; d) They should be simple, yet comprehensive, accurate, timely and understandable to all, with indicators disaggregated by sex, age, region, etc., that capture impact, process and expected outcomes; e) They should not duplicate existing systems, but rather build upon and strengthen national statistical and analytical capacities[28].

To address hunger among children, there are several issues that will need to be addressed. Resolving food insecurity does not necessarily ensure that children meet optimal dietary guidelines. Among others, participation and utilization of school breakfast and school meal programs as well as summer school programs can contribute to reducing the number of children experiencing hunger and the potential need for supplemental nutrition programs school-age children for evening meals and meals on weekends.

References

1. *FAO* 1996. Cumbre Mundial sobre la Alimentación. Declaración de Roma sobre la Seguridad Alimentaria Mundial y Plan de Acción. Roma. Disponible en: [http://www.fao.org/docrep/003/w3613s/w3613s00.htm] (Acceso 21 de noviembre 2014)
2. Casey PH, Simpson PM, Gossett JM, Bogle ML, Champagne CM, Connell C et al. The association of child and household food insecurity with childhood overweight status. *Pediatrics* 2006, 118:e1406–e1413.
3. Sharkey JR, Nalty C, Johnson CM, Dean WR. Children's very low food security is associated with increased dietary intakes in energy, fat, and added sugar among Mexican-origin children (6-11 y) in Texas border Colonias. *BMC Pediatrics* 2012, 12:16
4. Ibargüen Onsurbe J, Gómez de Arriba A (cords). Seguridad alimentaria en el marco de una trayectoria social descendente. Un estudio sobre riesgo social y alimentación en la Comunidad de Madrid. *Madrid: Acción Contra el Hambre* 2014
5. Nelson M, Erens B, Bates B, Church S, Boshier T. *Low income diet and nutrition survey Volume 3 Nutritional status Physical activity Economic, social and other factors London:TSO* 2007
6. Hager ER, Quigg AM, Black MM, Coleman SM, Heeren T, Rose-Jacobs R, et al. *Development and Validity of a 2-Item Screen to Identify Families at Risk for Food Insecurity Pediatrics* 2010;126;e26 DOI: 10.1542/peds.2009-3146
7. Cook JT, Frank DA. Food Security, Poverty, and Human Development in the United States. *Ann N Y Acad Sci* 2008;1136:193-209. Epub 2007 Oct 22.
8. Jyoti DF, Frongillo EA, Jones SJ: Food insecurity affects school children's academic performance, weight gain, and social skills. *J Nutr* 2005, 135:2831–2839.
9. Weinreb L, Wehler C, Perloff J, Scott R, Hosmer D, Sagor L, et al. Hunger: its impact on children's health and mental health. *Pediatrics* 2002;110(4). Available at: doi: 10.1542/peds.110.4.e41)
10. Seligman HK, Schollinger D. Hunger and socioeconomic disparities in chronic disease. *N Engl J Med* 2010, 363(1):6–9.
11. Nalty CC, Sharkey JR, Dean WR. Children's reporting of food insecurity in predominately food insecure households in Texas border colonias. *Nutr J* 2013; 12:15.
12. *FAO* 2011. El Estado de la Inseguridad Alimentaria en el Mundo. Disponible en: [http://www.fao.org/docrep/014/i2330s/i2330s00.htm)] (Acceso 10 de diciembre de 2014)
13. Martin-Fernandez J, Grillo F, Parizot I, Caillavet F, ChauvinP. Prevalence and socioeconomic and geographical inequalities of household food insecurity in the Paris region, France, 2010. *BMC Public Health* 2013, 13:486
14. *FAO* 2002. Memorias del Simposio Científico sobre Medición y Evaluación de la Carencia de Alimentos y la Desnutrición. Roma. Disponible en: [http://www.fao.org/DOCREP/005/Y4250S/y4250s00.htm] (Acceso 10 de diciembre de 2014).
15. Escala latinoamericana y caribeña de seguridad alimentaria (ELCSA): manual de uso y aplicaciones. Comité Científico de la ELCSA. *Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO)* Mayo de 2012
16. Food and Nutrition Technical Assistance Project (FANTA) Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide. VERSION 3. *August* 2007
17. Nord M, Hopwood H. Recent Advances Provide Improved Tools for Measuring Children's Food Security. *J Nutr* 137: 533–536, 2007
18. Radimer KL, Olson CM, Greene JC, Campbell CC, Habicht JP. Understanding hunger and developing indicators to assess it in women and children. *J Nutr Educ* 1992;, 24(1):36S-44S.
19. Opsomer JD, Jensen HH, Pan S. An evaluation of the U.S. Department of Agriculture food security measure with generalized linear mixed models. *J Nutr Educ* 2003, 133(2):421-7.
20. Carlson SJ, Andrews MS, Bickel GW. Measuring food insecurity and hunger in the United States:development of a national benchmark measure and prevalence estimates. *J Nutr Educ* 1999;129(2S):510S-16S.
21. Connell CL, Nord M, Lofton KL, Yadrick K. Food security of older children can be assessed using a standardized survey instrument. *J Nutr Educ* 2004;134(10):2566-72.
22. Melgar-Quiñonez H, Hackett M. Measuring Household Food Security: the Global Experience. *Revista de Nutrição* 2008; 21(S):27s-37s.
23. National Research Council and Institute of Medicine. Research Opportunities Concerning the Causes and Consequences of Child Food Insecurity and Hunger: A Workshop Summary. N. Kirkendall, C. House, C. Citro, rapporteurs, Committtee on National Statistics, Division of Behavioral and Social Sciences and Education, National Research Council, and Food and Nutrition Board, Institute of Medicine, Washington, DC: The National Academies Press, 2014
24. Fram MS, Frongillo EA, Jones SJ, Williams RC, Burke MP, DeLoach KP, Blake CE: Children are aware of food insecurity and take responsibility for managing food resources. *J Nutr* 2011, 141:1114-1119.
25. Sharkey JR, Dean WR, Nalty CC. Child hunger and the protective effects of supplemental nutrition assistance program (SNAP) and alternative food sources among Mexican-origin families in Texas border colonias. *BMC Pediatrics* 2013, 13:143
26. Deitchler M, Ballard T, Swindale A, Coates J. Validation of a Measure of Household Hunger for Cross-Cultural Use. *Washington, DC: Food and Nutrition Technical Assistance II Project (FANTA-2), FHI 360* 2010.
27. Kennedy G, Ballard T, Dop MC. Guidelines for measuring household and individual dietary diversity. *Rome: FAO* 2011. Recuperado en [http:// www.fao.org/fileadmin/ user_upload/wa_workshop/docs/FAOguidelines-dietary-diversity2011.pdf] (Acceso 20 de febrero de 2014).
28. Ballard TJ, Kepple AW, Cafiero C. The food insecurity experience scale: developing a global standard for monitoring hunger worldwide. Technical Paper. *Rome: FAO* 2013. (Available at http://www.fao.org/economic/ess/ess-fs/voices/en/) (Acceso 10 december 2014).
29. Pérez-Escamilla R, Himmelgreen DA, Ferris A. Community Nutritional Problems among Latino Children in Hartford, Connecticut. *Connecticut Family Nutrition Program Technical Report #1* 1997.

30. Álvarez Uribe, MC. Caracterización de los hogares de Colombia en Inseguridad Alimentaria según Calidad de Vida. *Revista de Salud Pública, Instituto de Salud Pública, Universidad Nacional de Colombia* 2010; 12 (6): 877-888 Disponible en: [http://www.scielosp.org/scielo.php?script=sci_arttext&pid=S0124-00642010000600001&lng=pt&nrm=iso].

31. Panigassi G, Segall-Corrêa AM, Pérez-Escamilla R, Sampaio MFA, Marín-León L, Maranha LK. Insegurança alimentar intrafamiliar e perfi l de consumo de alimentos. *Revista de Nutrição da PUCCAMP* 2008. Disponible en: [http://www.scielo.br/pdf/rn/v21s0/12.pdf].

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):279-289
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Methods for monitoring the functional status of the circadian system in dietary surveys studies: application criteria and interpretation of results

Marta Garaulet and Juan Antonio Madrid

Department of Physiology, University of Murcia. IMIB. Murcia. Spain.

Abstract

To evaluate the circadian system status of the subject may be of special interest in nutrition. Particularly for those studies related to the assessment of diseases related to malnutrition, as it is the case of most of the degenerative diseases such as obesity, cancer, or cardiovascular diseases. For this purpose, one of the approaches consists to measure a) the external synchronizers of the internal clock, such as light intensity, and changes from fasting to eating and from resting to activity. Indeed, "chronodisruptors" have been defined as "exogenous and endogenous exposures or effectors which are chronobiologically active and can thus disrupt the timing and order.

Another approach to assess the circadian system health is to measure the b) outputs of the internal clock (circadian marker rhythms). Among such outputs, the rhythm of body temperature, motor activity, melatonin, cortisol and clock gene expression are the most commonly used. From the genetic perspective, we are now able to measure failures in the internal clock, in order to assess c) the genetics of the molecular clock. Indeed, new nutrigenetics techniques are giving us the opportunity to measure the association between different genetic variants of our clock genes and several illnesses such as obesity, cardiovascular diseases, diabetes or cancer. In addition to these techniques, self-reported questionnaires based in the morning-evening preferences have been developed as complementary procedures to assess human chronotypes.

