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Methodological aspects of dietary intake assessment in food consumption surveys:

from a national to an international level

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Table of contents

General introduction

For the planning, construction and implementation of food and health programs, policy makers need information on food consumption of the population (Brussaard, J. H., Lowik, et al., 2002b). Also, food consumption data are an essential element for exposure assessment of potentially hazardous substances (EFSA, 2009). Food consumption surveys are therefore essential since they provide individual- or group-level data of consumption (Margetts, 2004).

Typically, food consumption or nutrition surveys are cross-sectional assessments of intakes of solid foods, beverages, including drinking water, and supplements (Gibson, 2005a; EFSA, 2009). Often, they are performed at the national level to generate valuable information on the extent of existing nutritional problems in order to allocate resources to those population subgroups in need and to formulate policies in order to improve the overall nutrition of its population (Gibson, 2005a). Usually, nutrition surveys performed in developed or industrialized countries have shifted over time from identifying groups at risk for malnutrition to estimating means and distributions of intake of the entire population with a strong emphasis on nutrition in the development of non-communicable chronic diseases. Nonetheless, in developing or low-income countries the focus of nutrition surveys is still on population subgroups at risk for malnutrition like (pregnant) women.

According to the World Health Organisation (WHO), surveillance is defined as *"the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice"* (WHO, 2013). Therefore, nutrition surveillance programs are different form nutrition surveys because they are performed over an extended period of time (i.e. repeated) in a systematic way. Also, a series of nutrition surveys like those performed and planned in Belgium, are more an episodic than an on-going collection of data. Obviously, the existence of a nations' nutritional surveillance plan depends on both its political priority and financial implications. For example, in Europe, The Netherlands have a 25 year tradition of performing nutritional surveillance, however, due to budgetary restraints they recently had to revise their long term planning (Ocké, van Rossum, de Boer, & van der A, 2012). In the UK, the National Diet and Nutrition Survey (NDNS) was first set up in 1992 and comprised a series of surveys over the next decade across different age groups gathering information on food consumption, nutrient intakes and nutritional status (Hoare et al., 2004). Following a review of this series of surveys (Ashwell et al., 2006), it was decided that a rolling program covering all age groups from 1,5 years and above should be introduced in order to identify and analyze trends more rapidly. Food consumption and nutrient intakes are collected using a four-day estimated diary. The survey also includes an interview to collect background information on dietary habits, socio-demographic status and lifestyle, collection of a blood sample to assess biochemical indices of nutritional status and a 24-hour urine collection to assess salt intake (Whitton et al. 2011). The

US Department of Agriculture (USDA) has collected national food consumption data for more than 70 years to monitor food use and food consumption patterns in the US population. Early small-scale studies were begun at the beginning of the 20th century to help people achieve good diets at low cost. US Nationwide surveys of dietary intakes by individuals started in 1965 and led to the Continuing Survey of Food Intakes by Individuals (CSFII). The first National Health and Examination Survey (NHANES) started from 1971-1975 and became a continuous, annual survey program in 1999. From 2001 to date, nationwide dietary intake data is collected in What We Eat in America (WWEI), the dietary interview component of NHANES (Dwyer et al., 2003).

In terms of methodological approach, food consumption can be assessed by national, household, or individual level food consumption surveys (Gibson, 2005a). Both direct and indirect approaches are available and resulting data is expressed as nutrients, foods and/or dietary patterns (Patterson & Pietinen, 2004). Figure 1 gives an overview of the methods available for the measurement of food intake. In this dissertation, individual-level intakes obtained directly are of interest, therefore, indirect measures are presented only briefly.

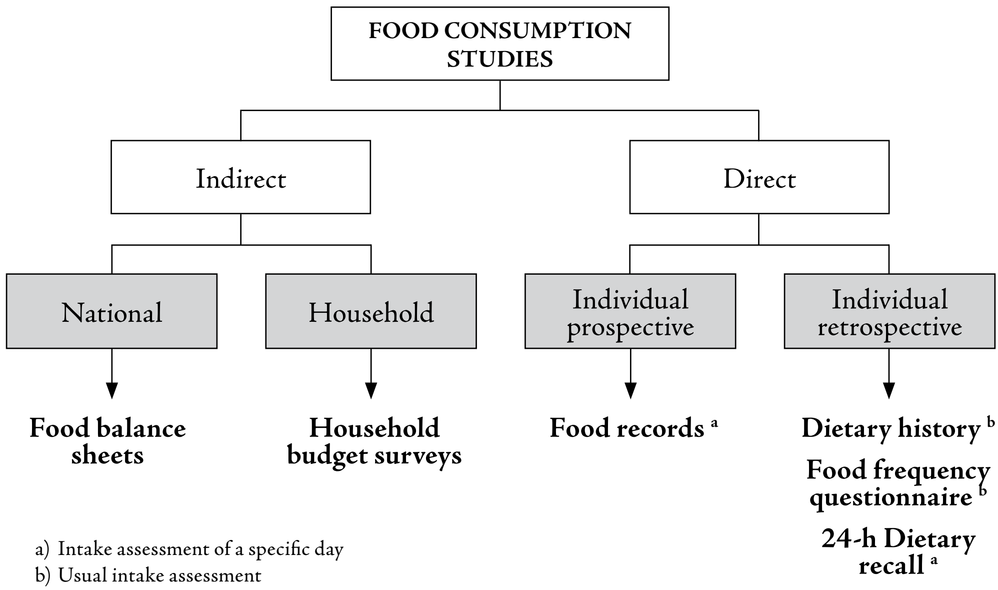

Figure 1 - Overview of methods available for the measurement of food intake (grey boxes indicate levels of unit measurement) (adapted with permission from Patterson & Pietinen, 2004)

Dietary assessment methods

Indirect measurement of food consumption

Food balance sheets

Food balance sheets (FBS) provide insight into the pattern of a country's food supply during a certain amount of time by presenting sources of supply and utilization of all food items (i.e. all primary commodities and a number of processed commodities) (FAO, 2008). FBS are also called "food disappearance data" since values are calculated as the difference between the production of a certain food plus its imports, minus the export of that food plus its use in animal feed or other utilisation. The resulting net value is divided by the total number of the population and expressed as kilogram food per capita over a specified time (Patterson & Pietinen, 2004).

A principal strength of FBS is that it offers an objective methodology for assessing overall food availability based on quantifiable measures. Also, they are inexpensive to perform and enormous amounts of data for a large number of individual countries are publicly available (FAO, 2013). An important limitation of FBS is that they do not provide information on food consumption at the individual level. Also, FBS do not yield data on food consumption in relation to regional, economic, demographic, seasonal, or socioeconomic difference within a country (Gibson, 2005a). In addition, because food waste is high in developed countries, FBS estimates of energy intake largely exceed estimates of energy intake using direct methods (Patterson & Pietinen, 2004). However, when performed periodically, FBS will demonstrate trends in the overall national food supply, reveal shifting of dietary patterns, and show the extent to which total food supply for any given country is adequate to meet nutritional requirements (FAO, 2008).

Household budget surveys

Besides FBS, Household Budget Surveys (HBS) can be used to estimate food consumption indirectly. HBS are national or regional surveys mainly focusing on consumption expenditure of households. Since most economies conduct measures of household expenditures to calculate weights for the Consumer Price Index, data of expenditure on foods and household composition can be translated into weights of foods or nutrients per household member (EC, 2013). Since 1990, Greece has been coordinating the Data Food Networking (DAFNE) initiative in order to compare the food habits of European populations and monitor overtime trends in food availability (WHO Collaborating Center for Food and Nutrition Policies, 2013).

The strengths of HBS are similar to those of FBS. An essential limitation of most HBS is that food expenditure out of home is not recorded. Of the Belgian population, 35% were defined as substantial out-of-home eaters meaning that they consumed on average at least 25% of their daily energy outside the home irrespective of the place of purchase or preparation (Vandevijvere, Lachat, Kolsteren, & Van Oyen, 2009). Also, a review of nutritional characteristics of eating out-of-home and its associations with energy intake showed that out-of-home foods were important sources of energy (Lachat et al., 2012). As for FBS, in HBS food waste is also not taken into account leading to overestimation of actual food intake (Serra-Majem, 2001; Nelson & Bingham, 2007).

In conclusion, both FBS and HBS share some strengths and limitations to be used in the assessment of food consumption by populations. Especially in countries with limited infrastructure for the collection of dietary intake data, FBS and HBS serve as valuable alternative methods (Patterson & Pietinen, 2004).

Direct measurement of food consumption

Individual-level dietary surveys estimate food and nutrient intake by measuring consumption on specified days (food records and recalls) or by measuring usual consumption (dietary history and food frequency questionnaires). When repeated food records or recalls are available, statistical modelling allows correcting for within-person variability of intake. Indeed, if the objective is to estimate intake distributions of usual intake, these statistical techniques can be used to remove the within-person errors (day-to-day variation), leaving only the between-person variation. This is needed for proper estimation of the proportion of a population below or above any given dietary recommendation cut-off point. Basic approaches rely on simple analysis of variance to separate within- from between-person variation and remove the within-person variation. Newer approaches involve additional steps such as normalizing transformations, back transformations of varying complexity and the use of empirical distributions. Several methods have been developed in the last years accompanied with a wide range of software solutions (Souverein, Dekkers, et al., 2011).

Dietary history

The technique of the dietary history is based on the assumption of that the person under study has certain regularity in its diet. Nowadays, dietary histories are face-to-face interviews in which usual intakes of foods, typically of a recent week, are summarized by outlining the individual's meal pattern followed by a detailed description of likely food items in terms of quantity and quality (Thompson & Subar, 2013). Dietary histories are rarely used in nutrition surveys in Europe (EFSA, 2009; Le Donne, Piccinelli, Sette, Leclercq, & European Food Consumption Validation, 2011) or countries outside Europe (see chapter 8). In settings where dietary intake assessment of individuals is performed (e.g. clinical setting, dietitian's practice), dietary histories are often preferred.

Food records

Food or dietary records (DR) serve as diaries in which the respondent systematically records all foods and beverages consumed during a specified time, usually one to more consecutive days. There is some debate on the number of days a dietary record should comprise. The optimal number of days depends on the level of accuracy that is anticipated and the variability of the nutrients under study. Using data on within-person variability of nutrient intakes, the number of days needed to estimate true intake can be calculated given a specified degree of error (see chapter 1). Although more recording days yield better estimates of true intake, it is also acknowledged that with increasing recording days, reported intakes decrease because of respondent fatigue (Biro, Hulshof, Ovesen, & Cruz, 2002). When more than two recording days are present in the dietary survey period, weekend days should be proportionally included for each respondent in order to account for day-of-the-week effects on food and nutrient intakes (Gibson, 2005b).

Data is typically recorded in an open-ended form, although close-ended forms have been developed also. These forms are organised according to a traditional meal pattern (breakfast, lunch, dinner and snacks). Every eating occasion is divided into sections containing headings like beverages, bread, margarine, etc. so respondents can find and record foods, dishes and beverages easily (Biltoft-Jensen et al., 2009). Amounts of consumed foods are either weighed using a kitchen scale or estimated by means of household measures, food models or picture series of foods with increasing portion size (Thompson & Subar, 2013). Generally, respondents are asked to keep written records of types and amounts of consumed foods, however, more sophisticated instruments to assist in dietary assessment like handheld devices have been investigated (Beasley, Riley, Davis, & Singh, 2008). When such devices are equipped with a camera, foods can be photographed by the respondent helping the investigators to estimate consumed quantities more accurately (Beasley et al., 2008; Weiss, Stumbo, & Divakaran, 2010).

Food records have been considered to be the gold standard of dietary assessment. Especially when consumed portions are weighed they are a precise method for estimating food and nutrient intakes of individuals. Both weighed and estimated food records are often used as a reference in studies assessing the relative validity of prospective dietary assessment methods given the low presence of recall-related errors.

Some of the drawbacks of food records are related to the fact that respondents must be literate and be motivated as the method imposes a large burden, especially for the weighed records. Also, respondents may alter their diets to make them easier to record or to mask poor eating behaviour, or they may forget to record food items or even meals consumed. Finally, foods eaten less than once a week may not be accurately recorded (Thompson & Subar, 2013).

When food records are used in nutrition surveys, it is advised to review the records by a dietitian or nutritionist during a debriefing session with the respondent to improve the dietary assessment (Cantwell et al., 2006). Depending in the scale of the survey, feasibility of this approach must be considered first due to the costs involved.

In Europe, food records have been used on a regular basis to measure food consumption of adults in national nutrition surveys (EFSA, 2009; Le Donne et al., 2011). For instance, in the UK, the National Diet and Nutrition Survey (NDNS) is collects information on food consumption, nutrient intakes and nutritional status based on 4-day estimated food records (Whitton et al., 2011). Nevertheless, the European Food Consumption Survey Method (EFCOSUM) group advised the use of two non-consecutive 24 hour recalls to measure food intake in adults and children (Brussaard, J. H., Lowik, et al., 2002b). However, for preschool children, two non-consecutive days of a structured food record are recommended in combination with a picture booklet and household measures for portion-size estimation (Andersen et al., 2011).

24-hour dietary recalls

The 24-hour dietary recall (24-HDR) is an interview-like method preferably conducted by a trained dietary interviewer. During a face-to-face or telephone interview, everything the respondent ate or drank during the past 24 hours from midnight to midnight is reviewed (Baranowski, 2013). Usually, the interviewer will proceed forward in time starting from the first thing the respondent had to eat or drink on the previous day. Collecting information on the respondent's activities before beginning to ask questions about food consumption may facilitate the recall process (De Vriese et al., 2005).

Since a 24-HDR is an open-ended interview, this type of dietary intake assessment method requires standardization in interview approach in order to obtain all relevant information. Computerized versions of this method are very helpful because they can be programmed to prompt the interviewer to collect detailed description and quantification of reported food items (Baranowski, 2013). Examples of interviewer-administered software programs used in national nutrition surveys are the Automated Multiple Pass Method (AMPM), developed by the US Department of Agriculture (USDA) (USDA, 2013), and the EPIC-Soft program developed by the International

Agency for Research on Cancer (IARC) in the framework of the European Prospective Investigation into Cancer and Nutrition (EPIC) study (IARC, 2013). Finally, ASA24, developed by the National Cancer Institute (NCI) of the US national Institute of Health, is a freely available web-based tool that enables automated self-administered 24-HDR and is freely available to researchers, clinicians, and teachers (NCI, 2013a).

In 2010, members of the EFSA Advisory Forum signed a declaration supporting the establishment of the EU Menu project (EFSA, 2010). This project will result in the first pan-European food consumption survey to be carried out in the EU called "What's on the Menu in Europe?". In their report, the Expert group on food consumption data agreed that the EPIC-SOFT program would be the best possible solution to collect dietary data within a pan-European dietary survey (EFSA, 2009). The program uses a multiple pass recall protocol, divided into four main steps: (1) general non-dietary information; (2) quick list (chronological list of consumed foods and recipes); (3) description and quantification of foods and recipes; and (4) quality controls at nutrient level (Slimani et al., 1999). Quantification of portion sizes is possible using weights or volumes, food photographs from the EPIC-Soft picture book (van Kappel, Amoyel, Slimani, Vozar, & Riboli, 1995), household measures, standard units and standard portions. Of particular use are food photographs because from a respondent's perspective they are attractive and easy to use. Studies addressing the validity of food photographs in adults have shown that food photographs are useful aids for portion size assessment although considerable under- and overestimation of portion sizes remain present (Nelson, Atkinson, & Darbyshire, 1994; Robinson, Morritz, McGuiness, & Hackett, 1997; Turconi et al., 2005; Ovaskainen et al., 2008; Souverein, de Boer, et al., 2011) (see chapter 2).

Due to within-person variation of intake both at the food and nutrient level, a single 24-HDR is not able to offer a critically valid estimate of one's usual dietary intake (Biro et al., 2002). Statistical modelling of two non-consecutive 24-HDR allows to correct for within-person variability of intake making it possible to calculate distributions of usual intake (Nusser, Carriquiry, Dodd, & Fuller, 1996; Guenther, Kott, & Carriquiry, 1997; Hoffmann et al., 2002; Harttig, Haubrock, Knuppel, Boeing, & Consortium, 2011; Souverein, Dekkers, et al., 2011). When it is not possible to perform repeated recalls on all respondents, it is advised that recalls should be repeated on a subsample of the population (Gibson, 2005b).

An important strength of 24-HDR is related to the fact that for the interviewer-administered assessment, no literacy of respondents is required. Also, data can be collected in a highly consistent manner from all respondents, especially for the computerized software versions and because respondent burden is relatively small, those who agree to give 24-HDR are more likely to be representative of the population than those who agree to keep dietary records (Baranowski, 2013; Patterson & Pietinen, 2004; Thompson & Subar, 2013). Another strength of 24-HDR over food records is that respondents are less likely to alter their eating behaviour, therefore, 24-HDR are preferably conducted unannounced, meaning that, prior to the 24-HDR, respondents are not informed about the exact purpose of the interview (Nelson & Bingham, 2007).

The main weakness of the 24-HDR is that respondents may not be able to report consumed foods accurately for reasons related to knowledge, memory or the interview situation (Thompson & Subar, 2013). Thus, although random errors may be accounted for, intake related and group-level biases may hamper validity. Furthermore, attention should be paid to training of the interviewers to conduct the 24-HDR so questions are asked in a non-judgemental manner, a neutral attitude towards all responses is maintained, open-ended questions are used when probing for foods and descriptive details and questions that might influence respondents' answers are avoided (Baranowski, 2013). Finally, 24-HDR may not be able to correctly estimate the usual intake distribution of occasionally consumed foods. Therefore, the inclusion of a food frequency questionnaire may be valuable.

Food frequency questionnaires

In 1947, Burke developed the dietary history method by interview by combining three dietary intake assessment methods: a single 24-HDR, a 3-day DR and a checklist of foods consumed over the preceding month (Burke, 1947). This checklist is considered to be the predecessor of the Food Frequency Questionnaire (FFQ) given its conceptual difference with methods capturing short term dietary intake (Willett, 2013b). An FFQ contains a list of questions about the usual frequency consumption of foods over a specified period of time (Willett, 2013b). Sometimes, besides frequency of consumption, information on portion sizes of consumed foods is also collected (Willett et al., 1985). Although providing more precision, it was demonstrated that portion size adds only limited information on variance of food intake suggesting that assignment of standard portions to frequencies of intake seems to be adequate (Noethlings, Hoffmann, Bergmann, Boeing, & European Investigation into Cancer & Nutrition, 2003).

In general, three types of FFQ exist: 1) qualitative, 2) semi-quantitative, and 3) quantitative FFQs. The first type, a qualitative FFQ, collects information on frequencies of consumption of foods or food groups (e.g. raw vegetables: tomato, cucumber, carrot). Such grouping of foods can be cognitively complex to answer by the respondent (e.g. for someone who often eats tomato and occasionally eats raw cucumber or carrots)

(Thompson & Subar, 2013). Also, when foods are grouped into one question, assumptions need to be made on the relative frequencies of intake of each single food constituting the group when assigning nutrient values to these groups. Usually, these assumptions are based on information from an external study like a national nutrition survey (Thompson & Subar, 2013). The second type of FFQ is called semi-quantitative because some information about consumed portion sizes is also collected. In a semi-quantitative FFQ, portion sizes are specified as part of the question on frequency of consumption (Willett, 2013b). From the respondent's perspective this type of question is easy to answer for foods that come in natural units such as single units of fruit (apple, banana, etc.), a glass of water or a slice of cheese. For foods that don't come in natural or typical units a typical portion is specified such as 175g-225g of fish or ½ cup of rice. A drawback of the semi-quantitative FFQ is that respondents are not able to indicate their usual portion size of consumption. If a respondent's usual portion size is twice the amount indicated on the FFQ, they would be expected to double their reported frequency of consumption. Willett and coworkers have evaluated if participants of the Nurses' Health Study responded in this way and observed that items about foods that come in natural units were consistently interpreted correctly, however, portion size specification of foods that don't come in natural units was sometimes omitted (Willett & Lenart, 2013). A third type of FFQ is called a quantitative FFQ in which an additional question for each food is added to report the usual portion size. Different approaches are available like describing a medium portion size and asking the respondents to describe their usual portion size as small, medium or large; using food models as a reference, providing pictures of food photographs with increasing portion size or ranges for categories of serving sizes (Willett & Lenart, 2013). In order to provide useful information on consumed portion sizes, respondents need to be able to conceptualize the proposed food item clearly and relate this to their own usual consumption (Nelson et al., 1994). Psychological constructs that need to be taken into account when using photographs as portion size measurement aid are addressed later (see chapter 2).

The advantages of an FFQ are that it is a relatively inexpensive, low burdensome – when short – and quick method that can be either interviewer- or self-administered without special training (Willett & Hu, 2007; Thompson & Subar, 2013). Also, episodically consumed foods which are relevant for some specific nutrients can be easily incorporated. Due to their questionnaire design FFQs also offer the possibility to be optically scanned making them simple and time saving to process. A major disadvantage is that long FFQs can be burdensome for participants, they are difficult to develop and experience in designing an FFQ is required. In addition, once developed, their validity and reproducibility needs to be evaluated using reference methods for comparison (Cameron & Staveren, 1988). In chapter 3, a short qualitative FFQ is evaluated against a 7-day food record. At Wageningen University, researchers have been able to develop a computer system to generate, apply and process FFQs using standardized procedures for multiple nutrients of interest (Molag et al., 2010).

FFQs remain best suited for dietary intake assessment related to epidemiologic applications (Willett, 2013b), however, in the framework of food consumption surveys and nutritional surveillance, they are of use to identify non-consumers of foods and to collect information on long term intakes.

Finally, to finish this part of dietary assessment methods, a comprehensive overview of advantages and disadvantages associated with the abovementioned instruments is given in table 1.

Table 1: advantages and disadvantages of dietary assessment instruments (adapted with permission from Thompson & Subar, 2013)

	Dietary records	24-hour recall	FFQ	Diet history
Type of information available				
Detailed information about foods/recipes	x	x		x
Not detailed information about food groups			x	
Scope of information sought				
Total diet	x	x	x	x
Specific components			x	
Time frame of one single administration				
Short term (e.g. yesterday, today)	x	x		
Long-term (e.g. last month, last year)			x	x
Adaptable for diet in distance past				
Yes			x	x
No	x	x		
Cognitive requirements				
Measurement or estimated recording of foods and drinks as they are consumed	x			
Memories of recent consumption		x		x
Ability to make judgements of long-term diet			x	x
Potential for reactivity				
Low		x	x	x
High	x			
Time required to complete				
Low			x	
High	x	x	x	x

Validation research

As described before, different methods are available to assess dietary intake in food consumption studies. Therefore, comparison of the performance of any two different methods of measurement is needed. More specifically, the results of a new method of dietary assessment need to be evaluated against a common method that is generally accepted (Cameron & Staveren, 1988). Furthermore, even if a method has been evaluated, additional validation research is warranted when used in a different population (Thompson & Subar, 2013).

Because in nutrition research a 'gold standard' is not available, the validity of a newer method can be assessed relative to a reference method only. Essentially, the aim of validation studies is thus to investigate the relative validity of a dietary intake instrument. Note that the term 'relative validity' is sometimes referred to as 'comparative', 'congruent' or 'concurrent validity' in the literature. Anyhow, these terms are used to denote there is uncertainty that the reference method fulfils the criteria of a true gold standard.

Calibration studies use the same information as validation studies, however, they are intended to relate (calibrate) the new method to an alloyed gold standard using a measurement error model (Slimani et al., 2000; Ferrari et al., 2009; Thompson & Subar, 2013). The NCI maintains a register of validation/calibration studies and publications on the web (NCI, 2013b).

Validity and reproducibility

Validity is described as: *"the degree to which a measurement is a true and accurate measure of what it purports to measure"* (Nelson, 2007). Therefore, an instrument is considered to be valid if its assessment can be taken as being a reasonable representation of the true situation. The validity of a study result describes the degree to which the inference drawn from a study is warranted when account is taken of the study methods, the representativeness of the study sample and the nature of its source population. In this context, validity can be divided into internal validity and external validity. Internal validity refers to the subjects actually sampled in the study. External validity refers to the extension of the findings from the sample to the target population (Martínez & Martínez-González, 2009).

Reproducibility indicates the extent to which an instrument is capable of producing the same result when used repeatedly under same circumstances and is therefore also called repeatability (Nelson, 2007). An instrument with high repeatability is also highly reliable. A reliable measure is measuring something consistently, though, not necessarily estimating its true value. If a measurement error occurs in two separate measurements with exactly the same magnitude and direction, this measurement may have good reproducibility and yet have poor validity (Nelson, 2007; Martínez & Martínez-González, 2009).

Types and sources of errors

The complex nature of diet poses an unusually difficult challenge to those responsible for assessing dietary intake. Even when methods are adequately selected and appropriately performed, any dietary intake assessment will be associated with measurement error.

Generally, two types of error exist, random and systematic, which can occur at two different levels: within a person and between persons (Willett, 2013a; Rutishauser, 2007; MacIntyre, 2009). Both types affect the average of repeated measures differently with random errors being eliminated by the law of large numbers. Contrary, systematic errors (bias) remain present when averaging repeated measures and therefore deviate from the true value (**Figure 2**). Random within-person error can be measured by performing replicate measures on the same individual, called a reproducibility study. Measurement of systematic error, however, requires a superior reference measure, called a validation or calibration study (Willett, 2013a).

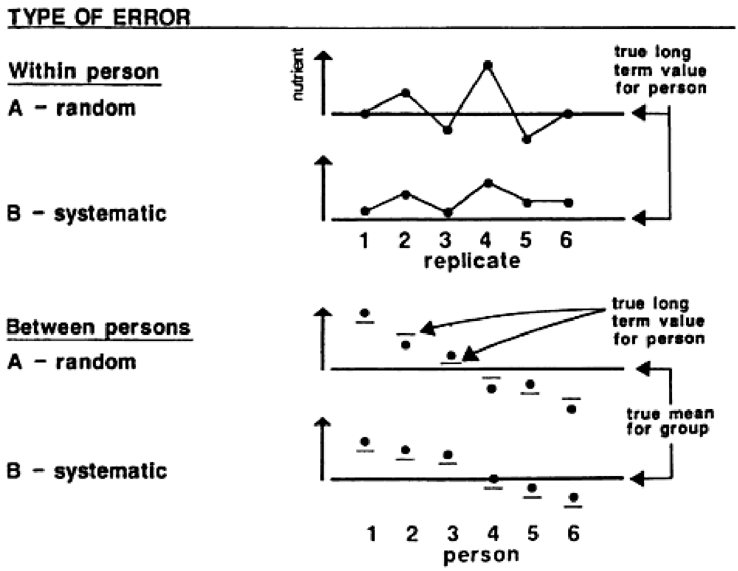

Figure 2 - Types of measurement errors (reprinted with permission from Willett, 2013a)

Different sources of error have been proposed in the literature and many classifications exist. The following sources of error possibly occur to some degree with all dietary methods, but can be minimized by careful study design and implementation: sampling bias, response bias, inappropriate coding of foods, and, the use of food composition tables as an alternative for chemical analysis (Rutishauser & Black, 2002). Moreover, errors associated with specific methods are generally much more dependent on the nature of the method and the abilities of the respondents. Errors of this type include: estimation of portion size; recall or memory error; day-to-day variation in intake; and, effect of survey method on food intake (MacIntyre, 2009).

As presented in section 1, different dietary assessment methods are available. Regardless of the method used, the process of translating food consumption data into energy and nutrient intakes is similar for all direct methods and involves five common steps (MacIntyre, 2009):

1) obtaining a report containing all foods consumed by each individual;
2) identifying foods in sufficient detail to select an appropriate item in the food composition tables (coding);
3) quantifying portion sizes;
4) measuring or estimating the frequency with which each food is eaten;
5) calculating nutrient intakes using food composition tables or data from chemical analyses.

Figure 3 summarizes all five steps of the dietary assessment process and illustrates the points at which aforementioned errors operate.

Person-specific characteristics possibly influence the first four steps of the dietary assessment process impacting reporting validity. Differential misreporting related to BMI and other person-specific biases have been shown to seriously distort measurement error correction procedures in nutritional epidemiological studies (Kipnis et al, 2003; Subar et al. 2003). In a pan-European context, this problem would be amplified if the effect of BMI differed between countries. A study performed by Freisling et al. (2010) using data from the EPIC-study showed that under-reporting of protein and potassium intake was associated to BMI, however, this effect seemed to be the same across countries despite their diverse dietary patterns and other cultural differences. More recently, Crispim (Geelen, de Vries, et al. 2012) performed the same analysis using a multilevel random effect model to differentiate individual- en center-level effects using a sample with larger geographical diversity, heterogeneity of dietary patterns and statistical power. From this analysis it could be concluded that BMI was an important factor influencing the biases in protein and potassium intake across centers (only for potassium intake in men a between-center variation in bias was present). The Observing Protein and Energy Nutrition (OPEN) study evaluated the 24-HDR method used in the US and Canadian food consumption surveys using urinary nitrogen and doubly labeled water as biomarkers for protein and energy intake, respectively. Results showed that significant obesity-related energy under-reporting occurred with the 24-HDR in both men and women (Lissner et al., 2007).

Apart from person-specific characteristics like BMI, country-/center- specific characteristics and design aspects may also be associated with variation of bias across countries. Nonetheless, analyses performed using data from the EFCOVAL study showed that center-level characteristics did not influence between-center variations in bias of protein or potassium intake (Crispim S., Geelen, de Vries, et al., 2012). In contrast, design aspects like mode of administration (face-to-face v. telephone), recall day (first v. second), day of the week (weekday v. weekend) and interview day (1 d later v. 2 d later) resulted in differential bias across countries (Crispim S.P., Geelen, Siebelink et al., 2012).

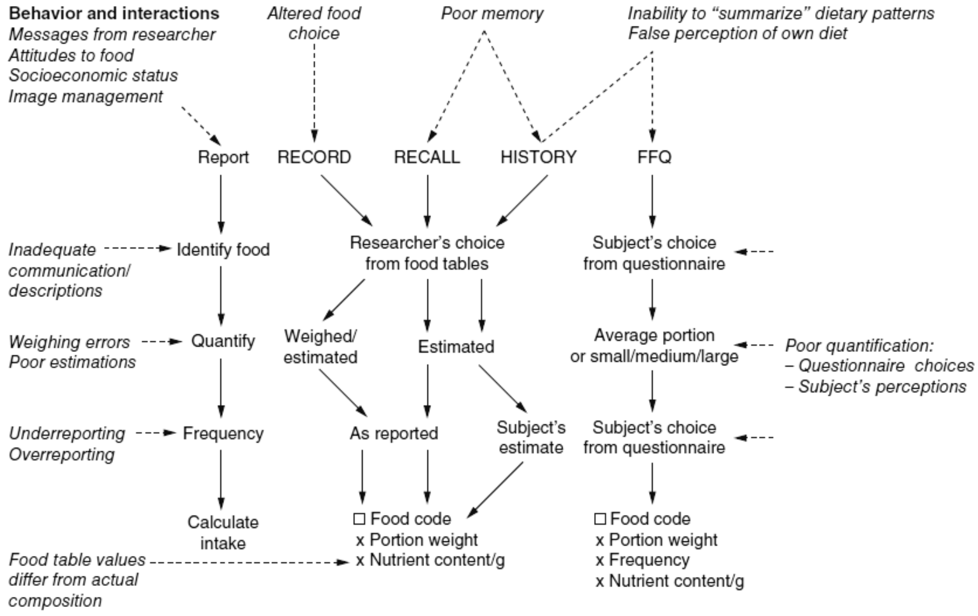

Figure 3 - The process of dietary assessment showing the different sources of error (shown in italics) and the stages at which they operate in different dietary methods (reprinted with permission from MacIntyre, 2009)

Finally, studies assessing the validity of instruments can either investigate the whole process of dietary intake assessment (e.g. comparing protein and potassium intake between five European centres, EFCOVAL study), or, focus on one or some particular aspects of this process (e.g. studies investigating the validity of portion size estimation using food photographs). Essentially, the aim of validation studies is to investigate the validity of a dietary intake instrument which may not always lead to the establishment of a valid instrument. Therefore, these types of studies should be denoted as validity studies rather than validation studies.

Biomarkers

Studies assessing the relative validity of one method compared to a reference method have a major shortcoming. The nature of such studies is to describe the agreement between both dietary intake assessment methods. However, good agreement of measures does not imply that they are valid since both methods just might have similar errors (Gibson, 2005c). Therefore, nutrition epidemiologists have been studying dietary biomarkers from biological samples to obtain objective and accurate measures of dietary intake or nutritional status which have uncorrelated errors with those obtained from dietary intake assessments (Jenab, Slimani, Bictash, Ferrari, & Bingham, 2009).

A nutritional biomarker can be describes as: *"any biological specimen that is an indicator of nutritional status with respect to intake or metabolism of dietary constituents. It can be a biochemical, functional or clinical index of status of an essential nutrient or other dietary constituent"* (Potischman & Freudenheim, 2003). Biochemical markers are not strictly considered to be measures of true intake. However, they provide reference estimates of dietary intake with errors that are unlikely to be correlated with errors of self-reported dietary intake (Ocké & Kaaks, 1997). Biomarkers can be categorized into short-term (reflecting intake over past hours to days), medium-term (reflecting intake over weeks to months) and long-term markers (reflecting intake over months to years), with the type of sample used being a main determinant of time (e.g. blood, hair or adipose tissue) (Potischman, 2003). In validation studies, biomarkers are divided into several classes; recovery, predictive, concentration or replacement biomarkers (**Table 2**) (Jenab et al., 2009).

In particular, recovery biomarkers have a precisely known quantitative relation to absolute dietary intake and therefore provide a reference estimate of the magnitude of bias in dietary intake (Kaaks, 1997). Unfortunately, only a few recovery biomarkers are available to assess nutrient intake. Among them are urinary nitrogen and potassium to assess the dietary intake of protein and potassium, respectively. Another type of biomarker, known as concentration biomarkers, can also be used to evaluate dietary assessment methods. Their concentration is a result of complex metabolic processes and is not as directly related to dietary intake as recovery biomarkers (Freedman et al., 2010). Finally, replacement biomarkers are closely related to concentration biomarkers and refer to compounds for which information in food composition databases is either unavailable or unsatisfactory or for compounds like sodium that are difficult to assess using traditional dietary intake instruments.

Table 2: Overview of dietary biomarker classes

Biomarker class	Description	Examples (indication of nutrient)
Recovery	provide an estimate of absolute intake levels based on the metabolic balance between intake and excretion over a fixed period of time, correlation between biomarker and nutrient/food >0.8	• doubly labelled water *(total energy intake)*; • 24-h urinary nitrogen *(protein intake)*; • 24-h urinary potassium *(potassium intake)*
Predictive	show a dose-response relationship with intake levels but overall recovery is lower	• 24-h urinary sucrose *(sugar intake)*; • 24-h urinary fructose *(sugar intake)*
Concentration	correlate with intakes of corresponding foods or nutrients, however, translation into absolute levels of intake is not possible, correlation between biomarker and nutrient/food <0.6	• blood lipids *(e.g. omega 3 fatty acids for fish intake)*; • serum carotenoids *(fruit and vegetable intake)*
Replacement	refer specifically to compounds for which information in food composition databases is unsatisfactory or unavailable (closely related to concentration biomarkers)	• 24-h urinary sodium *(salt intake)*; • phytoestrogens; • aflatoxins

In this dissertation, 24-h urinary nitrogen, potassium and sodium will be used to assess the validity of the 24HDR using EPIC-Soft (see chapter 4 and 5). In addition, urinary creatinine will be used as a marker to identify incomplete 24-h urine collections (see chapter 6). A thorough literature review of available dietary markers is available in the work performed by Jenab et al. (2009) and Hedrick et al. (2012).

Harmonization of food consumption surveys

In 1997, a programme of Community action on health monitoring was set up by the European parliament to promote the development and exchange of adequate, reliable and comparable indicators of public health (European Parliament, 1997). At that time, collected data and information by Member States were mainly for the purposes of use at national level and often of limited comparability and varying quality (Brussaard, J., Johansson, & Kearney, 2002). In addition, a set of dietary components which are relevant determinants of health was lacking. Therefore, the 'European Food Consumption Survey Method' (EFCOSUM) project was launched and aimed to develop a list of dietary indicators for health monitoring and to define a method for the monitoring of food consumption in nationally representative samples of all age – sex categories in Europe in a comparable way (Brussaard, J., Johansson, et al., 2002). In 2001, the following list of diet indicators was agreed upon by the EFCOSUM group, in order of priority: vegetables, fruit, bread, fish, saturated fatty acids as percentage of energy (%E), total fat as %E, and ethanol in grams per day (Steingrimsdottir, Ovesen, Moreiras, & Jacob, 2002). As the most suitable method to get internationally comparable new data on population means and distributions of usual intake, the standardized 24HDR using EPIC-Soft was selected, to be conducted at least twice (Brussaard, J. H., Lowik, et al., 2002a).

Following the EFCOSUM project, the European Food Consumption Validation (EFCOVAL) project was performed. The overall objective of EFCOVAL was to continue the work initiated by EFCOSUM and to further develop and validate the food consumption instrument to assess dietary intake necessary for studying associations with health and food safety issues in future pan-European monitoring surveys. A major outcome of EFCOVAL was an upgraded and adapted version of EPIC-Soft was, and the biomarker-based validation study of two non-consecutive 24-HDRs using EPIC-Soft (see chapter 4) (de Boer et al., 2011).

Finally, the European Food Safety Authority (EFSA) Expert Group on Food Consumption Data developed a guideline on general principles to collect dietary information (EFSA, 2009). In 2010, members of the EFSA Advisory Forum signed a declaration supporting the establishment of the EU Menu project, a pan-European food consumption survey among EU member states (EFSA, 2010). This project aims at harmonising data collection on food consumption across Europe and is coordinated by EFSA in close cooperation with Member States. The surveys within this project are planned to run from 2012 to 2016 (personal communication). The EPIC-Soft methodology was tested and evaluated in four countries in the EFSA funded PILOT-PANEU project (Slimani et al., 2013). The evaluation of a number of quality indicators showed comparable results between countries in terms of interview duration, reporting of specific foods (e.g., "flour, wheat" instead of "flour, non-specified"), and food and recipe description by facets.

Aims and research questions of this dissertation

The principal aims of this dissertation are to investigate the validity of instruments used in the Belgian food consumption survey, to further the scientific knowledge in the domain of nutrition research methodology and to formulate practical recommendations for the Belgian food consumption survey, policy recommendations and directions for future research.

More specifically, since the EPIC-Soft guided 24 hour dietary recall, the associated picture book with photographs of foods used for portion size estimation, and the short food frequency questionnaire had never been validated in a sample representing the Belgian population, the aim of this work was therefore to fill this gap.

The work collected in this dissertation is diverse and covers different aspects of methodological research in nutritional studies. Detailed research questions and aims of the various building blocks that substantiate the validity of nutritional surveillance can be consulted in the respective chapters.

Outline of the dissertation

The central theme of this dissertation focuses on methodological aspects associated with dietary intake assessment of national food consumption surveys. The general introduction provides the reader with a succinct background related to this field of research. This work is divided into three parts. In the **first part**, the emphasis is on the relative validity of instruments used during food consumption surveys in Belgium. In chapter one, the Belgian version of the EPIC-Soft guided 24 hour dietary recall methodology is compared with a five-day estimated food record and energy underreporting is investigated using accelerometry data. Chapter two covers the errors associated with the use of food photographs and drawings for portion size estimation during the 24 hour dietary interview. In chapter three, the relative validity of a short food frequency questionnaire used in the Belgian food consumption survey is presented. The **second part** comprises three chapters on the use of specific biochemical markers in validation studies. Another common feature of these chapters is that the studies are performed at the international level (EFCOVAL project) as opposed to those in part one which are at the national level (Belgium). Chapter four describes the comparability of protein and potassium intakes between five European centres. In chapter five, the performance of the EPIC-Soft 24 hour recall interview to assess dietary sodium intake is reported. Next, the usefulness of urinary creatinine for detecting incomplete urine samples is illustrated in chapter six. Finally, the **third part** gives an overview of the dietary assessment methods used during nutritional surveillance in Europe and the rest of the world. Chapter seven summarizes the experiences with dietary surveys using EPIC-Soft from a selection of European countries or regions. In chapter eight a comparative overview of methodological aspects related to dietary intake assessment of food consumption surveys performed in Africa, North America, South America, Asia and Australasia is given. Finally, this work is completed with a general discussion and recommendations for policy, future research and practical recommendations for the Belgian food consumption survey are given.

The chapters are written as separate articles for publication in scientific peer-reviewed journals. The content presented in chapter 1,2,3,4,6 and 7 has been published (De Keyzer, Huybrechts, De Vriendt, et al., 2011; De Keyzer, Huybrechts, De Maeyer, et al., 2011; De Keyzer, Dekkers, Van Vlaslaer, et al., 2013; Crispim S.P., de Vries, Geelen, et al., 2011; De Keyzer, Huybrechts, Dekkers, et al., 2012; Huybrechts, Casagrande, Nicolas, et al., 2011) as original research articles in peer-reviewed journals. The different chapters can be read independently from each other. However, it is inevitable that small overlap in background, material and methods sections is present between certain chapters.

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PART 1

Relative validity of instruments used during food consumption surveys

Chapter 1
24-h Recalls using EPIC-soft versus 5-day estimated food records

The methodology used in the first Belgian food consumption survey followed to a large extent the conclusions of the EFCOSUM reports that recommended repeated 24-hour recalls (24-HDR) using EPIC-Soft. The objectives of this chapter are 1) to evaluate the relative validity of two non-consecutive 24-HDR using EPIC-Soft by comparison with 5-day estimated dietary records (EDR), and, 2) to asses misreporting in energy for both methods by comparing energy intake with energy expenditure from accelerometry in a subsample. A total of 175 subjects (aged 15 years and over) were recruited to participate in the study. Repeated 24-HDR were performed with an interval of 2-8 weeks. After completion of the second interview, subjects were instructed to keep an EDR. Dietary intakes were adjusted for within-person variability to reflect usual intakes. A Student's T-test was calculated to assess differences between both methods. De-attenuated and Kappa correlation coefficients were used to investigate agreement. In total, 127 subjects completed the required repeated 24-HDR, as well as the EDR. Accelerometer data was available from 76 participants. In both methods, about 35% of participants had ratios of Energy Intake over Total Energy Expenditure (EI:TEE) above or below 95% confidence intervals for EI:TEE, suggesting misreporting of energy. Significant differences between the two dietary intake methods were found for total energy, total fat, fatty acids, cholesterol, alcohol, vitamin C, thiamine, riboflavin and iron. In general, intakes from 24-HDR were higher compared to EDR. Correlation coefficients for all nutrients ranged from 0.20 for thiamin to 0.95 for water, alcohol and iron. The results from this study show that in the context of nutritional surveillance, duplicate 24-HDR can be used to asses intakes of protein, carbohydrates, starch, sugar, water, potassium and calcium.

Chapter based on:

De Keyzer, W., Huybrechts, I., De Vriendt, V., Vandevijvere, S., Slimani, N., Van Oyen, H., & De Henauw, S. (2011). Repeated 24-hour recalls versus dietary records for estimating nutrient intakes in a national food consumption survey. Food & nutrition research, 55. doi: 10.3402/fnr.v55i0.7307.

Parts of this work was presented at the 7th International Conference on Diet and Activity Methods (ICDAM 7) in Washington DC, United States of America, June 2009.

Background

In Belgium, the first national food consumption survey was performed in 2004. The main objectives of the Belgian food consumption survey were to monitor the nutritional adequacy of food and nutrient consumption on one hand, and food safety-related aspects of food intake on the other hand. Information on food intake was collected using two non-consecutive 24-hour recalls (24-HDR) in combination with a self-administered food frequency questionnaire (De Vriese et al., 2005). This method was recommended by the European Food Consumption (EFCOSUM) project as best practice for Europe for estimating usual dietary intakes at the population level (Biro, Hulshof, Ovesen, & Cruz, 2002). To ensure standardization, a computer assisted 24-HDR method, the EPIC-Soft program, was used. This software programme was originally developed for use in the European prospective investigation on nutrition and cancer (EPIC) study and has been validated in different European countries (Ferrari et al., 2002; Slimani et al., 2003).

To date, a repeated 24-HDR has not been validated for use in national food consumption surveys among the Belgian population aged 15 years and over. Moreover, to our knowledge, no literature is available that explores the validity of 2 independent EPIC-Soft 24-HDR compared to an estimated dietary record (EDR). Therefore, the objective of the present study was to investigate the relative validity of the repeated 24-HDR, using EPIC-Soft, to assess nutrient intakes, against a 7-day EDR. In addition, energy intake estimation of both methods was externally validated using accelerometry.