(*Nutr Hosp* 2015;31(Supl. 3):279-289)

DOI:10.3305/nh.2015.31.sup3.8776

Key words: *Circadian rhythm. Circadian dysregulation. Meal timing. Cosinor analyses. Body temperature.*

MÉTODOS CRONOBIOLÓGICOS EN LAS ENCUESTAS ALIMENTARIAS: CRITERIOS DE APLICACIÓN E INTERPRETACIÓN DE RESULTADOS

Resumen

Evaluar el estado del sistema circadiano del sujeto puede ser de especial interés en la nutrición. En particular, para los estudios relativos a la evaluación de las enfermedades relacionadas con la malnutrición como es el caso de la mayoría de las enfermedades degenerativas tales como la obesidad, cáncer, o enfermedades cardiovasculares. Para este propósito, uno de los enfoques consiste en medir a) los sincronizadores externos del reloj interno, tales como intensidad de la luz, y los cambios de ayuno/ingesta y de reposo/actividad. De hecho, se ha definido el término de "cronodisruptor" que se refiere a "exposiciones o efectores exógenos y endógenos que son cronobiológicamente activos y que por lo tanto pueden interrumpir el tiempo".

Otro enfoque para evaluar la salud del sistema circadiano es medir b) las salidas del reloj interno (ritmos circadianos). Entre ellos las más utilizadas son la medición del ritmo de la temperatura corporal, la actividad motora, la melatonina, el cortisol y la expresión de genes reloj. Desde el punto de vista genético, ahora somos capaces de medir c) las alteraciones del reloj interno, con el fin de evaluar la genética del reloj molecular. De hecho, las nuevas técnicas de nutrigenética nos están dando la oportunidad de medir la asociación entre las diferentes variantes genéticas de nuestros genes reloj y varias enfermedades como la obesidad, las enfermedades cardiovasculares, la diabetes o el cáncer. Además de estas técnicas, se han desarrollado cuestionarios basados en las preferencias de mañana-tarde como procedimientos complementarios para evaluar cronotipos humanos.

(*Nutr Hosp* 2015;31(Supl. 3):279-289)

DOI:10.3305/nh.2015.31.sup3.8776

Palabras clave: *Ritmos circadianos. Cronodisrupción. Hora de la comida. Análisis de cosinor. Temperatura corporal.*

Correspondence: Marta Garaulet.
Department of Physiology. Faculty of Biology.
University of Murcia.
Campus de Espinardo, s/n.
30100, Murcia, Spain.
E-mail: garaulet@um.es

Introduction

To evaluate the circadian system status of the subject may be of special interest in nutrition. Particularly for those studies related to the assessment of diseases related to malnutrition, as it is the case of most of the degenerative diseases such as obesity, cancer, or cardiovascular diseases. Current epidemiological studies have demonstrated that several situations in life such as shift working, night eating, jet lag and short sleep, are accompanied by a disruption of the individual circadian rhythms. Chronodisruption (CD) is a relevant disturbance of the circadian organization of physiology, endocrinology, metabolism and behavior, which links light, biological rhythms and the development of several diseases.

The International Agency for Research on Cancer (IARC) classified shift-work that involves circadian disruption as probably carcinogenic to humans in 2007 and this was the prelude to extensive experimental and epidemiological research in coming years[1]. Moreover, it was pointed out in Lancet Oncology that among the many different patterns of shift-work, those including night work were the most disruptive for the circadian clock. Indeed, with 20% of people worldwide being engaged in some work at unusual times, including the night, it is a relevant task in public health to clarify the biologically plausible links *via* circadian disruption with epidemic cancers such as of the breast or prostate.

The effect of CD on human health is an emerging issue. Many records link CD not only with cancer but also with cardiovascular, cognitive impairment and obesity, all of them conducive to premature aging. The precise mechanisms linking obesity to CD are not well known. It has been hypothesized that current habits, such as high snacking frequency, a reduction in total daily sleep and increased exposure to bright light during the night, and "inadequate" meal timing induce brain to lose its 'feeling' for internal and external rhythms. The lack of day–night environmental contrast may lead to CD and metabolic disturbances, including obesity. Conversely, studies performed using experimental models have shown that developing obesity and diabetes itself disrupts the molecular clock system. Both, as a cause or as a consequence, CD is closely linked to obesity.

Methods for monitoring the functional status of the circadian system

The role placed by the circadian system in maintaining health underlines the importance of developing techniques for its objective evaluation, just as there are techniques that evaluate the respiratory and cardiovascular systems. The main challenge is to be able to measure a process that develops over long periods of time, which implies multiple measurements, preferably ones that do not interfere with the subject's daily routine[2].

One of the approaches consists to measure a) the **external synchronizers** of the internal clock, such as light intensity, and changes from fasting to eating and from resting to activity. Indeed, **"chronodisruptors**" have been defined as "exogenous and endogenous exposures or effectors which are chronobiologically active and can thus disrupt the timing and order, i.e. temporal organization of physiologic functions and hierarchies"[1]. In principle, whatever allows the establishment of temporal organizational order in organisms should also be capable of disrupting such order when present or applied in excess or deficit and, most importantly, at unusual and inappropriate times. In this sense, apart from light, other external chronodisruptors are inadequate meal timing and exercise timing[3].

Another approach to assess the circadian system health is to measure the b) **outputs of the internal clock** (circadian marker rhythms). Among such outputs, the rhythm of body temperature, motor activity, melatonin, cortisol and clock gene expression are the most commonly used[4]. From the genetic perspective, we are now able to measure failures in the internal clock c) **the genetics of the molecular clock**. Indeed, new nutrigenetics techniques are giving us the opportunity to measure the association between different genetic variants of our clock genes and several illnesses such as obesity, cardiovascular diseases, diabetes or cancer. In addition to these techniques, **self-reported questionnaires** based in the morning-evening preferences have been developed as complementary procedures to assess human chronotypes[5-7].

Methods to measure external synchronizers

Light exposure

The circadian system is regulated by external signals, which are responsible for setting the clock each day. Given that the light-dark cycle is the most important synchroniser, it is of great interest to be able to quantify the light exposure of individuals. Low levels of illumination during the day lower the central temperature and state of awareness compared with the levels observed in high illumination[8]. However, during the night exposure to light, especially blue light, should be avoided in order to maintain melatonin secretion.

Indeed, one key external chronodisruptor is light at night. Under natural conditions, biological circadian and seasonal rhythms are synchronized to the regular 24-hr and seasonal light–dark cycles and the suprachiasmatic nuclei and melatonin have critical roles in these processes. In fact, light is a key Zeitgeber affecting melatonin rhythms and the circadian rhythms of melatonin can provide clock (24 hr) and calendar (seasonal and yearly) information for many species, including humans[1].

The light-darkness cycle to which subjects are exposed can be quantified by small data loggers, that contain a photosensitive cell, that periodically record the light

intensity received by the individual. Recently, sensors that differentiate between light wavelengths (blue, red and green) have become available, which means that the blue light, which has a greater capacity to synchronise the circadian pacemaker, can be accurately evaluated. The combination of these sensors with environmental temperature sensors provides complete information concerning the quality of the environmental synchronisers that act on the circadian system[8]. They also enable poor sleep hygiene habits to be identified; for example, sleeping in illuminated environmental conditions or in too high temperatures.

Meal timing (changes from fasting to eating)

The meal times (and number of meals consumed) differ greatly from culture to culture and through time. Indeed, timing of food intake is a modifiable behaviour that may influence energy regulation and consequently the risk of obesity. Several studies performed in experimental animals have demonstrated that when the animals eat at the "wrong time" they become obese, although they apparently eat and expend the same amount of energy[3].

Our group of research have demonstrated that the timing of the main meal (lunch) in a Mediterranean population from Spain, is predictive of the weight loss during a 20-week dietary intervention conducted in 420 obese and overweight individuals[9]. Another relevant result from this study was that insulin sensitivity was lower in late eaters as compared to early eaters. However, the physiological explanation for this novel discovery was unknown. In order to deep in these results we developed a randomized, crossover protocol in which we studied the same women (n=32) in two conditions: one week having lunch at 1 PM and the other at 4.30 PM. We demonstrated that eating late is associated with decreased resting-energy expenditure, decreased fasting carbohydrate oxidation, decreased glucose tolerance, blunted daily profile in free cortisol concentrations and decreased thermal effect of food on peripheral temperature. These results may be implicated in the differential effects of meal timing on metabolic health (Fig. 1).

Different methods may be used to assess habitual dietary intake and meal timing: For example, to evaluate food habits, initial nutrient intake can be determined by a 7 days dietary record. In each day subjects should record everything they eat and also the timing that they start or finish each meal. Patients can also record during one week the time at the day that they start every meal with the questionnaire developed by Bertéus et al.10 (Fig. 2).

Other questionnaire used to assess the circadian changes on hunger and appetite is the one developed by Flint *et al.*, of visual analogue scales (VAS) for measurement of appetite sensations. VAS are used to record hunger, satiety, fullness, prospective food consumption, desire to eat something fatty, salty, sweet or savory, and palatability of the meals[11]. These questionnaires may be completed before and after each meal everyday during one week.

Exercise timing (changes from activity to inactivity)

Actigraphy is a non-invasive method useful to measure the rest-activity cycle in humans. It is based on the principle that during periods when the individual

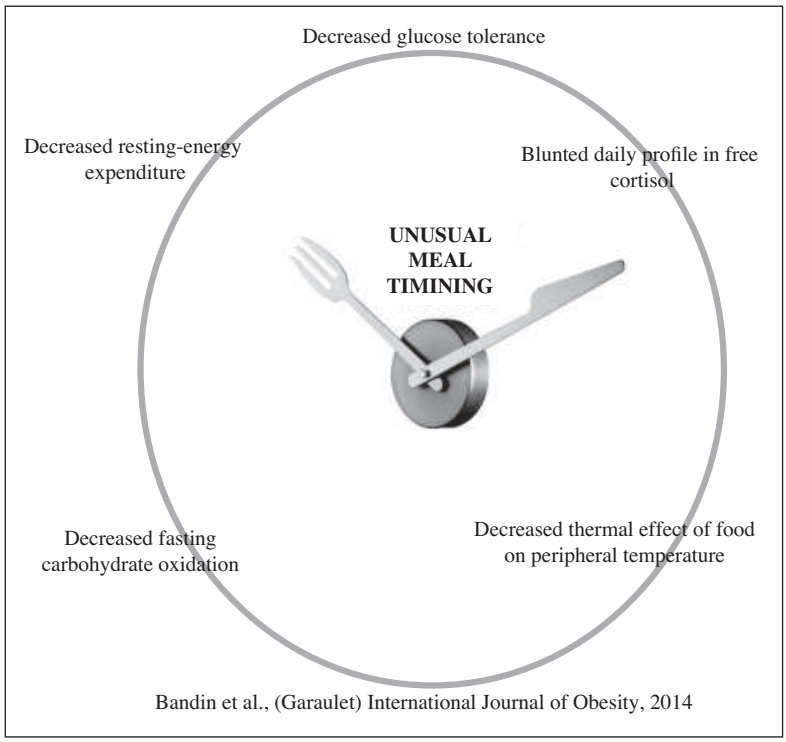


Fig. 1.—Effects of meal timing on metabolic health[34].

Describe how you cat during a usual 24-hour period. Give a time for cach cating episode and mark with a **cross** the type of meal which corresponds best.

Do not forget snacks, other "light meals" and drinks.

Note, you can have several main meals during a day.

	Type of meal			
Time	Main meal e.g. cooked dish, soup with bread, salad with bread, pizza	Light meal/ Breakfast e.g. porridge, cereals, sandwiches, soup, salad, omelette	Snack meal e.g. a sandwich, biscuit, bun, cake, fruit, sweets, ice cream (w/ or w/o a drink)	Drink, only e.g. coffee, tea, soft drink, juice, milk, beer, wine
Example: 2300				X

Fig. 2.—Questionnaire of Bertéus et al.,[10] in meal timing.

is awaken; activity levels are high compared to when the individual is asleep. For its measurement, an activity sensor (actimeter) is placed on the wrist of the non-dominant hand for not less than 5 days, the minimum period to obtain reliable data that reflect the characteristics of the subject[12].

Actigraphy has been used to study sleep/wake patterns for over 20 years. The advantage of actigraphy over traditional polysomnography (PSG) is that actigraphy can conveniently record continuously for 24-hours a day for days, weeks or even longer[13]. It is also considered the method of choice for evaluating and diagnosing circadian disorders such as chronodisruption in shift-workers, delayed and advanced sleep phase syndrome, free running syndrome and irregular circadian rhythms[14]. However, as with any other measurement, actigraphy is subject to masking and artefacts, for example, the difficulty in differentiating between the beginning of night rest and the removal of the sensor to shower just before going to bed, movements of one's bed partner, sleeping in a car or train, etc.[15].

Other methods are 7 days activity records, in which subject record the timing, type and intensity of the daily physical activity performed during one week, including weekdays and weekends.

Methods to measure "Outputs of the clock"

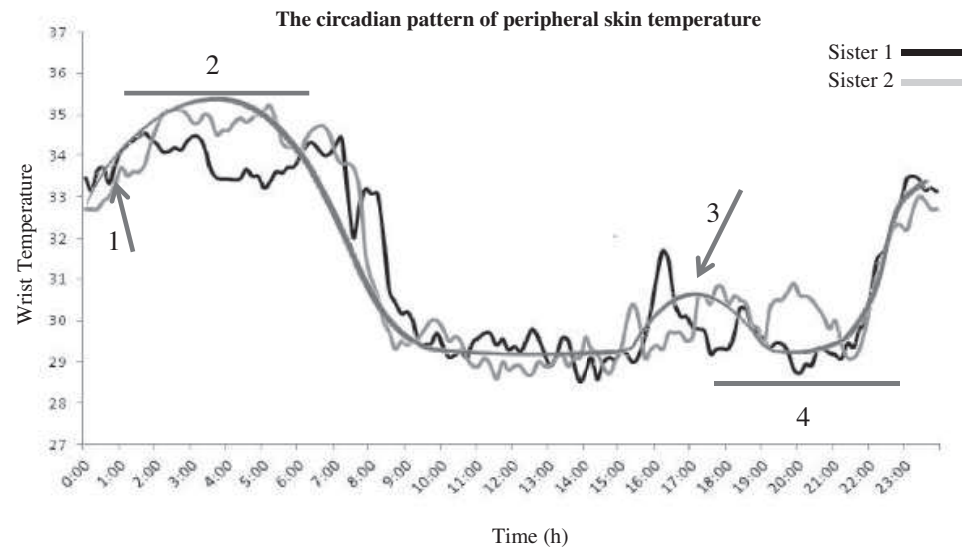
Central and peripheral thermometry

One of the most commonly used marker rhythms is the central temperature rhythm, whose profile has been widely described[16,17] and in which the highest values occur in the day and lowest at night.

In humans, the central temperature is usually measured by means of rectal probes that should be worn for several days, which is obviously uncomfortable. Recently as an alternative to measuring the central temperature, the rhythm of skin peripheral temperature has been proposed as a marker rhythm[18-21]. This rhythm is induced by the alternation between vasodilatation and vasoconstriction generated by the parasympathetic-sympathetic balance. The predominance of sympathetic activity during the day is associated with lower temperatures, while its inhibition and the simultaneous activation of the parasympathetic system are associated with higher temperature. Moreover, increased skin temperature constitutes a signal that favours the beginning of nocturnal sleep through stimulation of hypothalamic areas[22].

The circadian pattern of peripheral skin temperature exhibits some characteristics phases (Fig. 3)[18]. It increases prior to sleep and remains high during the night. Upon awakening, the temperature falls abruptly and remains low during the day. About 20-21h, when the peripheral temperature reaches its lowest value it is difficult to go to sleep in normal circumstances, this phase is known as wake maintenance zone.

The most used procedure to record skin temperature consists of a small autonomous data logger, placed on the internal surface of the wrist (over a radial artery) of the non-dominant hand and held in place by a bracelet or watch. The sensor can also be placed in any other peripheral region such as the arm, ankle or finger[18,19]. This easily obtained measure has been



1) Sharp increase in anticipation to sleep onset
2) High levels during nocturnal sleep
3) A secondary peak in the afternoon
4) A dip between 20:00 and 22:00h, a period known as the "wake maintenance zone"

Fig. 3.—24-h waveform of wrist skin temperature (WT) of two monozygotic sisters recorded continuously for seven days[59]. The standard skin temperature rhythm exhibits a sharp increase in anticipation to sleep onset, it maintains high levels during nocturnal sleep and shows a secondary peak in the afternoon.

shown to be useful to characterize biorhythms in a variety of population groups including babies[23] and young people[8,19] as well as to identify CD associated with different pathologies such as hypertension[24], metabolic syndrome and obesity[20,21,25,26]. Moreover, it has been shown that wrist skin temperature (WT) rhythm has a distinct endogenous component, even in the presence of multiple external influences. Therefore, WT has been proposed as an informative and minimally invasive technique to measure circadian rhythm in free-living subjects[27].

Melatonin

Melatonin is considered the best marker of the circadian system phase. However, its profile is strongly influenced by light exposure and, to a lesser extent, body position, physical activity, sleep, caffeine and drugs like beta-blockers[28-31]. Plasma levels of melatonin show a circadian profile, with low levels during the day and high levels during the night, the highest being between 02:00 and 04:00am. In humans, melatonin contributes to the body temperature rhythm since it is responsible for vasodilatation of the skin of the extremities through its activation of thermosensitive neurons present in brain areas involved in sleep regulation. The melatonin secretion schedule is closely related with the propensity to sleep and coincides with a fall in the central body temperature, arousal level and performance[32]. Indeed, since 1992 we know that the circadian rhythms of melatonin and body temperature are inversely coupled.

The hypothermic properties of melatonin are accountable for the generation of at least 40% of the amplitude of the circadian body temperature rhythm. Manipulation of melatonin levels might be clinically useful to resynchronize the body temperature rhythm under conditions of body temperature rhythm desynchronization.