Methods

Study design

Using a cross-sectional design, recorded food intake was compared to recalled food intake. Two computer-assisted 24-HDR interviews were performed in the participant's home with a 2 to 8 week interval. When planning the interviews, an equal distribution of the different days of the week was considered. Both interviews were performed by dietitians trained to use EPIC-Soft. Between the first and second interview, participants were asked to complete a general questionnaire comprising socio-demographic and anthropometric elements. After the second 24-HDR interview, participants were instructed on how to complete a pre-structured 7-day EDR. After the 7-day registration the dietitians visited the participants once more to collect the records and check them for completeness and correctness. A subsample was provided with an accelerometer and instructed on how to wear it. The motion sensor was worn during the 7-day food intake recording.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the regional Ethics Committee of Ghent University Hospital. Written informed consent was obtained from all subjects.

Participants

A different approach for recruiting participants was performed for adolescents, adults and elderly. In adolescents, a multi-stage sampling was performed. First, five secondary schools providing both general education as well as vocational training, were contacted in the region of Ghent. Four schools agreed to participate in the study. Second, parent's permission was asked by written request. Since selection of classes and communication with parents was performed by the school's administration, the number of invited participants is unknown. Adults invited for participation were acquaintances and family of students and researchers, elderly were recruited via social service centres. Elderly living in a residential care setting were excluded given the more limited freedom in food choices. Equality in gender was pursued at all time. A total of 233 adult men and women (adults and elderly) were invited accordingly. The subjects did not receive any incentive for their participation.

24-h Recall and EPIC-Soft

During a 24-HDR, the participants report the types and quantities of all foods and beverages consumed during the preceding day. Due to within-subject variation, a single 24-HDR is not able to offer a critically valid estimate of one's usual dietary intake (Biro et al., 2002). The collection of two non-consecutive 24-HDR allows for important correction for within-subject variability in nutrient intake (Nusser, Carriquiry, Dodd, & Fuller, 1996; Guenther, Kott, & Carriquiry, 1997; Hoffmann et al., 2002).

Since a 24-HDR is an open-ended interview, this type of data collection requires standardization. EPIC-Soft is a computerized 24-HDR program suitable for obtaining dietary information in national food consumption surveys (Slimani & Valsta, 2002). The 24-HDR interview performed with EPIC-Soft is divided into four main steps: 1) general non-dietary information; 2) quick list (chronological list of consumed foods and recipes); 3) description and quantification of foods and recipes; and 4) quality controls at nutrient level. Entering foods in chronological order of consumption and the use of probing questions supports the respondent's memory (De Vriese et al., 2005).

Quantification of foods was possible using weights or volumes, food photographs from the EPIC-Soft picture book (van Kappel, Amoyel, Slimani, Vozar, & Riboli, 1995), household measures, standard units and standard portions from the Belgian household weights and measures manual (Superior Health Council Belgium, 1997).

Estimated dietary record

Structured open-ended diaries containing predefined food groups (including the option "other food items") at six food occasions (breakfast, lunch, dinner and 3 snacks) were provided to all subjects. All participants were informed on how to complete the food record. The diary also contained a written example for future reference. During a seven day period, all consumed foods and drinks had to be reported with notification of date and place of consumption, estimated consumed quantity expressed as a household measure, unit or weight, qualitative specification and, if present, a brand name. Separate forms were included to report on homemade recipes so name of dish, total quantities of all ingredients and fraction of dish consumed could be stated. Foods reported in the EDR were entered in the 'Diet Entry & Storage' program (BECEL) (Nederlandse Unilever Bedrijven B.V., 1995) using a standardized set of food codes and exported for further linking.

The number of days necessary to estimate true energy intake can be calculated as $n = [(1.96 \text{ x } CV_{wEI})/D_0]^2$ where D_0 is the specified % of the true mean and CV_{wEI} is the within-person coefficient of variation of energy intake (Willett, 2013). Using this calculation, the number of days needed to estimate a person's energy intake to within 20% of his true mean, 95% of the time, would be 4.7 days (CV_{wEI} calculated from the EDR). Therefore, only participants who completed at least five days of the dietary record were included in the analysis and intakes were calculated from the first five consecutive days available.

Nutrients

Usual intakes of energy, water, 10 macronutrients (protein, fat, saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA), poly-unsaturated fatty acids (PUFA), carbohydrates, starch, simple sugars, fibres, alcohol) and seven micronutrients (cholesterol, thiamin, riboflavin, ascorbic acid, potassium, calcium, iron) were calculated. Therefore, food codes of the exported files from the 24-HDR and EDR were linked to food composition databases (FCDB). In total, five FCDB were used: 1) NUBEL - a Belgian database for regular foods (NUBEL, 2004) and 2) INTERNUBEL - a specific database with only brand foods (www.internubel.be) (NUBEL, 2005), 3) NEVO - a database from the Netherlands (NEVO, 2001), 4) McCance and

Widdowson's The Composition of Foods - a UK database (Food Standards Agency (FSA), 2002), and 5) Table de Composition des Aliments - a local FCDB (Institut Paul Lambin (IPL), 2004). Selection of a FCDB for any given food was based on the best proximate in those food composition databases. However, priority was given to the Belgian FCDB, followed by the database from the Netherlands and the UK. Finally, for both methods, calculated nutrients of all foods were aggregated on a day level. For both methods (24-HDR and EDR), use of food supplements was not taken into account.

Accelerometry

It is well known that, regardless the method used, self-reported food intake underestimates true food and nutrient intake (Bedard, Shatenstein, & Nadon, 2004; Poslusna, Ruprich, de Vries, Jakubikova, & van't Veer, 2009). Data on a persons' daily energy expenditure can be used to detect both under-and overreporting in conditions of energy balance since long term energy expenditure should correspond to energy intake. Accelerometers are motion sensors which provide objective information on daily physical activity with minimal burden for participants. The motion sensors used in this study are piezo-electric uniaxial accelerometers (the Computer Science and Applications, Inc.; CSA, model 7164) which are able to distinguish between regular body movement and other sources of movement like external vibrations. Subjects were instructed on how to wear the device. Special attention was given to the positioning of the device above the right hip. Participants were instructed to remove the accelerometer for bathing, swimming activities, high contact sports and during sleeping. In addition, participants were requested to keep an activity diary for registration of duration and type of activity performed when the accelerometer was not worn. Accelerometers had to be worn for a minimum of 10 hours a day during at least 4 days. Data from participants not meeting these conditions were excluded from analysis.

The CSA data were downloaded from the device using the CSA Inc. reader interface unit. For adults, classification of 1-min epochs was performed into the following three categories, resting/light, moderate, and vigorous intensity categories, using cut-offs proposed by Swartz et al. (2000). These cut-offs were chosen because both type of activity and age of participants resembled best our adult study sample. The categories of intensity of activity correspond to the ratios of work metabolic rate to resting metabolic rate (metabolic equivalents; METs) <3, 3-5.99 and ≥ 6 respectively. The specific count ranges used to classify activity in adults and elderly as resting/light, moderate, and vigorous intensity, respectively, were as follows: 0–573, 574–4944, $\geq$4945 (Swartz et al., 2000). For adolescents, age specific (15-17 years) counts per minute for 3, 6 and

9 METs were calculated using a derivative of the equation proposed by Freedson et al. (1998). Counts per minute are given by the equation:

$$\text{counts}\cdot\text{min}^{-1} = (MET\text{-}2.757+0.0895 \times A)/(0.0015\text{-}0.000038 \times A)$$

with *MET* being the MET value for which the corresponding counts per minute need to be calculated and *A* the age of the respective age category expressed in years.

Activity levels expressed in METs were assigned to all reported activities reported in the activity diary using the Compendium of Physical activities from Ainsworth (2000). Then, data from CSA and activity diary were summed in such a way that for every participant total time (expressed per minute) spent at the different physical activity levels (resting to vigorous) were obtained. Subsequently, total energy expenditure (TEE) per intensity category was calculated using the formula: TEE (kcal) = body weight (kg) x total minutes of activity (min.) x MET-value / 60. Self-reported body weight was taken from the general questionnaire. Since activity levels only correspond to certain ranges of METs, a mean MET value was used as follows: inactivity, 1 METs; light activity: 2 METs; moderate activity: 4.5 METs, vigorous activity: 7.5 METs.

Underreporting

In weight stable conditions, participants' reported energy intake (EI) should accord to their total energy expenditure (TEE), thus, the ratio of both measures should be equal to 1. Values above or below the 95% confidence limits of the ratio were taken to indicate over- or underreporting respectively using the equation from Black & Cole (2001)

$$2 \times \sqrt{[(CV^2_{wEI}/d) + CV^2_{wEE} - 2r.(CV_{wEI}/\sqrt{d}).\ CV_{wEE}]}$$

where CV_{wEI} is the mean within-person coefficient of variation for daily energy intake, *d* is the number of days of dietary records, CV_{wEE} is the within-person coefficient of variation for energy expenditure and *r* is the correlation between energy intake and expenditure.

CV_{wEI} was calculated from the EDR and the 24-HDR data and number of days (d) was set to 5 and 2 respectively. CV_{wEE} was taken from an analysis of studies with repeated doubly labelled water (DLW) measurements and set to 8.2% (Black & Cole, 2000). The correlation (r) between EI and EE from accumulated individual DLW data was set at 0.425 (Black, 2000).

Statistical analysis

Many factors contribute to the variance of food and nutrient intake data. However, from a statistical point of view, three main factors can be identified including between-subject variability, within-subject variability and measurement error (Cole, 2007). Correcting for within-subject variability gives a better estimate of the population distribution for usual intake, especially for episodically consumed foods and nutrients. In order to estimate usual nutrient intake distributions from short term dietary intake assessments, C-side (Software for Intake Distribution Estimation) was used to remove within-subject variability and transform the data to an approximately normal distribution (Nusser et al., 1996; Guenther et al., 1997; Iowa State University, 1997). During this procedure, dietary intake data was adjusted for day of week, age and gender. The differences between mean intakes of nutrients for both methods were assessed using Student's T-tests. For this, adjusted sample means and standard deviations were used. Agreement of both methods was evaluated using de-attenuated correlation coefficients (Beaton et al., 1979). Since the null hypothesis of a correlation test assumes that the ranks of one variable do not covary with the ranks of the other variable, which seems unlikely because both methods measure the same variables, weighted Kappa correlations were also calculated. In addition, ratios of estimated nutrients from 24-HDR over EDR were reported. For all nutrients, Kappa correlations between both methods were compared by gender after Fisher r-to-Z transformation. Comparison of misreporting between genders was performed using the Chi-square test. All statistical tests were performed using SPSS for Windows release 18.0.0 (SPSS Inc., Chicago, IL, USA), two-tailed and $P < 0.05$ was considered as statistically significant.

Results

In total, 156 subjects agreed to participate in the study, representing a response rate of 55% in adults and elderly. The response rate for adolescents could not be calculated since cluster sampling was used and the total number of adolescents invited was not known. Almost all participants completed both 24-HDR (n=155), however only 100 (64%) were able to complete all seven days of the food record. For the EDR, the first five consecutive days were used, bringing the final total to 127 (56% women). The subsample provided with accelerometers comprised 106 participants. Accelerometer data from 76 participants (50% women) were available for analysis.

Table 1 summarizes age and self-reported anthropometric measures of the participants. According to the three age categories, the number of subjects were 18 (14.2%), 51 (40.2%) and 58 (45.7%) for the adolescents, adults and elderly respectively.

Table 1: Characteristics of the participants

	Total (n=127)				Women (n=71)				Men (n=56)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Age (years)	50.2	24.7	15.1	91.1	51.7	25.3	15.2	84.7	48.3	23.9	15.1	91.1
Weight (kg)	71.6	13.4	44.0	119.0	65.9	11.2	44.0	98.0	78.9	12.5	55.0	119.0
Height (cm)	170.4	9.1	152.0	190.0	165.3	6.5	152.0	182.0	176.9	7.7	160.0	190.0
BMI (kg/m^2)	24.7	4.1	16.2	37.8	24.2	4.1	16.2	36.9	25.3	4.1	18.4	37.8

Total energy intake from foods assessed by both methods was compared to total energy expenditure calculated from accelerometer data. TEE and the ratio EI:TEE with 95% CIs were calculated. For EDR and 24-HDR the mean within-person coefficient of variation for energy (CV_{wEI}) was 22.0% and 21.6% respectively. The lower and upper ratio cut-offs for EDR and 24-HDR were 0.80 and 1.20; and 0.72 and 1.28 respectively. **Table 2** shows that for both methods, approximately 65% of participants were classified as acceptable reporters. The remaining 35% was equally distributed over the under- and overreporters categories. For energy intake assessed with the 24-HDR, the number of underreporters in men was significantly lower compared to women (χ^2 (2)=6.361, P=0.042). No significant difference was found in misreporting between both methods.

Table 2: Percentage classification (n) of energy misreporting based on EI:TEE presented by gender and dietary assessment method

	EDR			24-HDR		
	All	Women	Men	All	Women	Men
Under-reporting	15.8% (12)	15.8% (6)	15.8% (6)	17.1% (13)	26.3% (10)	7.9%(3)*
Acceptable-reporting	67.1% (51)	71.1% (27)	63.2% (24)	64.5% (49)	63.2% (24)	65.8% (25)
Over-reporting	17.1% (13)	13.2% (5)	21.1% (8)	18.4% (14)	10.5% (4)	26.3% (10)

EI, energy intake
TEE, total energy expenditure
The lower and upper ratio cut-offs for EDR and 24HDR were 0.80 and 1.20; and 0.72 and 1.28 respectively.
*Number of underreporters in men was significantly lower compared to women (χ^2(2)= 6.361, P=0.042).

Tables 3 and **4** show the usual mean daily macro- and micronutrient intakes assessed using both methods. Also, ratios of 24-HDR:EDR, p-values for differences using T-tests and de-attenuated correlation coefficients are presented. Ratios vary over nutrients and gender; however, in general, positive ratios were found indicating higher intake estimates in the 24-HDR compared to the EDR. Ratios less than 1.0 were

Table 3: Mean usual intakes, p-values for T-tests, ratios and de-attenuated correlation coefficients of macronutrients by both methods. All data are adjusted for day of week and age (in years). Figures representing total sample are additionally adjusted for gender.

	EDR						24-HDR						p†			24-HDR:EDR			r‡		
	All (n=127)		Women (n=71)		Men (n=56)		All (n=127)		Women (n=71)		Men (n=56)										
Macronutrient	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	All	♀	♂	All	♀	♂	All	♀	♂
Energy (MJ/d)	8.1	1.5	6.9	1.1	9.7	1.9	9.0	2.1	7.8	1.8	10.7	2.1	<0.01	<0.01	0.01	1.12	1.12	1.11	0.75	0.44	0.88
Energy incl. alc. (MJ/d)	8.4	1.5	7.0	1.1	10.3	2.0	9.4	2.2	7.9	1.8	11.5	2.5	<0.01	<0.01	0.01	1.12	1.12	1.12	0.79	0.47	0.89
Protein (g/d)	76.0	12.0	66.9	9.6	87.3	14.1	78.7	15.6	66.0	11.8	96.5	18.3	0.12	0.61	<0.01	1.04	0.99	1.10	0.76	0.53	0.77
Fat (g/d)	76.7	17.4	64.0	13.9	94.2	21.8	96.6	28.4	84.4	24.3	113.0	29.9	<0.01	<0.01	<0.01	1.26	1.32	1.20	0.80	0.61	0.95
SFA (g/d)	31.0	7.8	27.2	6.2	35.9	9.7	38.6	13.1	33.4	10.1	45.5	16.2	<0.01	<0.01	<0.01	1.24	1.23	1.27	0.66	0.46	0.77
MUFA (g/d)	29.5	6.8	23.9	5.3	37.7	8.4	34.7	9.9	30.1	7.7	40.9	10.8	<0.01	<0.01	0.08	1.18	1.26	1.09	0.84	0.69	0.99
PUFA (g/d)	12.9	3.5	10.4	3.1	16.7	3.9	19.1	6.2	17.5	5.6	21.1	5.9	<0.01	<0.01	<0.01	1.48	1.68	1.26	0.91	0.74	0.66
LA (g/d)	10.1	3.3	8.0	2.9	13.5	3.8	11.4	3.6	9.7	2.9	13.7	4.0	<0.01	<0.01	0.73	1.12	1.22	1.02	0.75	0.62	0.71
Cholesterol (mg/d)	275.7	54.1	244.1	43.8	316.5	67.9	296.5	87.1	256.6	96.7	350.7	54.9	0.02	0.32	<0.01	1.08	1.05	1.11	0.75	0.34	0.70
Carbohydrates (g/d)	233.4	56.0	202.6	42.9	277.1	73.7	239.5	57.9	206.5	46.3	287.3	74.4	0.39	0.60	0.47	1.03	1.02	1.04	0.78	0.74	0.82
Starch (g/d)	126.3	28.0	113.1	25.8	145.2	31.6	131.0	39.3	112.6	37.5	157.1	41.7	0.27	0.93	0.09	1.04	1.00	1.08	0.83	0.84	0.73
Simple sugars (g/d)	104.1	38.8	85.8	27.6	130.0	51.9	107.1	35.8	91.6	19.9	126.5	49.4	0.52	0.15	0.71	1.03	1.07	0.97	0.74	0.69	0.86
Fibre (g/d)	22.5	5.6	21.5	5.5	23.9	5.9	21.3	4.9	19.8	4.1	23.2	6.0	0.06	0.05	0.56	0.95	0.92	0.97	0.68	0.82	0.53
Alcohol (g/d)	12.6	13.1	5.0	6.3	22.1	17.5	15.1	15.3	5.9	6.6	26.9	25.4	0.17	0.44	0.25	1.20	1.17	1.22	0.95	0.65	0.93
Alcohol (g/d)§	34.1	16.1	19.1	11.5	44.2	16.3	38.7	17.1	19.8	8.1	53.1	29.8	0.03	0.68	0.05	1.13	1.04	1.20	0.73	0.18	0.86
Water (ml/d)	2235.1	583.8	2128.2	583.7	2359.8	576.4	2180.2	501.4	2005.5	436.5	2408.3	562.7	0.42	0.16	0.65	0.98	0.94	1.02	0.95	0.86	0.93
	Nob=236 Nind=90§		Nob=95 Nind=44§		Nob=141 Nind=46§		Nob=99 Nind=66§		Nob=42 Nind=30§		Nob=57 Nind=33§								Nind=56 ǁ	Nind=23 ǁ	Nind=33 ǁ

EDR, 5-day estimated dietary record; 24-HDR, 2-day 24-hour recall
† Student's T-test
‡ De-attenuated correlation coefficients
§ on consumption days only (Nob: number of observations, Nind: number of individuals)
ǁ positive alcohol consumption in both methods only

Table 4: Mean usual intakes, p-values for T-tests, ratios and de-attenuated correlation coefficients of micronutrients by both methods. All data are adjusted for day of week and age (in years). Figures representing total sample are additionally adjusted for gender

	EDR						24-HDR														
	All (n=127)		Women (n=71)		Men (n=56)		All (n=127)		Women (n=71)		Men (n=56)		p†			24-HDR:EDR			r‡		
Micronutrient	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	All	Women	Men	All	Women	Men	All	Women	Men
Vitamin C (mg/d)	79.4	32.0	92.9	41.0	63.2	23.4	98.8	34.8	90.3	31.5	110.7	39.6	<0.01	0.67	<0.01	1.2	1.0	1.8	0.67	0.58	0.81
Thiamin (mg/d)	1.4	0.4	1.3	0.3	1.5	0.3	4.0	2.1	3.9	2.2	4.1	1.7	<0.01	<0.01	<0.01	2.9	3.0	2.8	0.20	0.23	-0.04
Riboflavin (mg/d)	1.5	0.5	1.4	0.4	1.7	0.5	1.7	0.4	1.5	0.4	1.9	0.2	<0.01	0.12	<0.01	1.1	1.1	1.1	0.84	0.56	0.46
Potassium (mg/d)	3252.8	569.3	2959.9	495.7	3628.5	640.5	3130.0	681.1	2683.5	597.2	3755.7	718.8	0.12	<0.01	0.32	1.0	0.9	1.0	0.70	0.50	0.81
Calcium (mg/d)	807.7	217.8	746.1	179.4	871.7	251.1	814.5	250.3	755.6	231.7	891.8	268.9	0.82	0.79	0.68	1.0	1.0	1.0	0.51	0.37	0.69
Iron (mg/d)	10.9	2.5	9.4	2.3	13.0	2.6	11.8	2.2	10.1	1.9	14.0	2.1	<0.01	0.06	0.02	1.1	1.1	1.1	0.95	0.72	0.56

EDR, 5-day estimated dietary record; 24-HDR, 2-day 24-hour recall
† Student's T-test
‡ De-attenuated correlation coefficients

found for fibre in the total sample and both genders, for protein and potassium in women only, for simple sugars in men only and for water and riboflavin in the total sample and women only.

For the macronutrients, there is a significant difference between both methods for fat, fatty acids, cholesterol and alcohol; for the micronutrients the difference was significant for vitamin C, thiamine, riboflavin and iron. The de-attenuated correlation coefficients range from 0.66 to 0.95 for macronutrients and from 0.20 to 0.95 for micronutrients.

Table 5 shows weighted Kappa correlations between both methods based on correct ranking of participants into tertiles. The strength of agreement, as proposed by Altman (Altman, 1991), was moderate for carbohydrates and water (0.42 and 0.54 respectively), and fair for protein, fat and alcohol (0.29, 0.36 and 0.31 respectively). For micronutrients, a moderate agreement was found for iron (0.43). Agreement for thiamine and calcium was found to be poor (0.10 and 0.17 respectively). Kappa correlations were significantly higher in men compared to women for total energy, MUFA, carbohydrates, simple sugars and alcohol.

Discussion

The objective of this study was to compare nutrient intakes collected by two non-consecutive 24-HDR using EPIC-Soft against a 5-day EDR in order to assess its relative validity for use in Belgian food consumption surveys.

Main results and comparison with the literature

Only 100 participants completed all seven days of the estimated dietary record. Decreasing the number of days from seven to five increased the number of available participants to 127. The authors decided to use the first five consecutive days from the EDR in the analysis. Total energy intake from all seven days was compared, and although the median from day 7 was the lowest, no significant differences between days were found (data not shown).

Looking at the estimates of nutrient intakes obtained by both methods, some differences can be found. In general, there is a tendency of higher estimates by the 24-HDR compared to the EDR. Positive 24-HDR:EDR ratios were also found in other studies comparing 24-HDR and EDR (Bingham et al., 1994; Holmes, Dick, & Nelson, 2008). Other studies found negative ratios which were attributed to the omission of foods and errors in portion size estimations related to recalled intake (Baranowski, 2013).

Table 5: Agreement between EDR and 24-HDR by ranking of participants in tertiles expressed as weighted Kappa coefficients with 95% confidence intervals

	weighted Kappa (95% CI)		
Nutrient	All	♀	♂
Energy (MJ/d)	0.31 (0.19-0.43)	0.17 (0.01-0.34)	0.45 (0.26-0.63) †
Energy incl. alc. (MJ/d)	0.40 (0.28-0.52)	0.24 (0.07-0.40)	0.39 (0.21-0.58) †
Protein (g/d)	0.29 (0.17-0.42)	0.14 (-0.02-0.31)	0.23 (0.05-0.42)
Fat (g/d)	0.36 (0.24-0.49)	0.30 (0.14-0.46)	0.35 (0.17-0.54)
SFA (g/d)	0.33 (0.21-0.45)	0.11 (-0.06-0.27)	0.27 (0.09-0.46)
MUFA (g/d)	0.33 (0.21-0.45)	0.24 (0.07-0.40)	0.48 (0.29-0.66)
PUFA (g/d)	0.31 (0.19-0.43)	0.33 (0.17-0.50)	0.31 (0.13-0.50)
LA (g/d)	0.20 (0.08-0.33)	0.17 (0.01-0.34)	0.11 (-0.07-0.30)
Cholesterol (mg/d)	0.27 (0.15-0.40)	0.14 (-0.02-031)	0.27 (0.09-0.46)
Carbohydrates (g/d)	0.42 (0.29-0.54)	0.30 (0.14-0.46)	0.56 (0.37-0.74) †
Starch (g/d)	0.43 (0.31-0.56)	0.36 (0.20-0.53)	0.35 (0.17-0.54)
Simple sugars (g/d)	0.42 (0.29-0.54)	0.24 (0.07-0.40)	0.52 (0.33-0.70) †
Fibre (g/d)	0.27 (0.15-0.40)	0.33 (0.17-0.50)	0.31 (0.13-0.50)
Alcohol (g/d)‡	0.31 (0.13-0.50)	0.01 (-0.28-0.30)	0.37 (0.09-0.64) †
Water (ml/d)	0.54 (0.42-0.66)	0.52 (0.36-0.69)	0.60 (0.41-0.78)
Vitamin C (mg/d)	0.29 (0.17-0.42)	0.20 (0.04-0.37)	0.31 (0.13-0.50)
Thiamin (mg/d)	0.06 (-0.06-0.19)	0.11 (-0.06-0.27)	0.00 (-0.19-0.18)
Riboflavin (mg/d)	0.33 (0.21-0.45)	0.33 (0.17-0.50)	0.27 (0.09-0.46)
Potassium (mg/d)	0.33 (0.21-0.45)	0.20 (0.04-0.37)	0.31 (0.13-0.50)
Calcium (mg/d)	0.17 (0.05-0.29)	0.14 (-0.02-0.31)	0.19 (0.01-0.38)
Iron (mg/d)	0.43 (0.31-0.56)	0.24 (0.07-0.40)	0.35 (0.17-0.54)
	Nind=56‡	Nind=23‡	Nind=33‡

EDR, 5-day estimated dietary record; 24-HDR, 2-day 24-hour recall
† Kappa correlation coefficient significantly different from women (Fisher r-to-Z test, 1-sided)
‡ positive alcohol consumption in both methods only (Nind: number of individuals)

Strengths and limitations

The EDR was chosen as a relative reference method because of its acceptable level of accuracy when validated for assessing dietary intake compared to other methods (Bingham et al., 1995). Moreover, the measurement errors of the EDR and the 24-HDR are independent, since unlike the 24-HDR method, the EDR does not depend on memory and involves immediate estimation of portion sizes. However, like any dietary assessment method, the EDR is subject to some degree of misreporting. The degree of under- and/or overreporting in this study was assessed in a subsample (n=76) by comparison of energy intake in both methods against TEE calculated from accelerometer data. The type of accelerometer (CSA) used in this study has repeatedly been tested (Melanson & Freedson, 1995; Freedson et al., 1998; Sirard, Melanson, Li, & Freedson, 2000) and has shown to correlate significantly with DLW-derived energy expenditure estimations (Ainslie, Reilly, & Westerterp, 2003; Plasqui & Westerterp, 2007). Nevertheless, not all physical activity can be translated into acceleration or deceleration resulting in errors in predicted energy expenditure especially in high intensity activity (Ainslie et al., 2003). In addition, some literature suggests that CSA sensors are not sufficiently sensitive to quantify energy expenditure in free-living individuals (Bassett et al., 2000).

Participating in a study with a large battery of methods tested is very demanding and needs motivation. Therefore, it is likely that characteristics of participants are different than those from non-participants. When comparing BMI of the participants in the present sample with the BMI of those recruited during the Belgian food consumption survey, a lower BMI is found in the present sample. Consequently, this observation may indicate that a sampling bias is present weakening the generalizability of the instrument's performance in a national nutrition survey context.

In spite of these limitations, prevalence of underreporting for both the 24-HDR and EDR has shown to be quite similar to those available in the literature (Poslusna et al., 2009). Also, the higher prevalence of underreporting in women versus men, found in other published studies, was confirmed in this study (Hirvonen, Mannisto, Roos, & Pietinen, 1997; Price, Paul, Cole, & Wadsworth, 1997; Asbeck et al., 2002). A possible explanation for the fact that in the 24-HDR, prevalence of underreporting in men was significantly lower than in women could be that an interviewer guided recall in men provides more complete daily intakes than those based on self-reported food records.

Both underreporting and overreporting was observed for the two dietary assessment methods. Compared to DLW measurements, small underestimation of TEE (25 to 368 kJ/day) assessed using CSA devices has been found (Lof, Hannestad, & Forsum, 2003). Consequently, if underestimation of TEE using CSA devices is the case, this also implies underestimation of underreporting and overestimation of overreporting of the dietary intake assessment instruments under study.

A major strength of this study is that nutrient intake data has been corrected for within-person day-to-day variability using a statistical model. Other studies have used the arithmetic mean of daily intakes to estimate a persons' usual intake, however this approach is likely to be inaccurate since the presence of the day-to-day variability can greatly inflate the variance of the distribution of individual means (Dodd et al., 2006). Correcting for within-person day-to-day variability using statistical models produces comparable means for nutrient intake compared to unadjusted data, however, the distributions of intakes show smaller standard deviations which in turn decreases the odds of finding a different mean intake between both methods by chance alone.

With respect to the positive 24-HDR:EDR ratio for total fat (1.26) and, by extension, fatty acids and energy it should be mentioned that during the EPIC-Soft guided 24-HDR, participants are frequently prompted for missing ingredients like fats or sauces. Also, because of the presence of facets and descriptors in the EPIC-Soft program (Slimani et al., 2000), for instance related to facets such as 'cooking method', 'fat content' and 'type of fat used', the 24-HDR is more likely to yield higher intakes of fat compared to EDR were this information could be omitted by the participant. On the other hand, using standard factors for fat added during cooking could, in some participants, also result in an overestimation of fat consumption.

Another factor which could explain the differences in mean usual intake between both methods is related to portion size estimation. During the 24-HDR interview, food photographs were used in addition to other quantification methods. The use of two-dimensional models for portion size estimation can result in errors due to poor conceptualization and perception. In chapter two, participants' capability in estimating portion sizes of fat on bread using the EPIC-Soft picture book will be evaluated and shows high overestimation of portion sizes by both genders during perception testing (prevalence of overestimation equals 90%) (De Keyzer et al., 2011).

Conclusions

The present chapter shows that there is a similar degree of energy misreporting in both 2-day 24-HDR and 5-day EDRs. For national consumption surveys among the Belgian population, group-level intakes of protein, carbohydrates, starch, sugar, water, potassium and calcium from duplicate 24-HDR do not differ from those obtained by 5-day EDRs.

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Chapter 2
Errors in portion size estimation using food photographs

Food photographs are widely used as instruments to estimate portion sizes of consumed foods. Several food atlases are available, all developed to be used in a specific context and for a given study population. Frequently, food photographs are adopted for use in other studies with a different context or another study population. In this chapter, errors in portion size estimation of bread, margarine on bread and beverages by two-dimensional models used in the context of a Belgian food consumption survey are investigated. A sample of 111 men and women (age: 45-65 years) were invited for breakfast; two test groups were created. One group was asked to estimate portion sizes of consumed foods using photographs 1-2 days after consumption, a second group was asked the same after 4 days. Also, real time assessment of portion sizes using photographs was performed. At the group level, large overestimation of margarine, acceptable underestimation of bread and only small estimation errors for beverages were found. Women tended to have smaller estimation errors for bread and margarine compared to men, while the opposite was found for beverages. Surprisingly, no major difference in estimation error was found after 4 days compared to 1-2 days. Individual estimation errors were large for all foods. The results from this study suggest that the use of food photographs for portion size estimation of bread and beverages are acceptable for use in nutrition surveys. For photographs of margarine on bread, further validation using smaller amounts corresponding to actual consumption, is recommended.

Chapter based on:

De Keyzer, W., Huybrechts, I., De Maeyer, M., Ocké, M., Slimani, N., van 't Veer, P., & De Henauw, S. (2011). Food photographs in nutritional surveillance: errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption. British Journal of Nutrition, 105(7), 1073-1083.

Part of this work was presented at the 4th DIETS conference in Amsterdam, The Netherlands, December 2010.

Background

For nutritional surveillance, a variety of methods to collect food consumption data are available. A common challenge for individual-based dietary assessment methods is related to portion size estimation. Besides asking participants to weigh their foods or describe portion sizes in terms of natural or commercial units, typical serving sizes or household measures, two- and three-dimensional portion size measurement aids are available. Of particular use are food photographs because from a respondent's perspective they are attractive and easy to use (Huybrechts et al., 2011).

When using photographs as portion size measurement aid, three psychological constructs must be addressed (Nelson, Atkinson, & Darbyshire, 1994, 1996): perception, conceptualization and memory. Perception is related to the ability of a person to correctly link an amount of food that is actual present (e.g. on a plate, in a cup, etc.) to a series of two-dimensional photographs depicting different portion sizes of the same food. Conceptualization refers to the person's ability to link a mental construct of an amount of food that is not present in reality to an amount of the same food represented by a photograph. Since conceptualization is associated to recalled intake of foods, memory will influence the precision of conceptualization. In validation studies addressing errors related to portion size estimation by food photographs, the above mentioned psychological constructs are studied.

Studies addressing the validity of food photographs in adults have shown that food photographs are useful aids for portion size assessment although considerable under- and overestimation of portion sizes remain present (Nelson et al., 1994; Robinson, Morritz, McGuiness, & Hackett, 1997; Turconi et al., 2005; Ovaskainen et al., 2008). In the literature, many foods have been investigated. However, data on bread and margarine spread on bread are still scarce and portion size estimation of beverages by photographs of household measures is not frequently investigated. As proposed by Slimani (Slimani et al., 1999) et al. two-dimensional models of slices of bread indicating real thickness, shape and size should be used instead of photographs. This was supported by the findings from Ovaskainen (Ovaskainen et al., 2008) et al. which found poor estimates of portions of bread using photographs. Table 1 shows an overview of the literature indicating design, addressed psychological elements and characteristics of subjects under study.

During the food consumption survey in Belgium, the computerized 24-hour dietary recall method EPIC-Soft was used (De Vriese, Huybrechts, Moreau, & Van Oyen, 2006). EPIC-Soft is a computerized program suitable for standardized collection of dietary information in national food consumption surveys (Slimani & Valsta, 2002).

Different portion size aids were made available for respondents (e.g. units, household measures, standard portions) including a selection of pictures and drawings from the EPIC-Soft picture book (van Kappel, Amoyel, Slimani, Vozar, & Riboli, 1995). Since bread and fat spreads on bread are frequently consumed in Belgium during breakfast and lunch or dinner, the impact of errors in portion size estimation on daily intakes of certain nutrients and energy intake can be considerable. Consumption data from Belgium shows that in adults, bread is responsible for respectively 28% and 16% of the daily carbohydrate and total energy intake respectively, and fats spread on bread contribute to 21% of the daily total fat intake.

Table 1: study details of validation studies addressing portion size estimation using food photographs

		Psychological elements†			
Study	**Design**	P	C	M	**Subjects**
Ovaskainen *et al.*, 2008	*Present portion size:* photo portions selected at presentation vs. weight of the presented portions	+			Men and women 25-65 years *n*=146
Huybregts *et al.*, 2008	*Test meal portion size:* photo portions selected after test meal vs. weight of the test meal portions		+	+ (24 hrs.)	Women 15-45 years *n*=257
Turconi *et al.*, 2005	*Test meal portion size:* photo portions selected after test meal vs. weight of the test meal portions		+		Men and women 6-60 years *n*=448
Frobisher and Maxwell, 2003	*Test meal portion size:* photo portions selected after test meal (not consumed) vs. weight of the test meal portions		+	+ (3-4 d)	Adults 17-82 years *n*=47
Robson and Livingstone, 2000	*Test meal portion size:* photo portions selected after test meal vs. weight of the test meal portions		+	+ (24 hrs.)	Men and women 18-36 years *n*=30
Nelson *et al.*, 1996	*Test meal portion size:* photo portions selected after test meal vs. weight of the test meal portions		+		Men and women 18-90 years *n*=136
Nelson *et al.*, 1994	*Present portion size:* photo portions selected at presentation vs. weight of the presented portions	+			Men and women 18-90 years *n*=51
Faggiano *et al.*, 1992	*Test meal portion size:* photo portions selected after test meal vs. weight of the test meal portions		+	+ (24 hrs.)	Men and women 35-64 years *n*=103

† P, perception; C, conceptualization; M, memory (time before recall)

This chapter aims to investigate perception and conceptualization skills of adults between 45 and 65 years of age in a nutritional surveillance context using two-dimensional models from the Belgian food consumption survey. Therefore, a breakfast was provided and recalled portion size estimation using drawings of bread shapes, photographs of margarine on bread, coffee and water was compared to weighed intakes. In addition, real-time sessions were organised to test perception of bread and margarine on bread.

Methods

Subjects

A convenient sample of 111 adults between 45 and 65 years of age was recruited from family members, acquaintances and friends of students in nutrition and dietetics. Subjects were also recruited from a local social service department. Advertisement for a free breakfast was made. Potential participants were told that the study focused on nutrient content of breakfast foods. The true nature of the study was not disclosed until the end of the study. Beside age there were no other excluding criteria than being able to be contacted by telephone and acceptable vision.

Overall study design

Participants were invited to visit the study centre in four groups, due to capacity of infrastructure. On arrival, participants were asked to complete a short questionnaire comprising questions about gender, age, weight and height and level of highest achieved degree in education. BMI (kg/m^2) was calculated from self-reported weight and height values, three BMI categories (<25 kg/m^2, 25-29.9 kg/m^2, >30 kg/m^2) were used to characterise participants. Educational level was classified into three levels (low, intermediate and high) and age in two age groups (45-54 years, 55-65 years). For the conception and memory study, participants were given a breakfast and allocated into two groups based on their availability during the next days to participate in a short telephone interview (no random allocation). Group 'short-term' was interviewed about the foods and amounts consumed during the breakfast after 1 or 2 days, and group 'long-term' after 4 days. Immediately after the breakfast, participants took part in the perception study. A dietetics trainee supervised all conceptualization and perception sessions and also prepared and weighed the food servings presented.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the regional Ethics Committee of Ghent University Hospital. Written informed consent was obtained from all subjects.

Portions size measurement aids tested

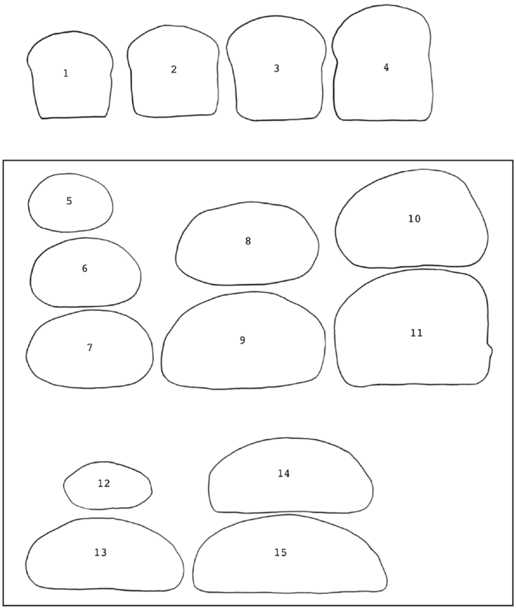
All two-dimensional models (drawings and photographs) used in the present study were taken from the Belgian food consumption survey. They originate either from the EPIC-Soft picture book (van Kappel et al., 1995) (margarine on bread, cups and glasses) or were developed for use in the Belgian food consumption survey from 2004 (drawings of bread). For bread, 15 drawings were available representing actual shape and size of bread slices. Two different shapes, common on the Belgian market, were included: squared and oval. Four increasing sizes were available for the squared slices originating from small to big squared breads, 11 different sizes were available for oval slices according to the dimensions of the bread (small or big) and location of the slice in a bread (on a frontal plane slices decrease in size from medial to lateral). The drawings of all bread slices provided are depicted on **Figure 1-a**. Different weights are assigned to the 15 drawings taking into account shape, size and density of the bread (e.g. white vs. whole-grain).

To estimate the amount of margarine spread on bread, a single A4 page containing six coloured photographs of a squared slice of bread with respectively 4, 8, 12, 16, 21 and 26 g of margarine was used. This page was extracted from the EPIC-Soft picture book (van Kappel et al., 1995). On the photographs one squared slice of bread on a standard white plate is depicted (angled view). A fork and knife is present as reference dimension.

For coffee amount estimation, a single A4 page depicting four coloured photographs of different cups was available. Finally, for water amount estimation another single A4 page depicting five coloured photographs of different types of glasses was available. The photographs of cups and glasses were in frontal view, all recipients were provided with five measures so estimation of beverages was also possible using a fraction of the full recipient. The recipients actually provided to the participants during the breakfast were also depicted. Examples of the food photographs used are shown on **Figure 1-b**.

Perception

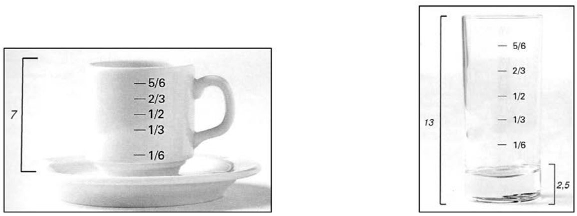
Perception error in portion size estimation was studied for bread drawings and margarine photographs. For bread, three slices (square slice A 21±0.8 g, square slice B 31±0.7 g and oval slice C 26±0.5 g) were presented to the participants in real time. With the slices in sight, the participants were asked to identify the corresponding drawings from Figure 1-a . For practical reasons, it was decided to allow minor deviations in weights of slices presented compared to the weights of the portions in the photographs (not more than 2g).



Squared bread

Oval bread

Figure 1-a



Coffee cup *High ball glass*

Figure 1-b

Figure 1: Depiction of drawings and photographs. (a) drawings of square and oval bread; (b) photograph of coffee cup and high ball glass indicating fractions available for reporting

For estimations of margarine spread on bread, three slices of bread identical to slice B were used and spread with margarine. Following portions were accurately weighed and spread on bread: 4, 12 and 21g (portion margarine A, B and C). These amounts are present on three of the six photographs used. After the perception test, participants left the study centre, no feedback on correctness of estimation during the perception test was given in order not to influence performance during the upcoming interview for the conceptualization test.

Conceptualization and memory

During the breakfast, every participant received six slices of bread (171±17.8 g), a small saucer with margarine (40 g), some sweet spreads, cold cuts, cheese, a fruit salad, coffee (266±14.2 g) and water (500 ml). Only the bread, margarine, coffee and water were of interest and therefore pre-weighed. The bread was brown and squared, only one type of bread was used for sake of logistic simplicity. Coffee was kept warm in individual thermoses, water was provided in a plastic bottle. Two recipients for beverages were also provided, a standard cup for coffee and a highball glass for water. The participants were asked to have their breakfast as they normally would (ad libitum within provided quantities). After breakfast, a food photograph atlas of selected foods was provided to the participants concealed in a closed envelope and instructions were given to open the envelope only when called by a dietetics trainee. All food leftovers were weighed by a calibrated scale (Metos, type MII-600; 600x0.1g) in absence of participants so consumed quantities of selected foods could be calculated.

Participants in the short-term group were interviewed for portion size estimation of consumed foods by telephone after one or two days, and those in the long-term group after four days. At the start of the telephone interview participants were requested to open the provided envelope. Participants were asked to recall bread, margarine on bread, coffee and water consumption and to report the amounts consumed by using the provided drawings and photographs. For bread, the number of slices and the size and shape of the bread consumed had to be reported. EPIC-Soft was used for data entry and calculation of estimated amounts. For margarine on bread, participants were asked if they consumed margarine and if they did, they were asked to select the thickness of the spread on their slice of bread from the six photographs. Also the number of slices that were spread had to be reported. EPIC-Soft calculates the total amount of estimated margarine based on the reported information. Estimation of bread and margarine on bread could be done either by entire portions or by fractions of the portions provided. Since estimation of portion size of bread can be erroneous on three individual or combined aspects (wrong size, wrong shape or wrong number of slices), errors in portion size estimation of bread for these three aspects result in errors in estimation of margarine on bread. To correct for this error propagation, estimations for margarine on bread were also calculated using the actual consumed size, shape and slices of bread.

Data analysis

All statistical analysis was performed using IBM PASW Statistics program version 17.0.3 (SPSS Inc., an IBM company, IL, USA).

A χ^2 test for independence of proportions in age category, educational level, BMI category and number of days before the recall across gender was used. The same was done for gender, age category, educational level and BMI category across number of days before recall. Difference in age and BMI between man and women was tested using Mann-Whitney U test.