The levels of melatonin can be reliably measured in plasma, saliva and urine (in the last case as its metabolite, 6-sulfatoximelatonin). The best time to evaluate melatonin as a marker of the circadian rhythm coincides with its rapid increase at nightfall. Since its levels are altered by exposure to environmental light of a given intensity and spectrum, it is generally accepted that melatonin samples taken during the dark period should be collected under a dim light (< 50 lux), which is why this protocol is known as *DLMO* (*Dim Light Melatonin Onset*)[33]. It is sufficient to start sampling 2 to 3 hours before the subject's normal bedtime (around 19:30-22:00h), assuming that the individual shows no phase alterations.

Cortisol

Cortisol is a corticosteroid with a robust circadian profile peaking around the usual waking time and with much lowers values as the day progresses and reaching its lowest value about 2 hours after going to sleep. The physiological significance of this increase consists of preparing the body for the forthcoming days, increasing the blood pressure, plasma concentrations of glucose, cardiac output, etc. Because of its robustness,

this rhythm is also considered a good marker of the circadian system.

Similarly to the other variables mentioned above, cortisol levels can be affected by external factors such as food timing[34], stressful situations, light exposure at given moments of the day[35], hyperproteic meals or obesity[36]. Non-pathological situations such as aging also affect the cortisol profile. The sleep-wake profile can even modify cortisol rhythm. Sleep deprivation, the predominance of light sleep, and a certain number of nocturnal awakenings will increase cortisol levels[37].

Cortisol can be measured in serum or saliva, the most critical times for measuring its circadian profile being the increase just before waking up and its minimum level in blood at the end of the day/beginning of night.

Sleep and Wakefulness patterns (integrated variables)

Sleep is not a clear "output" of our internal clock. However, it is modifiable by the subject, and because it can also change the individual exposition to the external synchronizers such as light, it is able to influence the internal clock function. Moreover, it is clear that synchronization of the sleep wake schedule and the internal clock is essential to an individual's ability to maintain sleep and wakefulness when desired. For example, to fly across time zones or to work night shifts, desynchronize sleep and wake patterns from the internal clock's circadian rhythms and result in an alerting signal that is too low when an individual wishes to be awake and too high to allow for a consolidated period of sleep.

Therefore, to measure the circadian pattern of sleep and wakefulness may be relevant in chronobiological and nutritional studies. For this purpose, Laboratory-based polysomnography (PSG) is widely used. It is a comprehensive recording of the biophysiological changes that occur during sleep. The PSG monitors many body functions including brain (EEG), eye movements (EOG), muscle activity or skeletal muscle activation (EMG) and heart rhythm (ECG) during sleep.

Although PSG is the gold standard to measure sleep objectively it is impractical for long-term and home utilization. Therefore, alternative techniques have been developed. The validity of self-recording as a means of collecting data on sleep and wakefulness is still an open question, though it is probably as reliable as any other subjective method and is the most convenient way of accumulating data when a large sample of subjects must be used. Current evidence has shown that, overall, actigraphy is an excellent tool for unobtrusive documentation of sleep/wake activity in normal individuals. However, a number of methodological issues remain to be resolved to warrant its use in clinical research.

In order to increase the reliability of circadian monitoring, integrated variables obtained from processing individual variables have been recently proposed. For example, the TAP algorithm, proposed by Ortiz-Tudela et al.[19], is based on integrating, after normalisation, the following variables: skin temperature, motor activity and body position (Fig. 4). The first of these variables, skin temperature, is under endogenous control, while motor activity is modified voluntarily but it is also under endogenous control. Lastly, of the three variables used for the integration, body position is the most closely dependent on voluntary control. TAP is modular thus it can be amplified by incorporating new variables that complement the information even further. TAP variable permits us not only to determine how the individual's circadian system functions, but also to infer the sleep-wake rhythm with a precision higher than 90% according to polysomnographic recording. This technique constitutes the base of ambulatory circadian monitoring procedure (ACM), which recently has been applied to evaluating the circadian maturity in newborns[23], and pathologies like metabolic syndrome[21].

Methods to measure "failures in the internal clock"

Genetics of the molecular clock

The capacity to undergo rhythmic oscillations is a characteristic intrinsic to living matter. A fundamental statement of chronobiology states 'many rhythms persist even in complete isolation from the major known environmental cycles'. This concept supports that natural rhythms can exist independently of the periods defined by geophysical cycles; this means that living matter has its own time, i.e., the 'biological time'. In this sense, it has been hypothesized the existence of a Chronome within the Genome.

Over the past two decades, biochemical, genetic, and molecular studies have been making substantial advances towards the elucidation of the molecular bases of rhythmicity in living things. Riding on the wave generated by the seminal studies in the 1970's focusing on in the circadian variability of hormones such as cortisol, melatonin or growth hormone (GH), or those related to the discovering and description of the physiological bases of the suprachiasmatic nucleous (SCN), current chronobiology has dramatically evolved thanks to the new genetic and molecular biology techniques.

A major stride in understanding the molecular basis of circadian rhythms was the identification by Konopa and Benzer in 1971[38] of a chromosomal region controlling the period of eclosion time in Drosophila, followed by the cloning of the first clock genes in *Drosophila melanogaster* in 1984[39]. Today, thanks to these molecular techniques, we are able to study the expression of the known clock genes implicated in the circadian machinery. We already know that, in mammals, the core components of the clock molecular ma-

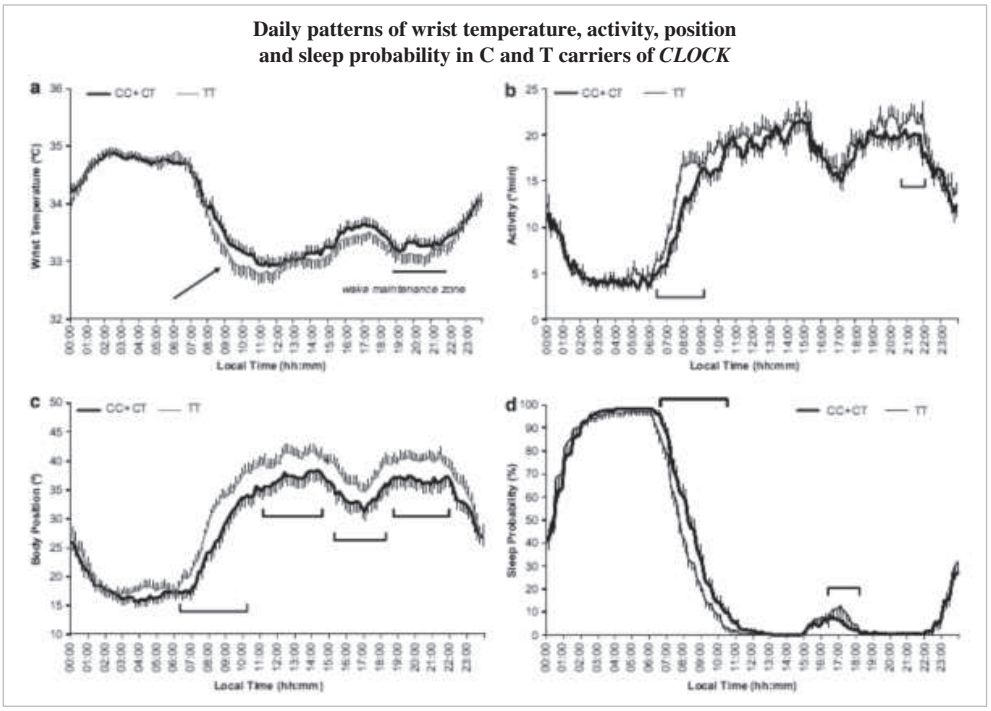


Fig. 4.—Skin temperature, motor activity and body position in CLOCK 3111TC[60].

chinery operate in almost all cells of the body through a complex network of transcriptional-translation loops and modulate the expression of specific target genes and their products to oscillate in 24-hour rhythm.

Nowadays, experimental models are allowing us to assess clock genes expression not only in the living animal but also outside of the body, (*in vitro* techniques), and we are also able to analyze the 24h fluctuations in gene expression and to assess the presence or absence of a peripheral clock in the different organs and tissues. Moreover, we can use experimental models to turn on and off specific components of the clock machinery to identify its effects on metabolic and disease phenotypes. From the genetic epidemiology point of view, the study of single nucleotide polymorphisms (SNPs), is contributing to the identification of the genetic background of chronotypes (morningness or eveningness), sleep alterations or seasonal mood disorders.

More recently, **epigenetic and nutrigenetic** approaches are also allowing us to study new interactions and layers of complexity that may have a significant impact on chronobiology as well as pathophysiology. *Epigenetics* is the study of heritable changes in gene expression or cellular phenotype caused by mechanisms other than changes in the underlying DNA sequence. *CLOCK* and *SIRT* have both epigenetics effect in acetylation and deacetylation of histones respectively. MicroRNAs may become novel therapeutic targets for disorders in the circadian clock. The knowledge achieved in the circadian epigenome could give us new answers to the connections among genetics, circadian rhythmicity and obesity.