For both conceptualization and perception data, the difference between the estimated weight and actual weight of the consumed/presented food was calculated (estimated weight – consumed or presented weight). The resulting difference corresponds to the estimation error. A negative difference is considered to indicate underestimation of the consumed portion and vice versa. For all foods, mean (s.d.) estimated and consumed weights were calculated and mean (s.d.) difference was presented both in grams or millilitres and in percentage (relational difference) to remove the effect of differences in portion size of the foods. The results were presented for all participants and in addition tabulated for gender (subgroups women and men). In addition, the results for the conceptualization study were also stratified by number of days before recall (subgroups short-term and long-term). Differences between estimated and consumed quantities were tested by paired Wilcoxon's test. Differences between subgroups were tested by Mann-Whitney U test. Both tests were 2-sided, a *P*-value of < 0.05 was considered significant.

A variable measuring both the correctness of the portion size estimation and the direction of estimation error was calculated so participants were categorized as correct estimator, under-estimator and over-estimator per food item. Correct estimations were defined as estimations within 10% difference of the actual weight (Frobisher & Maxwell, 2003), χ^2 tests were used to test any differences between groups.

Finally, Spearman's rank correlation coefficients were calculated to assess the relationship between estimated and consumed weights of portion sizes.

Results

A total sample of 111 subjects participated in the conceptualization part of the study, one male subject did not perform the perception part. Although equality in gender was pursued, more women than men participated in the study (respectively 62 and 49). Attention was paid to inclusion of lower educated persons (**Table 2**). A significant difference between the observed and expected number of men in the lowest education category was present (χ^2 (2)=9.809, P=0.007). Also, a significant difference between observed and expected number of participants in the 'short-term' group was present in the age category 55-65 years (χ^2 (1)=4.767, P=0.029) (data not presented). The BMI of men was significantly higher compared to women (U=1065, *P*=0.007), however, BMI of both genders reflect national figures of the same age category. No other significant contrast between men and women or short- and long-term group were present.

Table 2: Characteristics of subjects

		Total *(n=111)*	**Men** *(n=49)†*	**Women** *(n= 62)*
Age (years), mean ± s.d.		53±5.2	53±5.2	52±5.2
	45-54 (%)	71	67	74
	55-65 (%)	29	33	26
Educational level				
	Low (%)	39	22‡	51
	Intermediate (%)	22	29	18
	High (%)	39	49	31
BMI (kg/m^2), mean ± s.d.		25.9±3.7	26.7±3.3	25.2±3.9
	<25.0 (%)	47	37	55
	25-29.9 (%)	40	45	35
	≥30 (%)	13	18	10
Number of days before recall				
	1-2 (%)	43	41	45
	4 (%)	57	59	55

† for perception part of study data from 1 subject was not available (n=48)
‡ χ^2 (2)=9.809, P=0.007 (significant difference between observed and expected number of men in the lowest education category)

Table 3 presents the weights of the foods that were provided for consumption and presented during conceptualization and perception. The variation of the amount of bread that was presented for perception was kept as small as possible; CV for slice A, B and C was 3.8, 2.3 and 1.9 respectively.

Table 4 shows mean estimated and consumed weights for each food, the mean difference between estimated and consumed weights and the percentage difference. For bread, coffee and water, an underestimation of consumed portion size is observed in general. Margarine spread on bread is markedly overestimated. Since consumption of bread is underestimated, the amount of margarine spread on bread is also underestimated. Correcting the estimated amount of margarine for propagated errors in bread consumption estimation increased overestimation of margarine from 94.7 to 111.9 percent. Comparatively speaking, the estimation error is largest for margarine (especially if corrected for bread estimation error) and lowest for both beverages, coffee and water. Significant differences between consumed and estimated portions were found for bread and margarine. No significant difference was present for bread in the long-term group. For both beverages, differences were also non-significant except within the long-term group where significant underestimation was present. When the relational differences were compared between men and women, and short- and long-term, the only significant difference was found for water between short- and long-term (U=325, $P<0.001$).

Table 5 summarizes data from the perception part of the study. For bread and margarine, estimation error can be segregated from errors resulting from conceptualization and memory aspects since slice B corresponds to the slice that was used during breakfast. Overall, the estimation error is more or less equal (-9.6% vs. -8.7%). For the small squared slice of bread (slice A) the estimation error is smaller (-2.9%) and for the oval slice of bread (slice C) the estimation error is largest and, in addition, positive, indicating overestimation of portion size. Margarine spread on bread is consistently overestimated, decreasing in magnitude with increasing presented portion size. Estimated portions were significantly different from presented portions for all foods except for bread slice A in men. When relational differences were tested across gender, a significant difference was found between men and women for the smallest portion of margarine (A), for which the overestimation of portion size was smaller for women compared to men (U=1141, $P=0.026$).

Classification of participants as under-, over- or correct estimator for conceptualization and perception data is shown in **Table 6**. Firstly, for conceptualization, correct estimation of consumed foods was highest for water (33% of women, 26% of men) and for bread (29% of both genders). Largest frequency of underestimation was found for coffee consumption with 66% of women and 59% of men. Largest overestimation of consumed portions was found for margarine after correction for bread error (82% of women, 81% of men). In general, highest proportions of underestimation was associated with bread, coffee and water estimations, highest proportions of overestimation was seen in portion size estimation of margarine. No significant contrasts were present between men and women. When data was stratified by time before recall (short- and long-term), a significant difference was found for water in the underestimation category. More precisely, the proportion of underestimators was lower in the short-term group (χ^2 (2)=7.606, $P=0.022$). Secondly, for perception of squared slices (slice A and B) underestimation of portion size was mainly present; for the oval slice (slice C) proportions of correct estimators was highest but overestimation was nearly as high. For margarine spread on bread, again overestimation of portion size is predominantly present. The amount of margarine spread on bread did not influence the proportions of classification. No significant contrasts were present between men and women for any food.

The association between consumed and estimated portions was variable with Spearman correlations ranging from 0.42 to 0.75 (**Table 7**). Correcting margarine spread on bread for error propagation of bread improved the correlation coefficient between estimated and consumed weights from 0.62 to 0.68. Beverages had lowest correlation coefficients, respectively 0.42 and 0.48 for coffee and water. Since presented portions during the perception part of the study were fixed, little distribution of estimation data was obtained so calculating correlation coefficients between presented and estimated weights was not appropriate.

Table 3: Amounts of foods provided and presented to participants for conceptualization and perception respectively

	Conceptualization	**Perception**		
Food	Amount provided	Amount presented	Code	Specification
Bread (g)	171±17.8† *(6 slices)*	21±0.8†	Slice A	Squared, small
		31±0.7†	Slice B	Squared, large
		26±0.5†	Slice C	Oval, small
Margarine (g)	40	4	Portion A	Spread on large squared slice
		12	Portion B	Spread on large squared slice
		21	Portion C	Spread on large squared slice
Coffee (ml)	266±14.2†	-		
Water (ml)	500	-		

† mean ± s.d. amount provided

Note: slices consumed during breakfast for conceptualization correspond to slice B presented during perception

Table 4: Mean differences ± s.d. between estimated weights using photographs compared to consumed food portions: conceptualization part of study

Food	Group	Sub-group	n	Mean estimated weight±s.d.	n	Mean consumed weight±s.d.	Mean difference†	% difference	P‡
Bread (g)	All		111	111.2±47.5	111	121.8±40.1	-10.6*±33.6	-8.7	
	Gender	Women	62	97.6±44.6	62	105.3±34.5	-7.6*±31.5	-7.3	0.480
		Men	49	128.3±45.9	49	142.7±37.1	-14.4*±36.1	-10.1	
	Recall	1-2 days	48	99.1±43.1	48	114.7±44.0	-15.6*±25.6	-13.6	0.092
		4 days	63	120.4±48.9	63	127.2±36.3	-6.8±38.3	-5.3	
Margarine (g)	All		86§	29.4±25.8	88	15.1±8.1	+14.3*±22.0	+94.7	
	Gender	Women	44§	23.5±21.3	46	12.2±6.6	+11.6*±18.3	+92.6	0.822
		Men	42	35.5±28.9	42	18.3±8.5	+17.2*± 25.2	+94.0	
	Recall	1-2 days	33	25.5±21.1	35	13.8±7.8	+11.8*±17.3	+84.8	0.954
		4 days	53	31.8±28.3	53	16.0±8.3	+15.8*±24.5	+98.8	
Margarine (g)||	All		86§	32.0±24.6	88	15.1±8.1	+16.9*±20.4	+111.9	
	Gender	Women	44§	24.9±17.6	46	12.2±6.6	+13.0*±14.8	+104.1	0.990
		Men	42	39.4±28.6	42	12.2±6.6	+21.1*±24.5	+223.0	
	Recall	1-2 days	33	29.2±25.7	35	13.8±7.8	+15.5*±21.1	+111.6	0.986
		4 days	53	33.8±23.9	53	16.0±8.3	+17.8*±20.1	+111.3	
Coffee (ml)	All		107	230.9±67.2	107	235.0±46.9	-4.1±59.7	-1.7	
	Gender	Women	61	222.5±66.5	61	230.2±52.9	-7.7±58.6	-3.3	0.311
		Men	46	242.0±67.3	46	241.3±37.2	+0.7±61.4	+0.3	
	Recall	1-2 days	45	231.0±77.3	45	230.3±57.3	0.7±63.8	+0.3	0.677
		4 days	62	230.8±59.5	62	238.4±37.9	-7.5*±56.8	-3.2	
Water (ml)	All		74℄	361.8±187.3	75	374.5±143.9	-14.9±159.4	-3.4	
	Gender	Women	47℄	346.6±192.4	48	373.6±145.5	-30.7±156.5	-7.2	0.162
		Men	27	388.5±178.6	27	376.2±143.6	+12.2±163.7	+3.3	
	Recall	1-2 days	25	442.7±166.1	25	386.3±136.1	+56.5±144.6	+14.6	0.001
		4 days	49	320.6±185.5	50	368.7±148.6	-52.0*±155.4	-13.0	

† % difference = [(mean estimated weight – mean consumed weight) x 100/mean consumed weight]
* P<0.05 for the difference between estimated and consumed weight by paired Wilcoxon test
§ Two subjects did not recall to have used margarine during breakfast
|| Estimated amount of margarine corrected for error propagation from bread
℄ One subject did not recall to have consumed water during breakfast
‡ P-value of Mann-Whitney U test on relational differences across subgroups, 2-sided

Table 5: Mean differences ± s.d. (g) between estimated weights using photographs compared to presented food portions: perception part of study

Food	Group Subgroup§	Mean estimated weight±s.d.	Mean presented weight±s.d.	Mean difference	% difference†	*P*‡
Bread, slice A	All	20.3±4.1	20.9±0.8	-0.6*±4.4	-2.9	*0.343*
	Women	19.9±4.0	21.0±0.8	-1.1*±4.3	-5.2	
	Men	20.8±4.1	21.0±0.7	-0.1±4.4	-1.0	
Bread, slice B	All	28.3±5.0	31.3±0.7	-3.0*±5.0	-9.6	*0.172*
	Women	27.8±4.2	31.3±0.7	-3.5*±4.2	-11.2	
	Men	28.9±5.8	31.2±0.7	-2.3*±5.8	-7.4	
Bread, slice C	All	29.6±3.7	25.9±0.5	+3.7*±3.7	14.3	*0.339*
	Women	29.2±3.6	25.8±0.5	+3.3*±3.7	13.2	
	Men	30.2±3.7	25.9±0.5	+4.3*±3.6	16.6	
Margarine, portion A	All	11.0±3.8	4.0±0.0	+7.0*±3.8	175.0	*0.026*
	Women	10.2±3.5	4.0±0.0	+6.2*±3.5	155.0	
	Men	11.9±4.1	4.0±0.0	+7.9*±4.0	197.5	
Margarine, portion B	All	18.5±3.7	12.0±0.0	+6.5*±3.7	54.2	*0.191*
	Women	18.0±3.7	12.0±0.0	+6.0*±3.7	50.0	
	Men	19.1±3.7	12.0±0.0	+7.1*±3.7	59.2	
Margarine, portion C	All	25.3±2.0	21.0±0.0	+4.2*±2.0	20.5	*0.958*
	Women	25.3±2.0	21.0±0.0	+4.3*±2.0	20.5	
	Men	25.3±2.1	21.0±0.0	+4.2*±2.1	20.5	

† % difference = [(mean estimated weight – mean consumed weight) x 100/mean consumed weight]
* P<0.05 for the difference between estimated and consumed weight by paired Wilcoxon test
‡ P-value of Mann-Whitney U on relational differences across gender, 2-sided
§ All (n=110), Women (n=62), Men (n=48)

Table 6: Number (%) of subjects classified according to agreement between estimated and consumed/presented weights of foods within 10% difference†

Food	Women			Men		
	Under-estimation	Correct estimation	Over-estimation	Under-estimation	Correct estimation	Over-estimation
Conceptualization						
Bread	29 (47)	18 (29)	15 (24)	27 (55)	14 (29)	8 (16)
Margarine	8 (18)	3 (7)	33 (75)	5 (12)	2 (5)	35 (83)
Margarine‡	3 (7)	5 (11)	36 (82)	5 (12)	3 (7)	34 (81)
Coffee	40 (66)	2 (3)	19 (31)	27 (59)	2 (4)	17 (37)
Water	19 (41)	15 (33)	12 (26)	8 (30)	7 (26)	12 (44)
Perception						
Bread, slice A	40 (65)	12 (19)	10 (16)	27 (56)	8 (17)	13 (27)
Bread, slice B	41 (66)	20 (32)	1 (2)	25 (52)	20 (42)	3 (6)
Bread, slice C	2 (3)	32 (52)	28 (45)	1 (2)	22 (46)	25 (52)
Margarine, portion A	-	4 (6)	58 (94)	-	1 (2)	47 (98)
Margarine, portion B	1 (2)	9 (14)	52 (84)	-	4 (8)	44 (92)
Margarine, portion C	1 (2)	7 (11)	54 (87)	1 (2)	5 (10)	42 (88)

n, number of estimations
† no significant contrasts between men and women (χ^2 (2)), χ^2 could only be performed for bread and water during conceptualization and bread slice A during perception, all other foods had more than 20% of cells with expected counts lower than 5
‡ corrected for error propagation from bread

Table 7: Correlations between consumed and estimated weights by photographs

Food	All		Women		Men	
	n	rs	n	rs	n	rs
Bread	111	0.75*	62	0.75*	49	0.62*
Margarine	86	0.62*	44	0.55*	42	0.58*
Margarine†	86	0.68*	44	0.61*	42	0.61*
Coffee	107	0.42*	61	0.43*	46	0.39*
Water	73	0.48*	47	0.54*	27	0.38**

n, number of estimations
rs, Spearman correlation coefficient
* P<0.01
** P<0.05
†Margarine corrected for total portion size estimation of bread

Discussion

Findings

This study aimed at identifying magnitude and direction of portion size estimation errors using food photographs and drawings. Foods under study were selected either based on the relatively small amount of data present in the literature and experiences during the Belgian food consumption survey (De Vriese et al., 2006). The results obtained showed tendency for underestimation for all foods except for margarine, which was highly overestimated, and oval slices of bread in both genders and beverages in men.

Strengths

During conceptualization, participants were invited to a dining room where served food portions could be weighed covertly. Notwithstanding that participants are taken away from their usual environment, this approach is preferred to letting participants weigh their own food at home, as this reveals the true nature of the study and the participant's awareness towards portion sizes could be increased (Nelson & Haraldsdottir, 1998).

The study design presented here addressed several psychological constructs necessary for portion size estimation. Nonetheless, separating these constructs to identify their related errors remains difficult. Ultimately, the objective of the present study was to imitate the actual context in which the food photographs are used and to describe the size of errors in portion size estimation, given that context. This relevant context for the Belgian food consumption surveys is the recall of portion sizes after one day.

Sufficient participants were present in the study in order to have adequate power to demonstrate statistically significant differences between actual and estimated portion sizes. Also, factors like gender and BMI were taken into account and reflected the population within which dietary surveys are performed in Belgium. It was decided to investigate a narrow age group (45-65 years) in order to control variation in age-related estimation errors.

Limitations

Participants were provided with a closed envelope containing food photographs for use during the recall of consumed foods. Some participants might have opened the envelope earlier so memory could be addressed before actual recall. Especially in the long-term group, this might influence participant's performance. More important, participants were asked for portion size estimation to test perception skills before the recall for conceptualization skills was performed. This could also draw participants' attention to the portions consumed during the breakfast. Also, having breakfast in a non-usual environment, particularly when participating in a study, could also increase awareness of consumed quantities. Furthermore, results presented in the current study should be considered as best case scenario, since, in the real world (outside a study context) a larger variety in types of bread, cups and glasses will inevitable increase variance of portion size estimation errors. Due to the complex nature of the study design and the complexity of skills under study, the authors decided to keep the protocol as straightforward as possible.

Classification of participants as under-, over- or normal estimator using a margin of error of 10% within actual consumed quantities has been performed elsewhere (Frobisher & Maxwell, 2003). Nevertheless, it remains an arbitrary figure which could be too strict or too broad depending on the food or targeted sample. In their study, Lucas et al. (1995) considered estimations within 25% of the weighed amounts to be accurate. Especially for margarine, where the difference between photographs is larger than 10%, choosing one photograph smaller or larger than the actual photograph results in high under- or overestimation errors.

Comparison with other studies

Since some countries (e.g. in The Netherlands) also include recalls collected 48 hours after consumption (during dietary surveys no interviews are performed on Sundays so Saturdays' intakes are recalled on Monday) a recall of one and two days is considered as short-term in this study. In the present study, relational underreporting error for bread of -8.7% was found during conceptualization. Turconi et al. (2005) found a relational underestimation error for bread of -2.7%. In their study, however, influence of memory was not studied since portion size estimation took place within 10 min after consumption of foods. Because photographs were used in the study of Turconi et al., one cannot tell whether the differences are due to differences in drawings, in time intervals, or study populations. In the present study, two time frames between consumption and estimation were included, however, no significant difference in estimation error between short- and long-term recall was present.

For perception, estimation errors of the various bread slices were different in magnitude and direction. The squared slices were underestimated while the oval slice was overestimated (+14.3%). For the squared slice, estimation error for the small slice was much lower than the large slice (-2.9% vs. -9.6%). Ovaskainen et al. (2008) found a relational difference of about -30% for perception of bread in both genders. The shape and type of bread studied by Ovaskainen et al. (2008) differed from this study. Also, in the studies from Turconi et al. (2005) and Ovaskainen et al. (2008), photographs were used, where in this study, drawings of bread slices representing actual size of bread slices were used. It was indeed proposed by Slimani et al. (1999) and later, concluded by Ovaskainen et al. (Ovaskainen et al.) that models representing actual shape would be favourable over photographs of bread. Comparing the results of the models used in this study to previous findings with photographs is very difficult since none of the studies mentioned have incorporated the factor memory (time) in their design.

For conceptualization of margarine, large overestimation of portion size was found (+104.1% for women and +223.0% for men; data corrected for propagated error of bread estimation). In their study, Frobisher and Maxwell (2003) found estimation errors ranging from -50% to 300% in adults. Again, caution in comparing these findings is warranted since the time before recall was 3-4 days and foods were not actually consumed in their study. In contrary, Robson and Livingstone (2000) found negative estimation errors for margarine of about 10% to 20%. Although their study design was more close to the present study, it was not stated if the margarine on the photographs was presented as spread on bread. In addition, quantification of portion sizes was done in terms of fractions or multiples of the amounts shown in one single photograph, not by different photographs with increasing quantities, again hampering comparison. Finally, Nelson et al. (1996) found also a mean overestimation of margarine spread on bread of 107.6%. In their study however, memory influence was not included into the design.

During perception, margarine on bread was also overestimated in the present study, with increasing portions, errors became smaller (+175%, +54.2% and +20.5% respectively). Again, overestimation errors were larger for men compared to women for small portion sizes of margarine ($P=0.026$), whereas for larger portion sizes no differences between women and men were observed. Ovaskainen et al. (2008) have also investigated perception skills of different portions of fat spread. For the smallest portion (5g, portion A in this study was 4g) an underestimation of portion estimation was found (-14% for men; -18% for women). When a larger portion (12g; equal to portion B in this study) was spread on a big slice, an overestimation of 25% was found without any difference between genders.

In the present study, conceptualization skills and influence of memory on estimation errors of two beverages was also included. Women tended to underestimate both coffee and water while men had overestimation errors. Since more women consumed coffee and water, their underestimation of beverages resulted in a generalized underestimation of beverages. Turconi et al. (2005) found overestimation of portion sizes of beverages (only glasses were included, no coffee cups). In their study, consumed portions were recalled within 5-10 min so memory could not affect estimation.

The implications of the estimation errors presented here are dependent on the context in which the portion size estimation aid is used, whether it will be in the context of nutritional surveillance or epidemiology. For nutritional surveillance, the absolute level of consumption for the population is relevant. Looking at the data for beverages presented here, this would mean a rather small underestimation of coffee and water of 1.7% and 3.4% respectively. For bread and margarine on bread, estimation errors were found to be higher. For epidemiological association studies, the ranking of participants rather than the absolute amount is important. If Spearman's rank correlations between consumed and estimated weights are examined, the opposite is found suggesting a higher validity of the food photographs for bread and margarine on bread compared to coffee and water.

In practice, photographic atlases can be adopted from other countries, especially because developing and validating new food photographs is time and money consuming. If food photographs are adopted for use in another country or a different target group, adaptations might be overlooked. Sound evaluation is recommended to either include relevant, country- or sample-specific food photographs or to change existing photographs according to local customs.

Conclusions

In spite of large individual errors, the results of this study suggest that food portion photographs can be used as an instrument to estimate portion sizes of bread, coffee and water in the context of nutritional surveillance for adults. For margarine spread on bread, large overestimation was found for the current set of photographs. A study on the validity of photographs showing smaller amounts of margarine spread on bread is recommended.

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Chapter 3
A short food frequency questionnaire versus 7-day estimated food records

The aim of this chapter is to assess the relative validity of a self-administered qualitative food frequency questionnaire (FFQ) applied in the Belgian food consumption survey. Comparison of food consumption data from an FFQ with 7-day estimated diet records (EDR) was made in a sample of 100 participants (aged 15-90 years). The FFQ comprised a total of 50 foods. Both FFQ and EDR foods was categorized into 15 conventional food groups. De-attenuated Spearman rank correlation coefficients between the FFQ en the EDR ranged from -0.16 for potatoes and grains to 0.83 for alcoholic beverages with a median for all 15 food groups of 0.40. The proportion of participants classified in the same tertile of intake by the FFQ and EDR ranged from 32% for potatoes and grains to 76% for alcoholic beverages. Extreme classification into opposite tertiles was <10% for milk and soy products, alcoholic beverages, fried rest-group foods and fats. Notwithstanding the short nature and the absence of portion size questions, the FFQ has moderate to good validity in both genders and across different age categories for most food groups. However, for the food groups bread and cereals, potatoes and grains, and sauces, the FFQ showed poor ranking agreement.

Chapter based on:

De Keyzer, W., Dekkers, A., Van Vlaslaer, V., Ottevaere, C., Van Oyen, H., De Henauw, S., & Huybrechts, I. (2012). Relative validity of a short qualitative food frequency questionnaire for use in food consumption surveys. Eur J Public Health, 23(5), 737-742.

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Background

In 2004, the first food consumption survey was performed in Belgium (De Vriese, S, Huybrechts, Moreau, & Van Oyen, 2006). During this survey, a representative sample of the Belgian population aged 15 years and over was recruited from the national register. Food and nutrient intake was assessed at the individual level of by two non-consecutive 24-hour recalls using EPIC-Soft. A qualitative food frequency questionnaire (FFQ) was used to study the adequacy of food intake in different subgroups of the population. Furthermore, subgroups at risk for a deficient or excessive intake of specific foods or nutrients were identified. An extensive overview of the methods used in this first Belgian Food Consumption Survey is given elsewhere (De Vriese, S. et al., 2005).

Short FFQs satisfy many conditions to be used as dietary assessment instrument in the context of epidemiological studies because of their inexpensiveness and low burden for participants (Willett, 2013). Also, in the context of nutritional surveillance, they have potential to serve as a quick measure for long term usual food intake and identification of non-consumers both in adults and children (Osler & Heitmann, 1996; Andersen, Johansson, & Solvoll, 2002; Thompson et al., 2002; Therese L. Lillegaard, 2012). For both purposes (epidemiological and surveillance) however, it is paramount that validity of the instrument is assessed and taken into account during interpretation of results in future use.

Data from the Belgian food consumption survey indicated that the response rate of a short FFQ was higher compared to the 24-hour recall interviews, which is very likely to be due to the lower respondent burden. Because of these advantages, the FFQ is being used as a quick screening tool to assess different aspects in the diet of our Belgian population. Therefore, it is important to evaluate the validity of this short FFQ. Hence, the aim of the present study is to assess its validity compared to 7-day estimated diet records (EDR). For 15 food groups, the performance of the FFQ to rank individuals according to intake and agreement with a 7-d EDR will be evaluated. In addition, more extensive analyses will be performed to investigate associated measurement error.

Methods

Study design

Using a cross-sectional study design, food intake assessed with a 7-day EDR was compared to food intake assessed with a short FFQ. During a first visit, participants were provided with a general questionnaire comprising socio-demographic and anthropometric questions and a paper-based FFQ. After 2-6 weeks, a second visit was planned, during which both questionnaires were returned to the researchers. Furthermore, a 7-day EDR was provided and instructions were given for completion. During a final visit, the EDR was collected and checked for completeness by a dietitian. Any remaining quality issues were discussed with the participant and clarified or corrected.

Data collection was performed in Flanders from October 2005 to April 2006. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the regional Ethics Committee of Ghent University Hospital. A written informed consent was obtained from all participants.

Participants

In order to resemble the target population of the food consumption survey (i.e. nationally representative), different age categories were included and equality in gender was pursued. In total, three age categories were recruited: adolescents and young adults (15-29 years), adults (30-59 years), and elderly (60+ years). For those categories, a different approach for recruiting participants was performed, still, a convenient sample was drawn from the population. (1) In adolescents, a multi-stage sampling was performed. Firstly, five secondary schools providing both general education as vocational training, were contacted in the region of Ghent. Four schools agreed to participate in the study. Subsequently, parent's permission was asked by written request. Since selection of classes and communication with parents was performed by the school's administration, the number of invited participants is unknown. (2) Young adults and adults invited for participation were acquaintances and family of students and researchers. (3) Elderly were recruited via social service centres. Elderly living in a residential care setting were excluded given the more limited freedom in food choices. A total of 233 adult (>18 years) were invited accordingly. Equality in gender was pursued at all time. The participants did not receive any incentive for their participation.

Food frequency questionnaire

The FFQ under study was a self-administered qualitative questionnaire comprising 50 food items (see **addendum 2**). These food items were either individual foods (e.g. soft drink) or an aggregation of similar foods (e.g. soy products; comprising soy milk, -drinks and -desserts). The FFQ is data- and experience-based questionnaire to be used alongside the repeated 24-hour recall using EPIC-Soft in the Belgian national food consumption survey (De Vriese, S, Huybrechts, Moreau, & Van Oyen, 2004). The frequency categories used in the FFQ are: never; less than 1 day per month; 1-3 days per month; 1 day per week; 2-4 days per week; 5-6 days per week; 1 time a day; 2-3 times a day and more than 3 times a day. The usual food intakes derived from the FFQ were calculated by multiplying the frequency of consumption with a standard portion size (Superior Health Council Belgium, 1997) for each food item (see **addendum 3**). The same standard units were used to calculate portion sizes of estimated foods during data entry of the EDR.

Estimated dietary record

Structured open-ended diaries containing predefined food groups (including the option "other food items") at six food occasions (breakfast, lunch, dinner and 3 snacks) were provided to all participants. All participants were informed on how to complete the food record. The diary also contained a written example for future reference. During a seven day period, all consumed foods and drinks had to be reported with notification of date and place of consumption, estimated consumed quantity expressed as a household measure, unit or weight, specification, and, if present, a brand name. Separate forms were included to report home-made recipes, so name of dish, total quantities of all ingredients and fraction of dish consumed could be stated. Only participants with zero missing dietary records were included in the analysis.

Data and statistical analysis

For almost all food groups, consumption data was not normally distributed. Therefore, only non-parametric tests were used during analysis. First, Spearman rank order correlations of food group intakes between the 7-day EDR and FFQ were calculated for all participants and stratified by gender and age category. In addition, because day-to-day variation in intake of most specific foods is generally high, de-attenuated correlation coefficients were calculated to correct for within-person variation in the EDR (Beaton et al., 1979). Secondly, to assess measurement error of the FFQ, 'actual values for surrogate categories' were calculated (Willett & Lenart, 2013) as follows: participants were assigned to tertiles according to food consumption estimated by the FFQ, then the mean food intake in each tertile was calculated using data from the EDR. This gives an indication of the 'true' (EDR) values that are indicated by the FFQ tertiles. Kruskal-Wallis one-way analysis of variance was used to determine whether differences of means between tertiles were statistically significant. Third, intakes assessed with the EDR were classified into tertiles and agreement between both methods was assessed using the weighted κ statistic, calculated with a linear set of weights and CI of 95% (Altman, 1991). This analysis was not performed for food groups for which more than 33.3% of the participants had zero consumption either for the FFQ or EDR. Fourth, the percentage classified into the correct or adjacent tertile and the percentage grossly misclassified (lowest tertile for one method and highest tertile for the other) was calculated. Finally, agreement between the FFQ and the EDR at the individual level was assessed using mean difference and standard deviation of the mean difference, visually represented by a Bland and Altman plot (Bland & Altman, 2010). In order to correct for non-normal distributions, a Box-Cox transformation was performed on food group intake data from both instruments (EDR and FFQ) before plotting. The grand mean between both methods is plotted (dotted lines) including the 95% CI around the mean (error bars at the right). The fitted regression line is also plotted with the 95% CI (dash-dot lines) and 95% CI for new observations (dashed line). In order to quantify the error measurement structure, two additional tests were performed on the Bland & Altman plots. The first one tests whether the zero difference line (solid line) is outside of the grand mean 95% CI. The second one tests whether the fitted regression line's slope is significantly different from zero. Statistical tests were performed using IBM PASW Statistics program version 18.0.0 (SPSS Inc., an IBM company, IL, USA), two-tailed and $P < 0.05$ was considered as statistically significant. The construction of the Bland and Altman plots including the tests for difference and slope were created using the S-PLUS statistics program.

Results

In total, 156 participants agreed to participate in the study representing a response rate of 55% among adults and elderly. The response rate for the adolescents could not be calculated since cluster sampling was used and the total number of adolescents eligible for inclusion from all schools was unknown. Almost all participants completed the FFQ (n=155), however only 100 (64%) were able to complete all seven days of the food record.

Characteristics of participants are shown in **Table 1**. Twenty-six percent of the participants were between 15 and 29 years old and 22% were 30-59 years old. These percentages agree with those from the food consumption survey in 2004 where 33% from the sample was between 15 and 29 years, 19% between 30-59 years and 48% above 60 years old (De Vriese, S et al., 2004). Forty-four percent of men and 36% of women were overweight or obese (BMI ≥ 25.0 kg/m²). These body characteristics also agree with those from the Belgian food consumption survey where mean BMI was 25.0 kg/m² for men and 24.2 kg/m² for women and percentage of men and women being overweight or obese was 47% and 35% respectively (De Vriese, S et al., 2004).

Table 1: Distribution of age and body mass index categories of participants

	All		15-59 years		≥ 60 years	
	Male† (n = 44)	Female (n = 56)	Male† (n = 25)	Female (n = 23)	Male (n = 19)	Female (n = 33)
Mean age (SD)	50 (23.0)	56 (23.4)	32 (12.9)	30 (12.7)	73 (7.6)	74 (6.1)
Mean BMI (SD)	25.6 (4.0)	24.7 (4.1)	24.7 (4.1)	22.3 (3.0)	26.8 (3.6)	26.4 (4.0)
BMI category (n, %)						
Under-/ normal weight (BMI < 25.0 kg/m²)	24 (56)	36 (64)	16 (67)	21 (92)	8 (42)	15 (46)
Overweight (BMI: 25.0-29.9 kg/m²)	14 (33)	13 (23)	6 (25)	1 (4)	8 (42)	12 (36)
Obesity (BMI > 30.0 kg/m²)	5 (11)	7 (13)	2 (8)	1 (4)	3 (16)	6 (18)

† For one participant body length was missing so BMI could not be calculated.

Crude and de-attenuated correlations of consumed foods between both methods are presented in **Table 2**. For the food groups fish, alcoholic beverages and fried restgroup foods, correlation coefficients are calculated on consumers only given the high number of zero consumptions for these foods during the 7-day recording of dietary intake. For the total sample, a strong de-attenuated correlation coefficient (≥ 0.70) was found for alcoholic beverages. The de-attenuated correlation coefficients were moderate (0.40 to 0.69) for beverages, fruit, milk and soy products, cheese, restgroup drinks, fried restgroup foods and fats. Fair (0.20-0.39) de-attenuated correlation coefficients were found for vegetables, fish, meat and eggs, restgroup foods and sauces. Finally, weak de-attenuated correlations were found for bread and cereals, and potatoes and grains.

Large differences in de-attenuated correlation coefficients were found between men and wome. For both, strongest correlations were present for alcoholic beverages and milk and soy products in women. The weakest correlation was present for potatoes and grains in men and vegetables in women. For all age categories, alcoholic beverages yielded strongest de-attenuated correlation coefficients. In the youngest age category, the weakest correlation coefficient was present for beverages, while for the middle and oldest age category there was a negative correlation for potatoes and grains, and bread and cereals in the oldest age category only.

Table 2: De-attenuated Spearman rank correlation coefficients of food group intakes between the food frequency questionnaire and 7-day estimated diet records

	All	Gender		Age category (years)	
		Male	Female	15-59	60+
Food group	(*n* = 100)	(*n* = 44)	(*n* = 56)	(*n* = 48)	(*n* = 52)
Beverages[a]	0.40	0.57	0.24	0.30	0.49
Bread & cereals	0.16	0.07	0.29	0.36	-0.08
Potatoes & grains[b]	-0.16	-0.41	0.25	0.06	-0.08
Vegetables[c]	0.36	0.59	0.22	0.23	0.42
Fruit	0.52	0.60	0.48	0.56	0.41
Milk & soy products[d]	0.65	0.61	0.71	0.58	0.77
Cheese	0.51	0.56	0.49	0.66	0.33
Fish[e]	0.22	0.34	0.38	0.09	0.46
Meat & eggs[f]	0.35	0.29	0.36	0.33	0.30
Alcoholic beverages[g]	0.83	0.81	0.71	0.94	0.82
Restgroup foods[h]	0.37	0.32	0.48	0.30	0.60
Restgroup drinks[i]	0.59	0.65	0.43	0.67	0.18
Fried restgroup foods[j]	0.65	0.80	0.58	0.60	0.71
Sauces[k]	0.29	0.30	0.26	0.26	0.33
Fats[l]	0.68	0.60	0.65	0.65	0.56

For fish, alcoholic beverages and fried restgroup foods correlations are based on consumers only.
[a] All drinks (incl. fruit and vegetable juices and non-sugared soft drinks, excl. milk, soy drinks and drinks from restgroup)
[b] Potatoes (excl. fried potatoes and fries), rice and pasta
[c] Raw and cooked vegetables incl. legumes
[d] Milk, buttermilk, chocolate milk, milk added to coffee or tea, yoghurt, soy drinks and -desserts
[e] Fish, shellfish and fish products
[f] Meat, meat products, poultry, game, offal, eggs and vegetarian products (tofu, Quorn, tempeh)
[g] Wine, beer and spirits
[h] Sweets and candy bars, chocolate, biscuits and pastry
[i] Sugared soft drinks, sports drinks and energy drinks
[j] Fries, baked potatoes and crisps
[k] Cold sauces like mayonnaise and ketchup
[l] Butter, margarine, low-fat margarine and lard

Table 3 includes mean food group intakes based on the 7-day EDR for the FFQ tertiles. For all food groups significant differences, indicating good ranking of participants, were found between ranks of intake, except for bread and cereals, potatoes and grains, restgroup foods and sauces.

The degree of misclassification associated with categorised intakes assessed by the FFQ compared to the 7-day EDR was examined as the proportion of participants classified in the same, adjacent, or opposite tertile (table 3). For restgroup drinks, ranking into tertiles was not possible since more than 33.3% of participants did not consume any food from this food group during the 7-day EDR. The proportion of participants classified in the same tertile was 50% or higher for beverages, milk and soy products, cheese, alcoholic beverages, fried restgroup foods and fats. Extreme misclassification into the opposite tertile did not exceed 10% for milk and soy products, alcoholic beverages, fried restgroup foods and fats. Results from the weighted κ statistic showed good agreement (0.61-0.80) for alcoholic beverages, moderate agreement (0.41-0.60) for milk and soy products, and fats, fair agreement (0.21-0.40) for beverages, vegetables, fruit, cheese, fish, meat and eggs, and fried restgroup foods. For bread and cereals, potatoes and grains, restgroup foods and sauces, κ coefficients were poor (≤0.20).

Table 3: Mean food group intakes from EDR for categories based on FFQ tertiles with agreement of tertiles for both methods

	Mean intake EDR (g)				Agreement of tertiles			Weighted Kappa	
Food group[a]	T1	T2	T3	p^b	Same tertile %	Adjacent tertile %	Opposite tertile %	κ	95% CI
Beverages[c]	814.0	1017.5	1211.6	0.002	50.0	38.3	11.7	0.30	0.15-0.44
Bread & cereals	120.8	163.9	151.9	0.064	39.2	39.2	21.6	0.13	-0.01-0.27
Potatoes & grains[d]	105.3	105.4	105.3	0.894	32.0	42.3	25.8	-0.06	-0.20-0.08
Vegetables[e]	90.2	107.2	132.1	0.024	46.9	38.8	14.3	0.23	0.09-0.37
Fruit	48.8	115.0	149.3	<0.001	45.5	42.4	12.1	0.26	0.12-0.40
Milk & soy[f]	71.6	117.5	227.1	<0.001	57.4	36.2	6.4	0.45	0.31-0.60
Cheese	22.1	25.4	37.2	0.001	50.0	37.5	12.5	0.30	0.16-0.44
Fish[g]	14.0	25.7	33.3	0.003	44.8	44.8	10.4	0.23	0.09-0.38
Meat & eggs[h]	108.4	122.8	163.5	0.002	44.7	42.6	12.8	0.23	0.09-0.37
Alcoholic beverages[i]	18.7	120.3	437.5	<0.001	76.0	21.9	2.1	0.71	0.56-0.85
Restgroup foods[j]	48.9	56.6	74.2	0.076	43.8	41.7	14.6	0.20	0.05-0.34
Fried restgroup foods[k]	26.9	35.7	72.9	<0.001	52.0	39.8	8.2	0.37	0.23-0.51
Sauces[l]	6.3	6.2	11.0	0.137	38.1	42.3	19.6	0.10	-0.04-0.24
Fats[m]	4.1	15.8	22.4	<0.001	57.7	39.2	3.1	0.50	0.36-0.64

[a] For the food group restgroup drinks no tertiles could be calculated since >33.3% of the participants did not consume any food from this food group during the 7-day EDR period.
[b] Kruskal-Wallis one-way ANOVA
[c] All drinks (incl. fruit and vegetable juices and non-sugared soft drinks, excl. milk, soy drinks and drinks from restgroup)
[d] Potatoes (excl. fried potato products), rice and pasta
[e] Raw and cooked vegetables incl. legumes
[f] Milk, buttermilk, chocolate milk, milk added to coffee or tea, yoghurt and soy drinks and -desserts
[g] Fish, shellfish and fish products
[h] Meat, meat products, poultry, game, offal, eggs and vegetarian products (tofu, Quorn, tempeh)
i Wine, beer and spirits
[j] Sweets and candy bars, chocolate, biscuits and pastry
[k] Fries, baked potatoes and crisps
[l] Cold sauces like mayonnaise and ketchup
[m] Butter, margarine, low-fat margarine and lard

Observation of the Bland & Altman plots and associated tests suggested intake related bias for beverages, vegetables, milk and soy products, meat and eggs, and restgroup foods (**Table 4 and Bland & Altman plots**). Constant additive error was present for bread and cereals, potatoes and grains, cheese, alcoholic beverages, and restgroup drinks. For bread and cereals, underestimation by the FFQ was observed, while for all other foods listed here, overestimation errors were present.

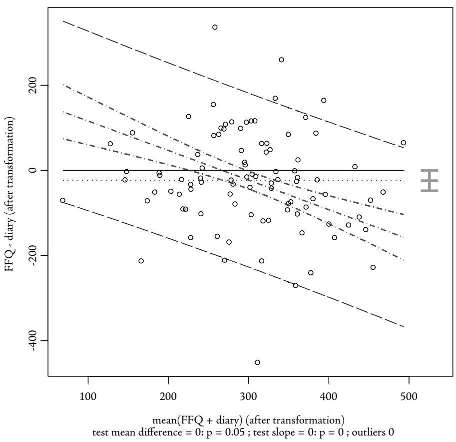
Table 4: Test statistics of mean differences and slopes of Bland & Altman data after Box-Cox transformation

	Mean difference		Regression			
Food group	FFQ-EDR	$p_{difference}$	intercept	slope	p_{slope}	*n*
Beverages[a]	-24.3	0.046	185.4	-0.695	< 0.001	94
Bread & cereals	-7.7	< 0.001	-2.5	-0.296	0.08	97
Potatoes & grains[b]	4.4	< 0.001	10.7	-0.281	0.14	95
Vegetables[c]	-1.5	0.01	9.6	-0.636	< 0.001	97
Fruit	0.56	0.21	-1.3	0.179	0.19	87
Milk & soy products[d]	-0.3	0.16	-3.04	0.371	< 0.001	87
Cheese	-1.43	< 0.001	-1.36	-0.018	0.89	81
Fish[e]	0.02	0.88	1.58	-0.366	0.06	77
Meat & eggs[f]	-5.1	< 0.001	4.95	-0.314	0.04	94
Alcoholic beverages[g]	-1.2	< 0.001	-1.20	-0.004	0.98	68
Restgroup foods[h]	-0.8	0.03	-3.04	0.276	0.02	96
Restgroup drinks[i]	-0.47	0.046	-1.38	0.167	0.25	37
Fried restgroup foods[j]	0.043	0.75	1.06	-0.196	0.15	83
Fats[k]	-0.095	0.70	-0.43	0.101	0.30	97

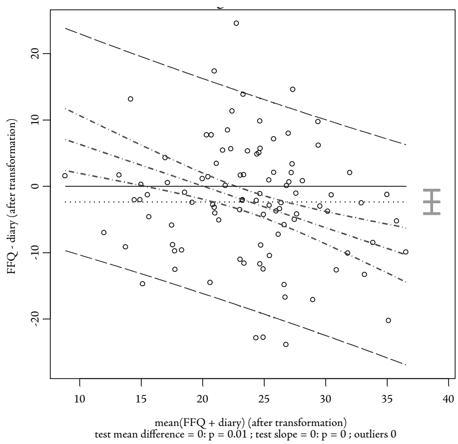
Note: values for mean difference, intercept and slopes are in transformed scale.
n: number of participants with positive consumptions of food groups during both collections (FFQ and EDR)
[a] All drinks (incl. fruit and vegetable juices and non-sugared soft drinks, excl. milk, soy drinks and drinks from restgroup)
[b] Potatoes (excl. fried potatoes and fries), rice and pasta
[c] Raw and cooked vegetables incl. legumes
[d] Milk, buttermilk, chocolate milk, milk added to coffee or tea, yoghurt, soy drinks and -desserts
[e] Fish, shellfish and fish products
[f] Meat, meat products, poultry, game, offal, eggs and vegetarian products (tofu, Quorn, tempeh)
[g] Wine, beer and spirits
[h] Sweets and candy bars, chocolate, biscuits and pastry
[i] Sugared soft drinks, sports drinks and energy drinks
[j] Fries, baked potatoes and crisps
[k] Butter, margarine, low-fat margarine and lard

Bland & Altman plots of selected food group intakes. Instruments for dietary intake assessment: short FFQ and 7-day estimated diet records. Plots show difference between both methods against their means (Box-Cox transformed data). The grand mean between both methods is plotted using dotted lines (….), the 95% CI around the mean is presented by error bars at the right. The fitted regression line is plotted as dash-dot lines (-.-.-.-) , the 95% CI and 95% CI for new observations are presented as dashed line (----). The zero difference line is presented using a solid line (___).