Moreover, the technological power of other "-omics" (i.e., metabolomics, proteomics) is becoming essential to our ability to "put-it-all-together" and we are fast learning about the timing of different metabolites such as aminoacids, lipids, xenobiotic, etc. in the liver in mice, and in plasma and saliva in humans, allowing us to achieve a more complete and refined knowledge of the circadian rhythm and its physiological effects. These advances have given to the science of chronobiology a renewed stimulus that makes this science increasingly robust and attractive.

Genetic variants associated to chronodisruption

Some examples of SNPs in chronobiology are *CLOCK* 3111TC which has been associated with eveningness, and different personality traits; *PERIOD2* (*PER2* rs2304672) polymorphism which moderates circadian-relevant reward circuitry; *CRY1* (rs8192440) related to psychological treatment effectiveness; *CRY2* associated with winter depression and S*IRT1* rs10997875 a good candidate gene for the pathophysiology for mood disorders.

Other candidate SNPs connected to obesity could be those associated to sleep disorders. Some examples are serotonin receptors, prepro-orexin or IL-6 SNPs which associate with obstructive sleep apnea syndrome. Others are SNPs residing in ROR1 and PLCB1which associated with insomnia.

Sleep disorders or short sleep duration, are both associated to several polymorphisms connected to obesity. In this regard, one of the best studied *CLOCK* SNPs (3111TC) has been significantly associated to short sleep duration, eveningness, several psychological traits, weight loss[40] and obesity[41,42].

Expression of clock genes in leukocytes and oral mucosa

The neurons that constitute the SCN and the cells of the peripheral oscillators show an autonomous rhythmicity that is controlled by the cyclic expression of the clock genes (*Clock, Bmal1, Per 1, Per 2, Per 3 y Cry 1 y Cry 2*). The involvement of these genes in numerous physiological processes (cell cycle regulation, adipogenesis, glucocorticoid synthesis, B cell maturation, etc.) and their probable misalignment in certain pathologies increase the interest of being able to quantify their expression. For this, polymerase chain reaction (PCR) techniques are usually used[43]. The most straightforward is RT-PCR, which enables us to qualitatively evaluate which genes are being expressed at the time of sampling. To know which genes are being expressed and its quantification, a quantitative PCR (Q-PCR) or a real time PCR is normally used.

Since it is not possible to evaluate clock gene expression in the SCN *in vivo*, samples obtained from peripheral tissues are used. In this case, there are two main options: evaluate gene expression in leukocytes or in the oral mucosa. In the first case, blood samples are periodically taken, the leukocytes are isolated from the rest of the blood cells and one of the above techniques is applied. In the case of oral mucosa, the most common practice has been to take small biopsies under local anaesthetic[44], although, more recently, pipette tips have been used to make scrape off a small amount of the mucosa, which provides sufficient tissue to be obtained[45].

Clock gene expression in adipose tissue (peripheral clock)

In the last years, one of the most influential discoveries relevant for this area of research is the presence of an active circadian clock in adipose tissue (Fig. 5). In particular, our group has recently demonstrated that the circadian clockwork can oscillate accurately and independently of the SCN in AT explants[46]. Moreover, we have provided an overall view of the internal temporal order of circadian rhythms in human AT including genes implicated in metabolic processes such as energy[47]. Thus, a specific temporal order in the daily patterns of these genes appears to be crucial for adipose tissue to exclusively either accumulate fat or to mobilize fat at the proper time, a phenomenon known as temporal compartmentalization.

Fig. 5.—Presence of an active circadian clock in adipose tissue[47].

Protocols for measuring circadian rhythms

To evaluate the circadian system, techniques that eliminate or minimise the influence of external factors (denominated masking factors) are used. For this reason, measurements are normally made in subjects in conditions of constant routine, for example, lying in bed, without sleeping, under constant dim light and ingesting food at regular intervals over 24 hours[48]. This situation of constant routine is usually maintained for 24, 36 or 48 hours, although this, in itself, may introduce its own masking factors. One such factor is that the subject must go without sleep and fight against sleep pressure. To avoid the accumulation of sleep pressure, the multiple-nap protocol has been designed. This is a constant routine protocol with multiple naps scheduled over a 24-hour period or longer.

In an attempt to cut the link between environmental cycles and endogenous rhythms, alternative protocols (known as forced desynchronization) have been developed in which the subject lives 28-hour (or, less frequently, 20-hour) days[48,49]. Under these protocols, sleep episodes occurred at all phases of the endogenous periods. Circadian and sleep components can be distinguished very well in this way.

Analyses of circadian rhythm.

The analysis of rhythmic data requires its own methodology that differs from conventional statistical and mathematical techniques. Two procedures are basically used for this purpose, one based on fitting sinusoidal functions (the cosinor method) and the other based on a non-parametric analysis.

Cosinor analysis is a mathematical procedure based on least squares fitting of a cosine function to the original data. Three main parameters are defined from the cosinor fit: MESOR (Midline Estimating

Statistic of Rhythm), amplitude and acrophase[50]. Since it is applicable to unequidistant data, Mesor does not always coincide with the data mean. The amplitude is the difference between the Mesor and the maximum or the minimum value of the cosinusoidal function. The acrofase is the temporal localisation of the maximum value of the function. Given that the human rest-activity rhythm has a asymmetric distribution over 24 hr (about 8 rest:16 activity) and a shape that looks more like a square wave than a pure cosinusoid, the cosinor method only provides a rough and general description of the rest-activity rhythm. However, it is a relatively straightforward method that enables a great quantity of quantitative information to be obtained.

To give a more precise estimation of the rhythmic parameters of physiological functions that do no exhibit a symmetrical waveform, non-parametric procedures are increasingly used. Although these procedures were initially developed for actimetry data[51], it is also useful for analysing other biological variables. The most frequent parameters are interdaily stability (IS), intradaily variability (IV), least active 5 hr (L5), most active 10 hr (M10), L5 and M10 onset or midtime, amplitude (AMP) and relative amplitude (RA). IS quantifies the regularity of the rhythm, that is, the degree of resemblance between the rhythmic patterns on individual days. It ranges from 0 to 1, a typical value for human actimetry data being about 0.6 for healthy adults. IV determines the fragmentation of the rhythm. It ranges from 0 to 2, typical values in healthy subjects being below 1. L5 indicates the average values for the 5 least active consecutive hours in the 24 hr cycle. M10 is the average of the activity values for the ten most active consecutive hours in the 24-hr cycle. The midpoint of L5 and M10 gives reliable information about the phase of the rhythm, similar to that given by the acrophase and nadir of the cosinor method. AMP is the difference between M10 and L5, whereas RA is calculated by dividing AMP by the sum of L5 and M10. It ranges form 0 to 1, with higher values indicating higher amplitude of the rhythm.

Chronodisruption scores and biomarkers

Given the importance of a normal circadian rhythm in maintaining regular weight, it could be useful to define a biomarker of circadian deregulation that could be implemented in clinical practice. This biomarker could also be used as a tool for monitoring the effects of introducing a change in lifestyle designed to reduce the risk of obesity[52]. For this purpose and to detect the best biomarker to assess CD in obesity, our group of research tested in a female population several biomarkers of the circadian system previously used in different population types. In this regard, we used techniques that have been shown to be easily measurable and non-invasive, such as (a) sleep diaries, which examine the wake/sleep cycle and which have been demonstrated to be a convenient tool to assess sleep quality and duration[53]; (b) a feeding diary, an adequate tool to analyze the timing and duration of food intake[54]; (c) the Horne–Ostberg questionnaire, which is recommended to define the morningness-eveningness of the subject[55,56]; (d) salivary melatonin and cortisol defined as good markers to assess CD[57]; and finally (e) the measurement of the skin temperature rhythmicity, particularly wrist temperature (WT)[24].

Our results show that from the different biomarkers studied in the present work, the measurement of skin temperature rhythmicity, together with two questions of the sleep diary (sleep onset and offset times), and one morning salivary cortisol determination could be enough to characterize the chronobiology of obesity.

After including the several factors studied in a factor analyses we were able to define a Cronodisruption (CD) score. The results obtained showed that patients could be divided into two populations attending to circadian misalignment. Indeed, the cut-off point to divide the population was found in a value of 40.3 points, with a higher score indicating major risk of CD. The correlation analysis showed that patients with major CD scores had higher risk of obesity and MetS. Indeed, body fat percentage, plasma glucose values, and blood pressure were positively correlated with the final punctuation. With respect to triglycerides, total cholesterol and LDL cholesterol correlated with higher scores, while HDL cholesterol correlated with lower scores.

Morning eveningness questionnaires

The morningness–eveningness questionnaire (MEQ) is a self-assessment questionnaire developed by Horne and Östberg in 1976[58]. Its main purpose is to measure whether a person's peak alertness is in the morning, in the evening or in between. The original published study on the MEQ showed that subjective peak alertness time correlates with a time of peak body temperature; morning types have an earlier peak of oral temperature than evening types, with the intermediate types having temperature peaks between the two groups. The MEQ is widely used in many areas of psychological and medical research.