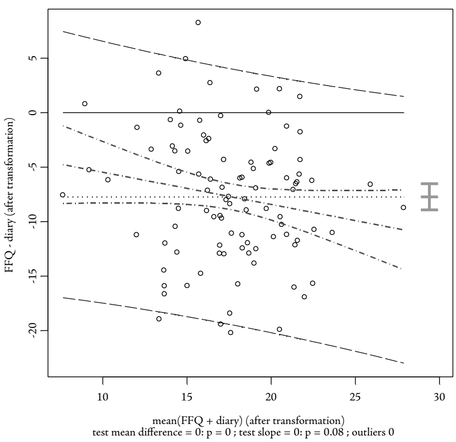
Beverages (intake related bias)



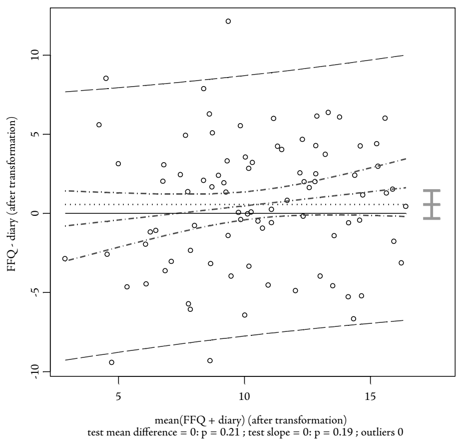
Vegetables (constant additive error & intake related bias)



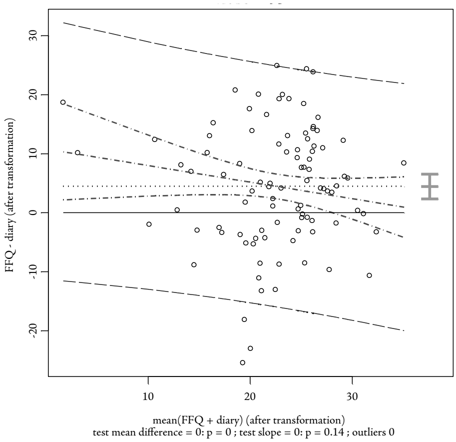
Bread and cereals (constant additive error)



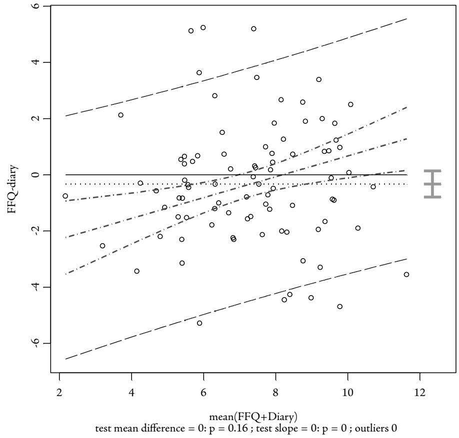
Fruit



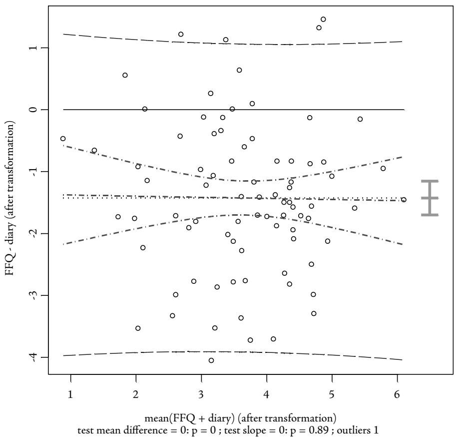
Potatoes and grains (constant additive error)



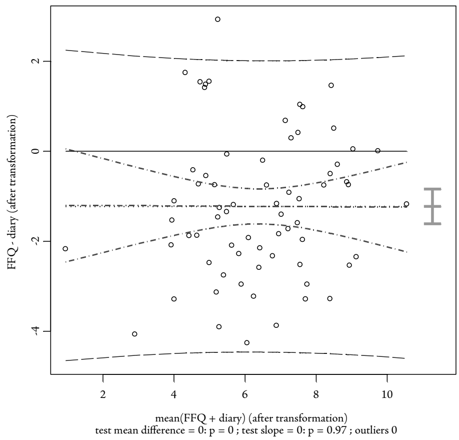
Milk and soy (intake related bias)



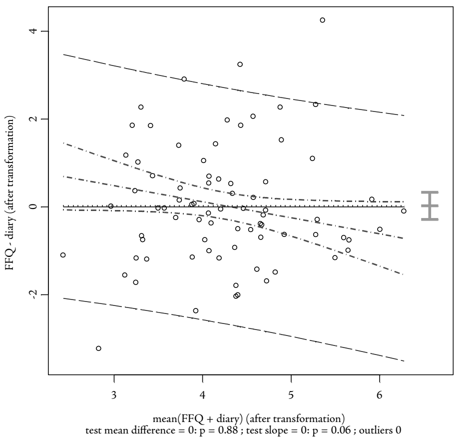
Cheese (constant additive error)



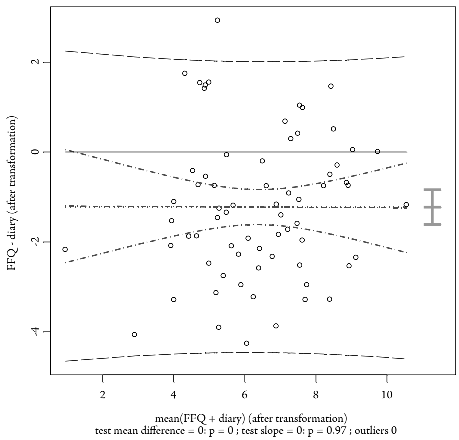
Alcoholic beverages (constant additive error)



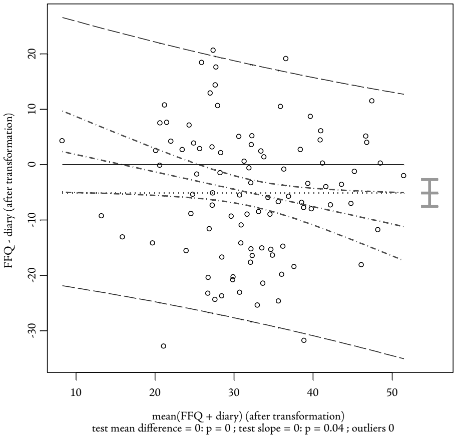
Fish



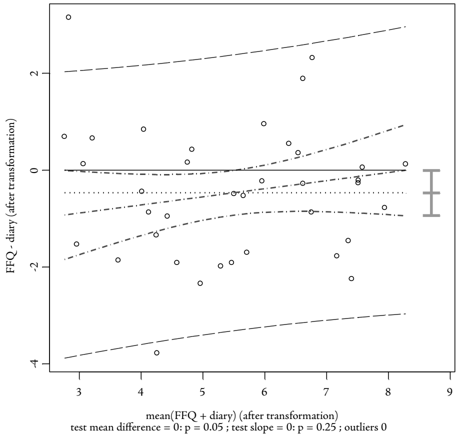
Alcoholic beverages (constant additive error)



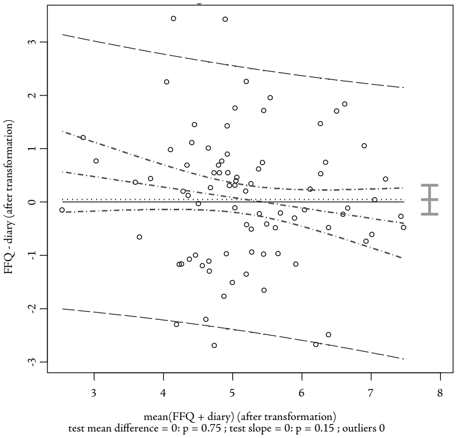
Meat & eggs (constant additive error & intake related bias)



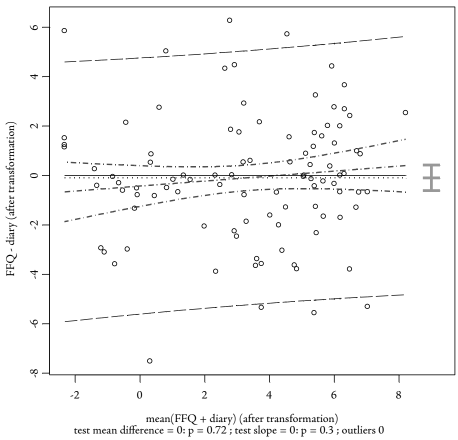
Restgroup drinks (constant additive error)



Fried restgroup foods



Fats



Discussion

The purpose of the short FFQ presented in this chapter is to be used in the context of nutritional surveillance (i.e. food consumption surveys), complementary to a repeated 24-hour recall interview, providing policy makers with a quick instrument to screen consumption behaviour of the population and to detect zero consumers necessary for proper estimation of food intake distributions from more detailed dietary interviews. The present qualitative FFQ showed a fair to moderate agreement in ranking participants towards their food intake compared to a 7-day EDR. Considerable differences were found across gender and age categories with respect to the FFQ's ability to correctly rank participants according to their usual intake. Acceptable ranking of participants by the FFQ was demonstrated for beverages, fruit, milk and soy products, cheese, alcoholic beverages, fried restgroup foods and fats. Correlation coefficients between FFQ and EDR-based estimates tended to be lower for vegetables compared to fruit in other studies also (Mikkelsen, Olsen, Rasmussen, & Osler, 2007; Wakai, 2009). According to Wakai (2009), a possible explanation could be that frequency of fruit consumption is easier to report then vegetables, since fruits are more often consumed as raw foods while vegetables are more frequently part of cooked dishes and therefore not integrally recalled. In addition, fruit is frequently consumed as a single food item and comes in natural or typical units, where vegetables are often sliced or cut which makes them more difficult to quantify. On the other hand, in a Mediterranean population, a higher correlation was found for vegetables compared to fruit by Fernandez-Ballart *et al.* (2010).

Food groups for which relative validity turned out rather low in the current study were typical carbohydrate containing food groups like bread and cereals, and potatoes and grains. A possible explanation for bread and cereals might be that bread is likely to be consumed more than once a day with large differences in portion sizes between participants which is not reflected by the FFQ and, especially in the older age category, breakfast cereals are consumed less frequently. Also, for the food group potatoes and grains it was found that in men, the FFQ largely overestimated potato consumption. For food groups with low validity, more detailed questionnaires containing more food items, may be needed to accurately assess actual food consumption. On the other hand, the trade-off between adding items for improvement of validity and longer questionnaires, which in turn can affect participation rate, should be kept in mind.

The correlation coefficients for cheese (0.33) and restgroup drinks (0.18) in the oldest age category were lower than those in the other age categories while for fish the correlation coefficient was higher (0.46). In elderly, data from both 7-d EDR and FFQ indicate very low consumption of restgroup drinks (data not shown). We are aware that the participants included in the different strata are a selected group of the population and not a population-based random sample due to the convenience sampling approach. No upper age limitation was set for inclusion into the study, therefore some participants were older than 80 years (15% of the oldest age category, data not shown). It was suggested by Rothenberg (2009) that elderly up to the age of 80 perform well in reporting their food habits retrospectively and that from the age of 80, elderly tend to report food habits earlier in life.

Although extensively used in other validation studies, a relative validity study has some drawbacks. When designing a validation protocol, a key step lies in identifying a method that will serve as a reference for the instrument to be validated. Given that no method is perfect to serve as gold standard, it is of vital importance that errors of both methods are as independent as possible (Willett & Lenart, 2013). Failing to select a reference method of which errors are uncorrelated with those from the instrument under study, will inevitably lead to higher estimates of validity. Major sources of error associated with FFQs are caused by restrictions resulting from a fixed list of foods, memory and interpretation of questions. Among the available and feasible comparison methods for validating a FFQ, diet records, with their open-ended format and independency towards memory, are likely to have the least correlated errors (Willett & Lenart, 2013). In addition, the reference method used in the present study (7-day EDR) is the best obtainable instrument that takes into account within-person variation in food intake and therefore better reflects usual food intake. Also, replicate measures by EDR allow correcting for within-person variability in food intake by calculating ratios of within- over between-person variances suitable for estimating de-attenuated coefficients of correlation.

A limitation of the current study is the different time frame over which food intake was assessed by both methods. Typically, FFQs are designed to measure long term dietary intake while EDRs measure short term intake when not repeated over time. Ideally, replicate 7-day periods, in which food intake is recorded over a time span of one year, is advised to include all seasonal variations. For instance, higher consumption of soups during winter months as opposed to summertime can have considerable impact on total beverages intake. The same will count for consumption of raw vegetables during summer.

The current study compared a quantitative EDR with a qualitative FFQ. In order to do so, standard portions sizes were used to calculate food intakes assessed by the FFQ. Therefore, it is very likely that two persons with identical frequencies of consumption have a different true consumption of a particular food due to differences in portion sizes consumed. This loss of detail, inherent to qualitative FFQs, will certainly attenuate ranking of individuals since variability in amounts of intake is reduced. On the other hand, it was demonstrated by Noethlings *et al.* (2003) that portion size adds only limited information on variance of food intake in a large European sample suggesting that assignment of standard portions to frequencies of intake seems to be adequate. This finding was also documented earlier in an American sample where it was concluded that due to a smaller contribution of between-person variance to the total variance in portion size, specification of a standard portion size may not introduce a large error in the estimation of food intake (Hunter et al., 1988).

Conclusion

In general, the FFQ tends to underestimate food intake compared to estimated diet records. For fruit, fish, fried restgroup foods and fats, no systematic bias was present. Considering the short character and the absence of portion size questions, the FFQ appears to be reasonably valid in both genders and across different age categories for assessment of group level intakes. However, for the food groups bread and cereals, potatoes and grains, and sauces estimates should be interpreted with caution because of poor ranking agreement.

Acknowledgements

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PART 2

Biochemical markers to evaluate validity of instruments

Chapter 4
Recovery biomarkers protein and potassium to assess comparability across five European centres

The use of two non-consecutive 24-h recalls (24-HDR) using EPIC-Soft for harmonized dietary monitoring in European countries has previously been proposed in the European Food Consumption Survey Method consortium. Whether this methodology is sufficiently valid to assess nutrient intake in a comparable way, among populations with different food patterns in Europe, is the subject of study in the European Food Consumption Validation consortium. The objective of this chapter is to compare the validity of usual protein and potassium intake estimated from two non-consecutive standardized 24-HDR using EPIC-Soft between five selected centres in Europe. A total of 600 adults, aged 45–65 years, were recruited in Belgium, the Czech Republic, France, The Netherlands and Norway. From each participant, two 24-HDR and two 24-h urines were collected. The mean and distribution of usual protein and potassium intake, as well as the ranking of intake, were compared with protein and potassium excretions within and between centres. Underestimation of protein (range 2–13 %) and potassium (range 4–17 %) intake was seen in all centres, except in the Czech Republic. We found a fair agreement between prevalences estimated based on the intake and excretion data at the lower end of the usual intake distribution (< 10 % difference), but larger differences at other points. Protein and potassium intake was moderately correlated with excretion within the centres (ranges = 0.39–0.67 and 0.37–0.69, respectively) and comparable across centres. In conclusion, two standardized 24-HDR using EPIC-Soft appear to be sufficiently valid for assessing and comparing the mean and distribution of protein and potassium intake across five centres in Europe as well as for ranking individuals.

Chapter based on:

Crispim, S. P., de Vries, J. H. M., Geelen, A., Souverein, O. W., Hulshof, P. J. M., Lafay, L., Rousseau, A.-S., Lillegaard, I. T. L., Andersen, L. F., Huybrechts, I., De Keyzer, W., Ruprich, J., Dofkova, M., Ocké, M. C., de Boer, E., Slimani, N., & van't Veer, P. (2011). Two non-consecutive 24 h recalls using EPIC-Soft software are sufficiently valid for comparing protein and potassium intake between five European centres – results from the European Food Consumption Validation (EFCOVAL) study. British Journal of Nutrition, 105(3), 447-458.

Part of this work was presented at the 7th International Conference on Diet and Activity Methods (ICDAM 7) in Washington DC, United States of America, June 2009.

Background

National food consumption surveys aim to provide information on the mean and distribution of food and nutrient intakes of the population and related subgroups, in order to develop and evaluate nutrition policies. In addition, national food consumption surveys are essential to provide data for risk assessment work, as conducted by the European Food Safety Authority – EFSA (EFSA, 2009). In Europe, food consumption data originating from national surveys are not always comparable because they differ in a number of aspects, such as the choice of the dietary assessment method and the reference period of the data collection (Charzewska, 1994; Pietinen & Ovaskainen, 1994; Verger et al., 2002). Furthermore, some countries do not have national food consumption surveys in place (Verger et al., 2002).

The European Food Consumption Survey Method (EFCOSUM) consortium has acknowledged the need for policy-relevant dietary indicators that are comparable among European countries, which could contribute to the establishment of a Community Health Monitoring System (Brussaard, J., Johansson, & Kearney, 2002). They recommended two non-consecutive days of 24-HDR using EPIC-Soft software (Lyon, Rhone Alpes, France) as the preferred method to assess the dietary intake in future pan-European monitoring surveys in adults. In addition, they specified total fat, saturated fatty acids and ethanol as the components of most relevance in this assessment (Biro, Hulshof, Ovesen, & Amorim Cruz, 2002; Brussaard, J. H., Lowik, et al., 2002; Slimani & Valsta, 2002).

The 24-HDR is a commonly used dietary assessment method in food consumption surveys in Europe (Verger et al., 2002) and is also being used in surveys in the USA (Conway, Ingwersen, & Moshfegh, 2004), Canada (Statistics Canada, 2004), Australia (McLennan & Podger, 1995) , and New Zealand (Russell, Parnell, & Wilson, 1999). A major advantage of using 24-HDR in (inter)national surveys is that the method is useful for comparison of heterogeneous populations with different ethnicity and literacy (Biro et al., 2002). In addition, a computerised version of 24-HDR seems to be the best means of standardizing and controlling for sources of error attributable to 24-HDR interviews (Willett, W. C., 2013; Biro et al., 2002). Nevertheless, computerised 24-HDR need to be tailor-made to every included country and/or study, e.g., by adaptations of the food and recipe list. Therefore, whether this methodology performs in a comparable way across countries with different food consumption patterns in Europe deserves further exploration, as validity of the 24-HDR depends on both the characteristics of the method and the study population.

Biological markers offer an important opportunity to evaluate the dietary assessment methods since errors are likely to be truly independent between the measurements of biomarker and dietary intake (Ocké & Kaaks, 1997). Urinary nitrogen and potassium are two of the few available recovery biomarkers to assess the nutrient intakes (Bingham, S. A. & Cummings, 1985; Tasevska, Runswick, & Bingham, 2006). With the use of these two biomarkers, a single 24-HDR using EPIC-Soft has been previously validated for assessing the group mean intakes of protein of twelve centres in six countries within the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort study (Slimani et al., 2003). Yet, the accuracy of this methodology needs to be determined when aiming at estimating usual dietary intake among different European populations by collecting two independent 24-HDR. Hence, following the path of EFCOSUM, the European Food Consumption Validation (EFCOVAL) consortium aimed to further develop and validate a European food consumption method using EPIC-Soft software for assessing the food and nutrient intakes within European countries, and for comparisons between them. In the present chapter, we aim to compare the validity of usual protein and potassium intake estimated from two non-consecutive standardized 24-HDR using EPIC-Soft between five selected centres in Europe. This was done by addressing the bias present in the estimation of each centre's mean and distribution of intake, as well as the ranking of individuals within and between centres according to their intake.

Methods

Subjects

Data were collected in five European countries: Belgium, Czech Republic, France (Southern part), the Netherlands, and Norway. These countries were selected to represent a large variety in food patterns across Europe. Data were collected in the South of France to include the characteristics of the Mediterranean diet. A food pattern from Central/Eastern Europe was represented by the Czech Republic, from the Scandinavian countries by Norway and from the western part of Europe by Belgium and The Netherlands. Another reason for their selection was their experience in performing national nutrition surveys.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by ethical committees in each centre involved in the data collection.

We recruited subjects by convenience sampling through advertisements (newspaper and websites), mailing lists, among others. Recruitment of institutionalised subjects was not allowed, nor included more than one member of a household. Subjects were informed about the study through information meetings at the institutions/universities in the Czech Republic, France, and The Netherlands, and by phone, letter and personally in Belgium and Norway. At these occasions, a screening questionnaire was filled in to confirm the subjects' eligibility in the study. Subsequently, the eligible participants gave written informed consent, and appointments for later visits were scheduled. Exclusion criteria were currently taking diuretics, following prescribed dietary therapy, being enrolled in another study in the same period, not being able to read or speak the national language, being pregnant, lactating, having diabetes mellitus or kidney disease, and donating blood or plasma during or less than four weeks before the study. *para*-Aminobenzoic acid (PABA) was used to check the completeness of urine collections; therefore, subjects hypersensitive to PABA or taking antibiotics containing sulphonamides, which are PABA-antagonistic, were not eligible for the study.

Taking into account an anticipated dropout percentage of 20% and aiming at a net sample of 50 per stratum, a total of 60 men and 60 women were recruited per centre (*n* 600). The age range of subjects was 45 to 65 years, which was chosen to limit the heterogeneity of the sample. Furthermore, we aimed to include at least ten men and ten women in each of the three predetermined categories of education level (low, intermediate and high) per centre. We used country-specific classifications to define each category level.

We excluded one subject because no data for recall and biomarker collected on the same day were available. Therefore, the study population comprised 599 subjects (296 men and 303 women).

Study design

Wageningen University (The Netherlands) was, as the coordinating centre, responsible for the overall logistics of the validation study in the EFCOVAL consortium. For standardization, all study procedures, i.e. on recruitment and fieldwork conditions, data processing formats, quality-control aspects and specimen collection, storage and transport details, were described in protocols. The recruitment of subjects and data collection in The Netherlands were performed from April to July 2007, six months before the other four centres, in order to test all the procedures of the fieldwork beforehand and to be able to refine the protocols. The other centres started the fieldwork in October or November 2007 with the last centre finalising the collection by April 2008.

At the beginning of the study, subjects had their body weight and height measured in the study centres. Then, a 24-HDR and a 24-h urine collection were obtained covering the same reference day. Subjects were aware of the days of data collection but not of the purpose of the interviews. The second recall and urine collection were obtained at least one month after the first one.

Dietary data

The two 24-HDR were collected using two modes of administration: one by phone and one face-to-face at the centre since it is likely that future food consumption monitoring surveys will be conducted in both ways across European countries. The order of the two modes of administration was randomly allocated among the subjects.