More recently, new questionnaires have been also developed, this is the case of the Munich Chronotype Questionnaire (MCTQ)[7]. Questions about work day and free day sleep schedules, work details, and lifestyle provide data to aid in the understanding of how biological clocks work in social life, such as Roenneberg's conclusions of social jetlag. The MCTQ categorizes each participant into one of seven chronotype groups, and utilizes data on participants' midsleep phase and sleep debt to survey what "type" of sleeper each person is.

References

1. Erren TC, Reiter RJ. Defining chronodisruption. *Journal of pineal research* 2009; 46:245-247.
2. Touitou Y, Haus E. Aging of the human endocrine and neuroendocrine time structure. *Annals of the New York Academy of Sciences* 1994; 719:378-397.
3. Garaulet M, Gomez-Abellan P. Timing of food intake and obesity: A novel association. *Physiology & behavior* 2014.
4. Hofstra WA, de Weerd AW. How to assess circadian rhythm in humans: a review of literature. *Epilepsy & behavior : E&B* 2008; 13:438-444.
5. Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International journal of chronobiology* 1976; 4:97-110.
6. Smith CS, Reilly C, Midkiff K. Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. *The Journal of applied psychology* 1989; 74:728-738.
7. Roenneberg T, Wirz-Justice A, Merrow M. Life between clocks: daily temporal patterns of human chronotypes. *J Biol Rhythms* 2003; 18:80-90.
8. Martinez-Nicolas A, Ortiz-Tudela E, Madrid JA, Rol MA. Crosstalk between environmental light and internal time in humans. *Chronobiology international* 2011; 28:617-629.
9. Garaulet M, Gomez-Abellan P, Alburquerque-Bejar JJ, Lee YC, Ordovas JM, Scheer FA. Timing of food intake predicts weight loss effectiveness. *Int J Obes* (Lond) 2013; 37:604-611.
10. Berteus Forslund H, Lindroos AK, Sjostrom L, Lissner L. Meal patterns and obesity in Swedish women-a simple instrument describing usual meal types, frequency and temporal distribution. *European journal of clinical nutrition* 2002; 56:740-747.
11. Flint A, Raben A, Blundell JE, Astrup A. Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. International journal of obesity and related metabolic disorders : journal of the *International Association for the Study of Obesity* 2000; 24:38-48.
12. Acebo C, Sadeh A, Seifer R, Tzischinsky O, Wolfson AR, Hafer A, Carskadon MA. Estimating sleep patterns with activity monitoring in children and adolescents: how many nights are necessary for reliable measures? *Sleep* 1999; 22:95-103.
13. Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. The role of actigraphy in the study of sleep and circadian rhythms. *Sleep* 2003; 26:342-392.
14. Morgenthaler TI, Lee-Chiong T, Alessi C, Friedman L, Aurora RN, Boehlecke B, Brown T, Chesson AL, Jr., Kapur V, Maganti R, Owens J, Pancer J, Swick TJ, Zak R. Practice parameters for the clinical evaluation and treatment of circadian rhythm sleep disorders. An American Academy of Sleep Medicine report. *Sleep* 2007; 30:1445-1459.
15. Sadeh A, Acebo C. The role of actigraphy in sleep medicine. *Sleep medicine reviews* 2002; 6:113-124.
16. Krauchi K. How is the circadian rhythm of core body temperature regulated? Clinical autonomic research : official journal of the *Clinical Autonomic Research Society* 2002; 12:147-149.
17. Waterhouse J, Drust B, Weinert D, Edwards B, Gregson W, Atkinson G, Kao S, Aizawa S, Reilly T. The circadian rhythm of core temperature: origin and some implications for exercise performance. *Chronobiology international* 2005; 22:207-225.
18. Sarabia JA, Rol MA, Mendiola P, Madrid JA. Circadian rhythm of wrist temperature in normal-living subjects A candidate of new index of the circadian system. *Physiology & behavior* 2008; 95:570-580.
19. Ortiz-Tudela E, Martinez-Nicolas A, Campos M, Rol MA, Madrid JA. A new integrated variable based on thermometry, actimetry and body position (TAP) to evaluate circadian system status in humans. *PLoS Comput Biol* 2010; 6:e1000996.
20. Corbalan-Tutau MD, Madrid JA, Ordovas JM, Smith CE, Nicolas F, Garaulet M. Differences in daily rhythms of wrist temperature between obese and normal-weight women: associations with metabolic syndrome features. *Chronobiology international* 2011; 28:425-433.
21. Corbalan-Tutau MD, Gomez-Abellan P, Madrid JA, Canteras M, Ordovas JM, Garaulet M. Toward a chronobiological characterization of obesity and metabolic syndrome in clinical practice. *Clin Nutr* 2014; .
22. Raymann RJ, Swaab DF, Van Someren EJ. Skin deep: enhanced sleep depth by cutaneous temperature manipulation. *Brain : a journal of neurology* 2008; 131:500-513.
23. Zornoza-Moreno M, Fuentes-Hernandez S, Sanchez-Solis M, Rol MA, Larque E, Madrid JA. Assessment of circadian rhythms of both skin temperature and motor activity in infants during the first 6 months of life. *Chronobiology international* 2011; 28:330-337.
24. Blazquez A, Martinez-Nicolas A, Salazar FJ, Rol MA, Madrid JA. Wrist skin temperature, motor activity, and body position as determinants of the circadian pattern of blood pressure. *Chronobiology international* 2012; 29:747-756.
25. Bandin C, Martinez-Nicolas A, Ordovas JM, Madrid JA, Garaulet M. Circadian rhythmicity as a predictor of weight-loss effectiveness. *Int J Obes* (Lond) 2013; .
26. Corbalán-Tutau MD G-AP, Madrid JA, Canteras M, Ordovás JM and Garaulet M. Toward a chronobiological characterization of obesity and metabolic syndrome in clinical practice. *Clinical Nutrition In Press*.
27. Martinez-Nicolas A, Ortiz-Tudela E, Rol MA, Madrid JA. Uncovering different masking factors on wrist skin temperature rhythm in free-living subjects. *PloS one* 2013; 8:e61142.
28. Monteleone P, Maj M, Fusco M, Orazzo C, Kemali D. Physical exercise at night blunts the nocturnal increase of plasma melatonin levels in healthy humans. *Life sciences* 1990; 47:1989-1995.
29. Shilo L, Sabbah H, Hadari R, Kovatz S, Weinberg U, Dolev S, Dagan Y, Shenkman L. The effects of coffee consumption on sleep and melatonin secretion. *Sleep medicine* 2002; 3:271-273.
30. Zeitzer JM, Duffy JF, Lockley SW, Dijk DJ, Czeisler CA. Plasma melatonin rhythms in young and older humans during sleep, sleep deprivation, and wake. *Sleep* 2007; 30:1437-1443.
31. Cardinali DP, Pevet P. Basic aspects of melatonin action. *Sleep medicine reviews* 1998; 2:175-190.
32. Dijk DJ, Cajochen C. Melatonin and the circadian regulation of sleep initiation, consolidation, structure, and the sleep EEG. J *Biol Rhythms* 1997; 12:627-635.
33. Van Someren EJ, Nagtegaal E. Improving melatonin circadian phase estimates. *Sleep medicine* 2007; 8:590-601.
34. Bandin C, Scheer FA, Luque AJ, Avila-Gandia V, Zamora S, Madrid JA, Gomez-Abellan P, Garaulet M. Meal timing affects glucose tolerance, substrate oxidation and circadian-related variables: A randomized, crossover trial. *Int J Obes* (Lond) 2014; .
35. Scheer FA, Buijs RM. Light affects morning salivary cortisol in humans. *The Journal of clinical endocrinology and metabolism* 1999; 84:3395-3398.
36. Garcia-Prieto MD, Tebar FJ, Nicolas F, Larque E, Zamora S, Garaulet M. Cortisol secretary pattern and glucocorticoid feedback sensitivity in women from a Mediterranean area: relationship with anthropometric characteristics, dietary intake and plasma fatty acid profile. *Clinical endocrinology* 2007; 66:185-191.
37. Caufriez A, Moreno-Reyes R, Leproult R, Vertongen F, Van Cauter E, Copinschi G. Immediate effects of an 8-h advance shift of the rest-activity cycle on 24-h profiles of cortisol. American journal of physiology *Endocrinology and metabolism* 2002; 282:E1147-1153.
38. Konopka RJ, Benzer S. Clock mutants of Drosophila melanogaster. *Proc Natl Acad Sci* USA 1971; 68:2112-2116.
39. Bargiello TA, Jackson FR, Young MW. Restoration of circadian behavioural rhythms by gene transfer in Drosophila. *Nature* 1984; 312:752-754.
40. Garaulet M, Corbalan MD, Madrid JA, Morales E, Baraza JC, Lee YC, Ordovas JM. CLOCK gene is implicated in weight reduction in obese patients participating in a dietary programme based on the Mediterranean diet. *Int J Obes* (Lond) 2010; 34:516-523.

41. Bandin C, Martinez-Nicolas A, Ordovas JM, Ros Lucas JA, Castell P, Silvente T, Madrid JA, Garaulet M. Differences in circadian rhythmicity in CLOCK 3111T/C genetic variants in moderate obese women as assessed by thermometry, actimetry and body position. *Int J Obes* (Lond) 2012:1-7.
42. Garaulet M, Esteban Tardido A, Lee YC, Smith CE, Parnell LD, Ordovas JM. SIRT1 and CLOCK 3111T>C combined genotype is associated with evening preference and weight loss resistance in a behavioral therapy treatment for obesity. *Int J Obes* (Lond) 2012.
43. Johnson CH. Forty years of PRCs--what have we learned? *Chronobiology international* 1999; 16:711-743.
44. Bjarnason GA, Jordan RC, Wood PA, Li Q, Lincoln DW, Sothern RB, Hrushesky WJ, Ben-David Y. Circadian expression of clock genes in human oral mucosa and skin: association with specific cell-cycle phases. *The American journal of pathology* 2001; 158:1793-1801.
45. Cajochen C, Jud C, Munch M, Kobialka S, Wirz-Justice A, Albrecht U. Evening exposure to blue light stimulates the expression of the clock gene PER2 in humans. *The European journal of neuroscience* 2006; 23:1082-1086.
46. Gomez-Santos C, Gomez-Abellan P, Madrid JA, Hernandez-Morante JJ, Lujan JA, Ordovas JM, Garaulet M. Circadian rhythm of clock genes in human adipose explants. *Obesity* (Silver Spring) 2009; 17:1481-1485.
47. Garaulet M, Ordovas JM, Gomez-Abellan P, Martinez JA, Madrid JA. An approximation to the temporal order in endogenous circadian rhythms of genes implicated in human adipose tissue metabolism. *Journal of cellular physiology* 2011; 226:2075-2080.
48. Minors DS, Waterhouse JM. The use of constant routines in unmasking the endogenous component of human circadian rhythms. *Chronobiology international* 1984; 1:205-216.
49. Waterhouse J, Jones K, Edwards B, Harrison Y, Nevill A, Reilly T. Lack of evidence for a marked endogenous component determining food intake in humans during forced desynchrony. *Chronobiology international* 2004; 21:445-468.
50. Halberg F. Frequency spectra and cosinor for evaluating circadian rhythms in rodent data and in man during Gemini and Vostok flights. *Life sciences and space research* 1970; 8:188-214.
51. van Someren EJ, Hagebeuk EE, Lijzenga C, Scheltens P, de Rooij SE, Jonker C, Pot AM, Mirmiran M, Swaab DF. Circadian rest-activity rhythm disturbances in Alzheimer's disease. *Biol Psychiatry* 1996; 40:259-270.
52. Ko CH, Takahashi JS. Molecular components of the mammalian circadian clock. *Human molecular genetics* 2006; 15 Spec No 2:R271-277.
53. Naismith SL, Rogers NL, Mackenzie J, Hickie IB, Lewis SJ. The relationship between actigraphically defined sleep disturbance and REM sleep behaviour disorder in Parkinson's Disease. *Clinical neurology and neurosurgery* 2010; 112:420-423.
54. Baron KG, Reid KJ, Kern AS, Zee PC. Role of sleep timing in caloric intake and BMI. *Obesity* (Silver Spring) 2011; 19:1374-1381.
55. Eisenmann JC, Ekkekakis P, Holmes M. Sleep duration and overweight among Australian children and adolescents. *Acta paediatrica* (Oslo, Norway : 1992) 2006; 95:956-963.
56. Urban R, Magyarodi T, Rigo A. Morningness-eveningness, chronotypes and health-impairing behaviors in adolescents. *Chronobiology international* 2011; 28:238-247.
57. Erren TC, Reiter RJ. Axelrod, the pineal and the melatonin hypothesis: lessons of 50 years to shape chronodisruption research. *Neuro endocrinology letters* 2010; 31:585-587.
58. Horne JA, O O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International journal of chronobiology* 1976; 4.
59. Lopez-Minguez J, Ordonana JR, Sanchez-Romera JF, Madrid JA, Garaulet M. Circadian system heritability as assessed by wrist temperature: A twin study. *Chronobiology international* 2014:1-10.
60. Bandin C, Martinez-Nicolas A, Ordovas JM, Ros Lucas JA, Castell P, Silvente T, Madrid JA, Garaulet M. Differences in circadian rhythmicity in CLOCK 3111T/C genetic variants in moderate obese women as assessed by thermometry, actimetry and body position. *Int J Obes* (Lond) 2013; 37:1044-1050.

Nutrición Hospitalaria

Nutr Hosp. 2015;31(Supl. 3):290-292
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Uses and applications of the results from food surveys, physical activity estimates and other lifestyle related surveys at a population level

Javier Aranceta Bartrina[1,2,6], Carmen Pérez Rodrigo[3], Goiuri Alberdi Aresti[4], Lluis Serra-Majem[2,5,6] and Gregorio Varela-Moreiras[7,8]

[1]Departamento de Medicina Preventiva y Salud Pública. Universidad de Navarra. [2]Fundación para la Investigación Nutricional, Parc Científic de Barcelona. [3]Fundación FIDEC. Bilbao (Spain). [4]School of Medical Sciences, University of Aberdeen, Institute of Medical Sciences, Aberdeen, Scotland, UK. [5]Instituto de Investigaciones Biomédicas y Sanitarias, Universidad de Las Palmas de Gran Canaria. [6]CiberOBN, Instituto de Salud Carlos III, Madrid. [7]Department of Pharmaceutical and Health Sciences, Faculty of Pharmacy, CEU San Pablo University; Madrid (SPAIN). [8]Spanish Nutrition Foundation (FEN), Madrid (SPAIN).

Abstract

The results and conclusions of well design nutrition studies, using the appropriate methods to achieve the intended aims with the best validity and precision possible are of great value for nutritional, food and toxicological surveillance systems; also in the planning, follow-up and evaluation of nutrition and health policies and providing high value information for the formulation of recommended reference intakes, nutritional objectives and food based dietary guidelines.

(*Nutr Hosp* 2015;31(Supl. 3):290-292)

DOI:10.3305/nh.2015.31.sup3.8777

Key words: *Dietary assessment. Health plans. Nutrition policies. Recommendations.*

UTILIDAD Y APLICACIÓN PRÁCTICA DE LOS RESULTADOS OBTENIDOS EN LAS ENCUESTAS ALIMENTARIAS, DE ESTIMACIÓN DE LA ACTIVIDAD FÍSICA Y OTROS ESTILOS DE VIDA A NIVEL POBLACIONAL.

Resumen

Los resultados y las conclusiones de los estudios nutricionales bien diseñados, utilizando la metodología adecuada para lograr los objetivos planteados, con la mayor validez y precisión posible, son de gran utilidad en los sistemas de vigilancia nutricional, alimentaria y toxicológica, en la planificación, seguimiento y evaluación de políticas nutricionales y proporcionan información de gran interés en el planteamiento de ingestas de referencia, objetivos nutricionales y guías alimentarias.

(*Nutr Hosp* 2015;31(Supl. 3):290-292)

DOI:10.3305/nh.2015.31.sup3.8777

Palabras clave: *Ingesta nutricional. Planes de salud. Políticas nutricionales. Recomendaciones.*

Surveys on Nutrition, health and quality of life

Dietary surveys and nutritional studies conducted with varying complexity are always demanding projects that require the involvement of a large number and diversity of professionals and resources. The analysis of derived findings and availability of the database will always be very useful for subsequent actions, especially if the quality of the data is a consistent reality.

At a clinical level the results obtained are specifically oriented to therapeutic intervention. At a community or population level, a descriptive display or a more complex analysis of the results will be helpful for a better understanding of the reality and for decision making process that will contribute to the improvement of the nutritional and health status of a particular community. In this regard, the active collaboration of people who can benefit from the proposed improvements will always be needed, especially considering the possible application of those improvements comfortably to the objectified reality[1] (figure 1).

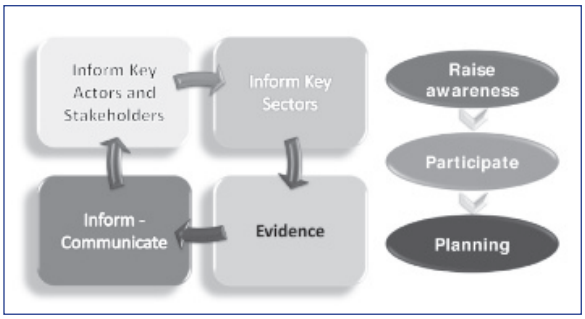


Fig. 1.—Uses and applications of results of Food and Nutrition studies.

Correspondence: Javier Aranceta
Community Nutrition
PO Box 5199. 48080 Bilbao (Spain).
E-mail: jaranceta@unav.es

Here are presented the different levels of practicality distributed in strategic areas:

1. National Surveys such as Food Balance Sheets, Household Budget Surveys (INE)[2], studies of the food shopping basket and consumption at home or away (MAGRAMA)[3,4], or the annual data on sales obtained from the Central Markets of different Spanish cities (MERCASA)[5].
2. Health Surveys at a National or Country level that embody data on food intake, anthropometric measurements, characterization of physical activity, alcohol and tobacco consumption and other matters related with health.
3. Representative surveys of different groups (children, school age youth, elderly or general population) driven by the Public Institutions such as PERSEO[6], ENALIA[7,8] and ALADINO[9] among others, or by Scientific Societies in collaboration with private industries such as ANIBES (Assessment of Energy Balance, Anthropometry and Food Intake of the Spanish population) or the ENPE study (Nutritional study of the Spanish population).
4. Total Diet Studies that estimate the average intake of potential contaminants according to the average values of the Spanish diet or across the different countries that compared with the values of the Acceptable Daily Intake (ADI) allow stable control policies and recommendations from AECOSAN[10] and other scientific organizations[11,12] for the general and most vulnerable population groups).
5. Food Policy. Food and nutrition policies are drawn from the information provided by various kinds of dietary surveys along with other social and health indicators. Production strategies, food imports, food regulation and fortification programs would be included under this heading.
6. Nutrition Education Programs. Educational plans included in the education system and in the community environment to facilitate changes towards a more balanced, varied and healthy diet. The data obtained by identification of nutritional risks will help to formulate specific contents for future projects.
7. Environmental Policy. Environmental improvement and an appropriate legislative framework can redirect to better food profiles and lifestyles. The health system, education system and environments are the key for the improvement and maintenance of healthy behaviours, promoting the availability and accessibility of those foods whose consumption should be enhanced as well as the ability to implement a more active lifestyle.
8. Surveillance systems for agricultural production and plant environment. The Normalized Difference Vegetation Index (NDVI). Also the environmental impact and sustainability of food production, food safety and consumption should be prioritized.

Contribution to Community Nutrition

In addition to the analysis of food and beverage consumption habits, physical activity and maybe other related factors are assessed in order to evaluate the situation and/or the effectiveness of interventions aimed at modifying behavioral characteristics for a better food profile, a more active life style and reduce sedentarism. Tools are also used to measure the intake of specific nutrients, specific aspects of the diet or even the general profile in longitudinal epidemiological studies, case-control studies or randomized trials contexts to investigate the association between exposure to nutritional or dietary factors and health outcomes[13-17].

In food surveys and cross-sectional studies, the assessment of the current intake can detect deficiencies, groups at risk and determinant risk factors, leading to evidence based scientific documents or nutritional standards that can be used by professionals from both health and education fields. They provide high value and interesting information for the formulation of nutritional policies and health policies and for other relevant areas.

1. Current food intake description, food models and determinant factors.
2. Trend analysis. Evolution of food intake. Ecological postulates.
3. Food Transitions, of great interest for the immigrant population.
4. Nutritional surveillance programs.
5. Food security programs.
6. Food hygiene programs.
7. Research methods of diet-health-nutritional state.

We have mentioned the application of nutritional studies for the development or review of nutritional standards as well as to support or confirm the evidence, if the conditions for applying the scientific method were met. Undoubtedly, well-designed nutritional studies with large enough subjects and long enough periods of observation that include dietary exposure indicators, biomarkers of nutritional status and adequate health outcomes measured using the appropriate methodology, as well as the relevant procedures for data analysis, are essential to arise the scientific evidence that supports the development of some key documents:

1. Nutritional standards, of weight characterization or of reference values for biochemical, haematological or immunological indicators[18].
2. Development or update of Nutritional Objectives as a technical document for the prevention of chronic diseases and health promotion.
3. Development or revision of Dietary Guidelines for the population as instructive document that eases up the compliance of nutritional goals; from science to the plate.
4. Development of community level guidelines for physical activity by age and gender, for the wor-

kplace or the health-institution settings. Moreover, soon enough, personalized physical activity prescriptions may become a reality in all health care settings[19].

5. Collaboration with the food industry to achieve improved formulation of the processed products and the launch of new products of interest for health.
6. Use of specialized media to inform and create awareness of the available evidence, the detected reality and the actions for improvement considered the most appropriate each time for the general population or specific groups.

In conclusion, nutritional studies are an indispensable tool for health promotion. They should be coordinated from public institutions to prevent the proliferation of studies of limited nature that just means a financial expense and a major effort that do not provide the objective of a sustainable common interest. The implementation of a periodic nutritional survey in Spain, similar to the NHANES projects, is a pending issue in our country that will hopefully be solved shortly, taking into account in its foundation the major studies that have been conducted in recent years by various institutions and research groups.

References

1. Aranceta J. Nutrición Comunitaria (3ª edición). *Barcelona: Elsevier-Masson* 2013
2. INE. Encuesta de Presupuestos Familiares (EPF). INEbase. Available at: [www.ine.es] (Accessed 15 January 2015)
3. La Alimentación mes a mes en España Año 2014. *Madrid: MAGRAMA* 2014. Available at: [http://www.magrama.gob.es/es/alimentacion/temas/consumo-y-comercializacion-y-distribucion-alimentaria/panel-de-consumo-alimentario/ultimos-datos/] (Accessed 15 January 2015)
4. Del Pozo de la Calle S, García Iglesias V, Cuadrado Vives C, Ruiz Moreno E, Valero Gaspar T, Ávila Torres JM, Varela Moreiras G. Valoración Nutricional de la Dieta Española de acuerdo al Panel de Consumo Alimentario. *Madrid: Fundación Española de la Nutrición (FEN)- MAGRAMA* 2012. Available at: [http://www.fen.org.es/imgPublicaciones/30092012125258.pdf] (Accessed 15 January 2015)
5. Informe 2013 sobre Producción, Industria, Distribución y Consumo de Alimentación en España. *Madrid: MERCASA* 2013. Available at: [http://www.mercasa.es] (Accessed 15 January 2015).
6. Aranceta J, Pérez Rodrigo C, Campos Amado J, Calderón Pascual V, en nombre del Grupo Colaborativo Proyecto PERSEO. Proyecto PERSEO. Diseño y metodología del estudio de evaluación Revista Española de Nutrición Comunitaria 2013; , 19, 76-87
7. AECOSAN. "ENALIA" Encuesta Nacional de Alimentación en la población Infantil y Adolescente. Available at: [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enalia.shtml] (Accessed 15 January 2015)
8. AECOSAN. "ENALIA 2" Encuesta Nacional de Alimentación en la población adulta y mujeres embarazadas. Available at: [http://aesan.msssi.gob.es/AESAN/web/evaluacion_riesgos/subseccion/enalia_2.shtml] (Accessed 15 January 2015).
9. Ortega Anta RM, López Sobaler AM, Perea Sánchez JM, González Rodríguez LG, Villalobos Cruz T, Pérez Farinós N, et al. Estudio Aladino. *Estudio de Vigilancia del Crecimiento, Alimentación, Actividad Física, Desarrollo Infantil y Obesidad en España* 2011. Madrid: AECOSAN, 2013. Available at: [http://www.observatorio.naos.aesan.msssi.gob.es/docs/docs/documentos/estudio_ALADINO.pdf] (Accessed 15 January 2015).
10. Estudio de Dieta Total. *Madrid: AESAN-Fundación Bamberg* 2007. Available at: [http://www.fundacionbamberg.org/innovacion/estudios-publicaciones/estudios/estudio-dieta-total] (Accessed 15 January 2015)
11. Varela Moreiras G (coord.). Libro Blanco de la Nutrición en España. *Madrid: FEN-AESAN-Ministerio de Sanidad y consumo* 2013. Available at: [http://www.fundacionbamberg.org/innovacion/estudios-publicaciones/estudios/estudio-dieta-total] (Accessed 15 January 2015).
12. SEQC. Recomendaciones para reducir la exposición al metilmercurio en España. Dec 2014. Available at: [http://www.seqc.es/es/Actualidad/2/266/Recomendaciones_para_reducir_la_exposicion_al_metilmercurio_en_Espana/] (Accessed January 19 2015).
13. Serra Majem Ll, Aranceta Bartrina J (eds). Nutrición y salud pública: Métodos, bases científicas y aplicaciones. 2 ed. *Barcelona: Elsevier- Masson* 2006.
14. Gibson RS. Principles of nutritional assessment (2nd edition). *New York: Oxford University Press* 2005
15. Estruch R, Ros E, Salas-Salvadó J, Covas MI, Corella D, Arós F, et al. Primary Prevention of Cardiovascular Disease with a Mediterranean Diet. *N Engl J Med* 2013; 368:1279-1290 DOI: 10.1056/NEJMoa1200303
16. Batlle J., Ferrari P., Chajes V., Park J.Y., Slimani N., McKenzie F et al. Dietary folate intake and breast cancer risk: European prospective investigation into cancer and nutrition. *J Nal Cancer Inst* 2015; 107(1):
17. Falbe J, Willett WC, Rosner B, Gortmaker SL, Sonneville KR, Field AE. Longitudinal relations of television, electronic games, and digital versatile discs with changes in diet in adolescents. *Am J Clin Nutr* 2014 Oct;100(4):1173-81. doi: 10.3945/ajcn.114.088500. Epub 2014 Aug 13.
18. Institute of Medicine (IOM). The development of DRIs 1994–2004: Lessons learned and new challenges—workshop summary. *Washington, DC: The National Academies Press* 2008.
19. Hallal PC, Lee IM. Prescription of physical activity: an undervalued intervention. *Lancet* 2013 Feb 2;381(9864):356-7. doi: 10.1016/S0140-6736(12)61804-2. Epub 2012 Nov 28.