Furthermore, the appointments for the dietary recalls followed a randomised schedule, which included all days of the week. This randomisation allowed the same person to have the same recalled weekday for both interviews by chance. Interviewers in each centre were nutritionists or dietitians who were trained in interviewing skills and working with EPIC-Soft in the context of the validation study. They were guided by qualified local trainers who were previously trained by staff from the Wageningen coordination centre and the National Institute for Public Health and the Environment in the Netherlands (RIVM). Interviewers were aware of the objectives of the study. The centres were allowed to organise their data collection in the same way they would do in a future performance of their national nutrition survey. An example is that interviewees were permitted to check food packages and household measures in their home for more detailed information during the phone interview while this was not possible during the face-to-face interview at the study centre. Another example is that dietary recalls in Belgium, the Czech Republic and The Netherlands were not conducted on Sundays. Therefore, Saturdays' intake was recalled two days later, on Mondays.

The two 24-HDR were collected using EPIC-Soft (version 9.16). The structure and standardization procedure of EPIC-Soft has been described elsewhere (Slimani et al., 1999; Slimani et al., 2000). Briefly, EPIC-Soft is a computer-assisted 24-HDR that follows standardized steps when describing, quantifying, probing and calculating the food intakes (Slimani et al., 1999). All the participating countries had an existing version of EPIC-Soft available, except the Czech Republic for which a new country-specific version was developed. In addition, EPIC-Soft databases were adapted for each centre in terms of some common specifications for the EFCOVAL study (e.g., soups were treated as recipes rather than food items). Furthermore, the centres generated or updated a list of the single food items and recipes expected to be consumed by their participants. Modifications of such lists were needed afterwards based on notes made during the interview. The methods of estimation of portion size included household measures, weight/volume, standard units and portions, bread shapes and photographs. The set of photographs was developed in the context of the EPIC study (van Kappel, Amoyel, Slimani, Vozar, & Riboli, 1995). Each centre chose from the EPIC portfolio of photographs the pictures that best represented their national food habits.

In the absence of harmonized recent food composition tables (FCT) including all countries of our assessment, protein and potassium contents in foods were calculated using country-specific FCT (NUBEL, 2004; MVT-06, 2006; NEVO-TABEL, 2006; AFSSA/CIQUAL, 2008). Carbohydrates, total fat, saturated fat, alcohol and dietary fibre intake as well as energy content were also computed. We calculated energy values by summing the contributions from protein, carbohydrates, fat and alcohol and using related Atwater factors (17, 17, 37 and 29 kJ per gram, respectively). In the Czech Republic, the national FCT was published about 20 years ago. Therefore, a FCT was compiled for EFCOVAL purposes in the Czech Republic with composition of most foods based on the Slovakian tables (Food Research Institute, 1997-2002). In all the centres, missing nutrient data for a food was imputed from a similar food or another FCT, based on country-specific decisions, but in a few cases, this was not possible for potassium, saturated fat, dietary fibre and alcohol. The percentage of missing values was less than 6% of all reported foods for all nutrients.

24-h urine collections and recovery biomarkers

The subjects were instructed not to make use of acetaminophen painkillers, such as paracetamol, and sulphonamide drugs, during the days of urine collection. To check the completeness of urinary collections, one tablet of 80 mg PABA (PABAcheck, Laboratories for Applied Biology, London, UK) had to be taken three times on the day of the urine collection: with the morning, midday and evening meals. Hence, we expected that 240 mg of PABA would be almost completely excreted within 24-h (Bingham, S. & Cummings, 1983; Runswick et al., 2002). The collection of the 24-h urine started with voiding and discarding the first urine in the morning after waking up. Subsequently, the urine excreted during the next 24-h, up to and including the first voiding of the following day, was collected. For this purpose, each subject received labelled containers (at least two), one funnel to help the collection, one safety pin to be fixed in the underwear as a reminder for collection and a diary scheme booklet to register the timing, observations (e.g., use of medication and supplements) and possible deviations (e.g., missing urine) of the urine collection protocol. Boric acid

(3g/2 litre bottle) was used as preservative. The subjects provided their urine samples to the dietitians at the study centre when a face-to-face dietary recall was scheduled. If the 24-HDR interview was by phone, urine samples were collected at the subject's home or delivered to the study centre. When a long period was anticipated between the end of the collection and the receiving of samples, subjects were instructed to keep the urine samples at approximately 4°C, which in most cases was not more than 12-h. To verify the stability of PABA in urine, a pooled urine sample of three participants from The Netherlands were kept at four different temperatures (-20, 6, 20 and 30°C) for 8 days. At five moments (days 0, 1, 2, 4 and 7), PABA concentrations were measured. No significant changes in PABA concentrations were observed during the storage period at each temperature. The regression equation for PABA content as a function of time during storage at 20°C (assumed to be the most common storage temperature) was as follows: PABA (mg/L) = 140.2 - 0.8 (time in days) with the 95% confidence interval for the time coefficient being [-2.5,0.8].

At the laboratory of the local centres, urine was mixed, weighed and aliquoted. Then, the specimens were stored at -20°C until shipment on dry ice to the central laboratory at Wageningen University, where they were kept at the same temperature.

Chemical analysis

On the day of chemical analysis, aliquots were rapidly thawed at room temperature. Urinary nitrogen was determined colorimetrically by the Kjeldahl technique on a Kjeltec 2300 analyser (Foss, Hilleroed, Denmark) after destruction of the sample with concentrated sulphuric acid. Urinary potassium was measured by an ion-selective electrode on a Beckman Synchron LX20 analyser (Beckman Coulter, Mijdrecht, The Netherlands). PABA was measured by colorimetry (Bingham, S. A., Williams, Cole, Price, & Cummings, 1988). The intra-assay precision, expressed as coefficient of variation (CV), of these three analyses was less than 2%. Taking into account the extra-renal losses (approximately 19%) and the fact that protein on average contains 16% of nitrogen, urinary protein was calculated as [6.25 x (urinary nitrogen/0.81)] (Bingham, S. A. & Cummings, 1985; Bingham, S. A., 2003). Urinary potassium was estimated by dividing the measured value by 0.77, assuming that 77% of potassium intake is excreted through the urine when considering faecal excretion (Holbrook et al., 1984; Tasevska et al., 2006).

Urine samples with PABA recoveries below 50% were treated as incomplete and excluded from the data analysis (*n* 14). Additionally, the subjects who took drugs containing sulphonamides or acetaminophen, or one who took less than three PABA tablets had their urine diaries checked for other deviations in the urine collection.

In cases where other deviations were observed, namely urine loss during the collection or absent registration of collection time, samples were excluded from the analysis (*n* 4). Otherwise, samples were included (*n* 13) as we did not want to exclude potentially complete urines. Results of the present study did not change by excluding these subjects. As described before (Johansson, Bingham, & Vahter, 1999), specimens containing between 50 and 85% of PABA recovery (*n* 105) had their urinary concentrations proportionally adjusted to 93% of PABA recovery. Recoveries above 85% were included in data analyses without adjustments (*n* 1062).

Data analysis

The analyses were performed using SAS statistical package, version 9.1 (SAS Institute Inc, Cary, NC, USA). The statistical analyses were stratified by sex and using the average of two days of intake and excretion, except for 18 subjects who only had one day of 24-HDR and biomarker. For these subjects, the 24-HDR matched with the day of the urine collection. To assess the presence of bias (systematic errors), the mean difference between nutrient intake and excretion was calculated. Analysis of covariance (ANCOVA) followed by the Tukey post hoc test was used for testing whether biases differed between the centres. The ANCOVA model included age (continuous), education level (three categories) and body mass index (BMI continuous), given that stratified analysis of these variables showed us differential performance of the method within and between the centres. To estimate and compare the distribution of usual intake and excretion of protein and potassium between the centres, the Multiple Source Method (MSM) was used as the measurement error model (German Institute of Human Nutrition, 2009). This model removes the effect of day-to-day variability and random error in the two 24-HDR and biomarker estimates. The MSM was developed in the framework of the EFCOVAL study and enabled us to estimate individual usual intake. We decided not to use covariates in the calculation of usual intakes with the MSM. Plots of usual intake distributions based on the 24-HDR and biomarker were created using R software, version 2.8.1 (http://cran.r-project.org). The percentages of subjects consuming above certain cut-off points for each distribution curve were calculated. For both sexes, we specified eleven cut-off points to cover the whole range of protein and potassium intake among the five centres. For the evaluation of ranking of individuals, we computed Pearson's correlation coefficients. For adjusted correlations, we used usual intake and excretion data corrected for within-person variability, as estimated by the MSM method, and further corrected for age, BMI and education level by using partial Pearson correlations. Confidence intervals of the correlations were obtained using the Fisher Z-transformation (Kleibaum, Kupper, Nizam, & Muller, 2008). Energy-adjusted correlations were calculated using the residual method (Willett, W., Howe, & Kushi, 1997). To test the equality of correlations, pairwise comparisons were made using Fisher Z-transformation (Kleibaum et al., 2008). Pooled correlations of the five centres were calculated by first converting the correlations into a standard normal metric (Fisher's r-to-Z transformation). Next, the pooled average was calculated, in which each transformed correlation coefficient was weighted by its inverse variance, followed by the back transformation (Kleibaum et al., 2008). The cochrane Q test was used for testing the heterogeneity of the pooled correlation (Field, 2005).

Results

The mean age of the subjects was similar in the five centres (**Table 1**). In both sexes, mean BMI was comparable across the centres (ranges: 23.2-25.5 kg/m^2 in women and 25.5-27.9 kg/m^2 in men). Subjects with moderate and high education levels were over-represented in the study compared with individuals with a low education level, especially men in Norway. The variations in energy intake across the centres were less pronounced than in macronutrients, especially for carbohydrates.

A degree of underestimation was seen in the assessment of protein intake in all the centres. Underestimation varied from 2.7% (Norway) to 12.4% (The Netherlands) in men and from 2.3% (Norway) to 12.8% (France) in women, based on the crude differences between intake and excretion (**Table 2**). After adjusting for age, BMI and education level, the bias did not differ between the centres for women. However, men in the Czech Republic had a significantly smaller bias compared with those in France and The Netherlands. For potassium, the underestimation varied from 1.7% in Norway to 17.1% in France for men and from 6.6% in The Netherlands to 13% in France for women. An overestimation of 5.9% for men and 1.6% for women was found in the Czech Republic. A statistically significant difference in the adjusted bias was seen in men between France and three other centres: Belgium, Czech Republic, The Netherlands. In women, differences were statistically significant only between France and the Czech Republic. BMI was the only factor influencing the differences between the countries at a significant level ($p<0.01$ for all analyses, except for potassium in women; $p=0.16$). Upon inclusion of energy intake into the ANCOVA model, the conclusion about the differences between the centres changed only for protein results in men, which lost statistical significance ($p=0.08$). Additionally, when we pooled the data from all the countries, no consistent trend in mean protein and potassium biases was observed across the different education levels and modes of administration (data not shown).

Table 1: Characteristics of five European centres in the EFCOVAL validation study [1]

	Men										Women									
	BE[2] (n=63)		CZ (n=58)		FR (n=54)		NL (n=59)		NO (n=62)		BE (n=60)		CZ (n=60)		FR (n=59)		NL (n=62)		NO (n=62)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Age (years)	54	5.5	55	6.9	56	5.4	57	4.3	55	6.0	55	5.0	55	6.1	55	6.0	55	5.6	54	6.0
Weight (kg)	81.1	13.3	85.7	13.2	78.1	9.7	83.8	14.4	85.7	9.9	67.6	12.5	66.8	9.8	60.6	8.6	71.4	13.8	68.4	11.4
Height (cm)	175.6	7.1	175.4	6.4	174.8	7.0	177.5	8.8	179.9	7.2	163.6	6.8	163.8	6.1	161.6	6.7	167.6	8.8	166.0	6.8
BMI (kg/m2)	27.2	3.6	27.9	4.2	25.5	2.7	26.5	3.8	26.4	2.5	25.2	4.2	25.0	3.9	23.2	3.0	25.5	5.0	24.8	3.7
Energy (MJ/day)	11.0	0.3	12.1	0.5	10.4	0.3	11.2	0.4	11.8	0.4	8.4	0.3	8.4	0.2	8.1	0.2	8.6	0.3	8.4	0.3
Energy % protein	16.0	0.4	14.5	0.3	15.9	0.4	15.8	0.4	17.2	0.5	16.1	0.4	14.8	0.4	16.0	0.3	15.4	0.4	17.9	0.5
Energy % total fat	35.2	0.8	34.7	0.8	35.8	0.8	34.1	0.8	36.0	1.1	33.8	0.8	34.0	1.0	39.3	0.9	34.6	0.9	38.6	1.0
Energy % carbohydrates	41.6	0.9	47.0	1.1	44.0	1.0	43.1	1.0	42.8	1.1	44.8	1.0	49.1	1.1	42.4	1.0	46.0	0.9	40.0	1.1
Energy % saturated fat	13.7	0.4	12.7	0.3	13.7	0.4	13.0	0.4	13.9	0.6	13.7	0.4	12.8	0.4	14.0	0.5	12.5	0.4	14.8	0.5
Alcohol (g/day)	30.2	4.2	17.8	3.4	15.1	2.5	27.6	3.4	16.5	2.8	17.3	2.7	6.3	1.3	6.9	1.3	12.3	2.0	10.7	2.1
Dietary fibre (g/MJ/day)	2.3	0.1	2.5	0.1	2.2	0.1	2.4	0.1	2.5	0.1	2.7	0.1	3.1	0.1	2.7	0.1	3.0	0.1	2.7	0.1
Education % of total																				
Low	15.9		20.7		25.9		20.3		3.2		16.7		16.6		35.6		24.2		16.1	
Intermediate	23.8		24.1		24.1		20.3		30.7		25.0		46.7		27.1		40.3		19.4	
High	60.3		55.2		50.0		59.4		66.1		58.3		36.7		37.3		35.5		64.5	

[1] Dietary intake based on 2x24-h recalls
[2] BE=Belgium, CZ=Czech Republic, FR=France, NL=the Netherlands, NO=Norway

Table 2: Protein and potassium intake and excretion (Mean ± SE) based on 2x24 hour recalls and 2x24 hour urinary biomarkers for five European centres in the EFCOVAL validation study

	Men										
	BE (n=63)		CZ (n=58)		FR (n=54)		NL (n=59)		NO (n=62)		p-value†
Protein (g)	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Intake	101.7	3.3	100.4	4.2	95.9	3.4	101.5	3.5	115.2	3.8	
Excretion‡	110.8	3.2	104.1	3.0	109.1	2.8	115.9	3.6	118.4	3.1	
% crude difference	-8.2		-3.5		-12.1		-12.4		-2.7		
Adjusted difference	-7.5[ab]	3.4	-1.4[a]	3.6	-14.7[b]	3.6	-14.1[b]	3.6	-2.3[ab]	3.6	0.02
Potassium (mg)											
Intake	4024	131	3726	164	3464	138	4326	139	4847	182	
Excretion§	4301	148	3517	143	4180	141	4491	157	4935	138	
% crude difference	-6.4		+5.9		-17.1		-3.7		-1.7		
Adjusted difference	-230[ab]	144	282[a]	150	-759[b]	153	-123[a]	150	-66[a]	151	<0.01

	Women										
	BE (n=60)		CZ (n=60)		FR (n=59)		NL (n=62)		NO (n=62)		p-value†
Protein (g)	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Intake	79.0	2.5	70.8	2.1	74.7	1.9	78.2	3.3	85.5	2.6	
Excretion‡	87.5	2.6	78.8	2.2	85.7	2.0	85.1	2.9	87.5	2.1	
% crude difference	-9.7		-2.7		-12.8		-8.2		-2.3		
Adjusted difference	-7.9	2.5	-7.9	2.5	-12.2	2.5	-6.3	2.4	-1.8	2.5	0.07
Potassium (mg)											
Intake	3513	148	3155	143	3146	141	3618	157	3630	138	
Excretion§	3928	138	3150	111	3617	124	3871	142	3899	102	
% crude difference	-10.5		+1.6		-13.0		-6.6		-6.9		
Adjusted difference	-414 [ab]	115	9 [a]	113	-503 [b]	114	-224 [ab]	110	-274 [ab]	114	0.02

BE=Belgium, CZ=Czech Republic, FR=France, NL=the Netherlands, NO=Norway
a,b Mean values with unlike superscript letters were significantly different between the countries (P<0·05).
† One-way ANCOVA (General Linear Model) based on mean difference between intake and excretion. Tukey's post-hoc test was used for pair-wise comparison between the countries. ANCOVA model included age, BMI, and educational level.
‡ Urinary protein=(urinary nitrogen/0.81)x6.25 (Bingham, S. A. & Cummings, 1985)
§ Urinary potassium=(urinary potassium/0.77) (Tasevska, Runswick, & Bingham, 2006)

The bias in mean intake can also be observed when comparing the distributions of usual intake based on food consumption data with those obtained from excretion data (**Figure 1 to 4**). The intake data curve shifted somewhat to the left (underestimation of intake) for almost all the centres compared with the excretion data. Since the prevalence of subjects consuming below or above a certain cut-off point is an important indicator for a population's nutritional status, we assessed and compared the prevalence of subjects consuming above specific cut-off points for both usual intake and usual excretion distributions (**Figure 5 to 8**).

Overall, we found a fair agreement between prevalences estimated based on the intake and excretion data at the lower end of the usual protein and potassium intake distribution, but larger differences at middle cut-off levels. For protein in men, the smallest differences in prevalence between intake and excretion were seen in Norway (up to 15%) and the largest ones in France (up to 46%) and The Netherlands (up to 41%). For women, the smallest differences were seen in Norway (up to 11%) and the largest ones in the Czech Republic (up to 38%) and France (up to 55%). The smallest difference between potassium intake and excretion distribution in males was observed in the Netherlands (up to 7%) while the larger differences were seen in the Czech Republic and France (up to 21 and 40%, respectively). In women, France was the centre with the largest difference (up to 29%) between potassium usual intake and excretion, and The Netherlands the smallest (up to 17%).

Unadjusted Pearson correlation coefficients between average protein intake and its biomarker within centres ranged between 0.42 and 0.65 in men and between 0.46 and 0.57 in women (**Table 3**). After adjusting for within person variability, age, BMI and education level, correlations ranged between 0.43 and 0.67 in men and between 0.39 and 0.63 in women. For potassium, unadjusted correlations ranged between 0.45 and 0.65 in men and between 0.31 and 0.69 in women. Adjusted correlations ranged between 0.40 and 0.69 in men and between 0.37 and 0.68 in women. For both protein and potassium, adjusting only for the within-person variability slightly increased the correlations between intake and excretion (data not shown). Statistically significant differences between correlation coefficients were only found between Belgium and the Czech Republic ($p=0.04$) for unadjusted correlations of potassium in women. However, after adjusting the correlations for energy, we found a significant difference between the Czech Republic ($r=0.25$) and France ($r=0.65$) for protein intake in men ($p= 0.01$).

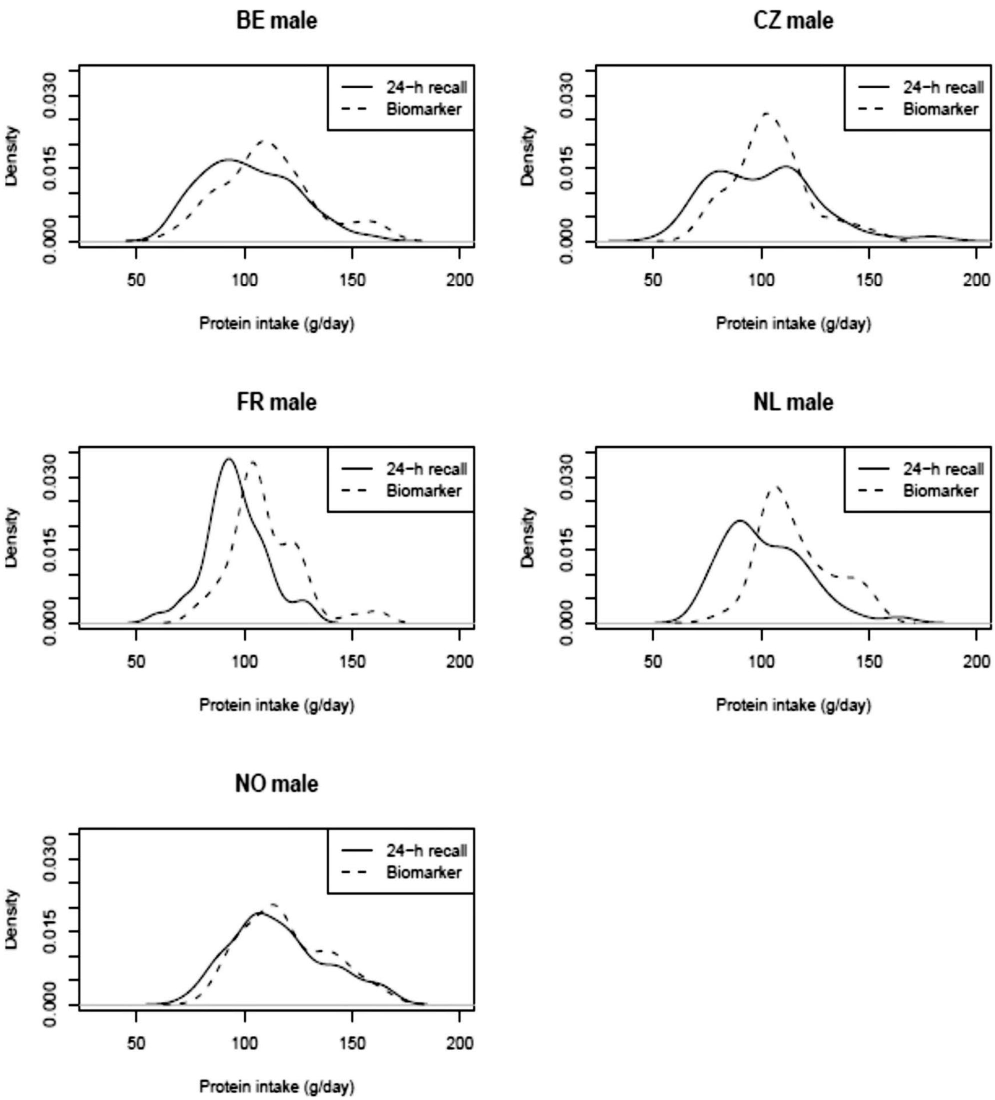

Figure 1 – Estimated distribution of usual protein intake in men, based on 2x24-h dietary recall and biomarker for five European centres in the EFCOVAL validation study BE=Belgium, CZ=Czech Republic, FR=France, NL=the Netherlands, NO=Norway

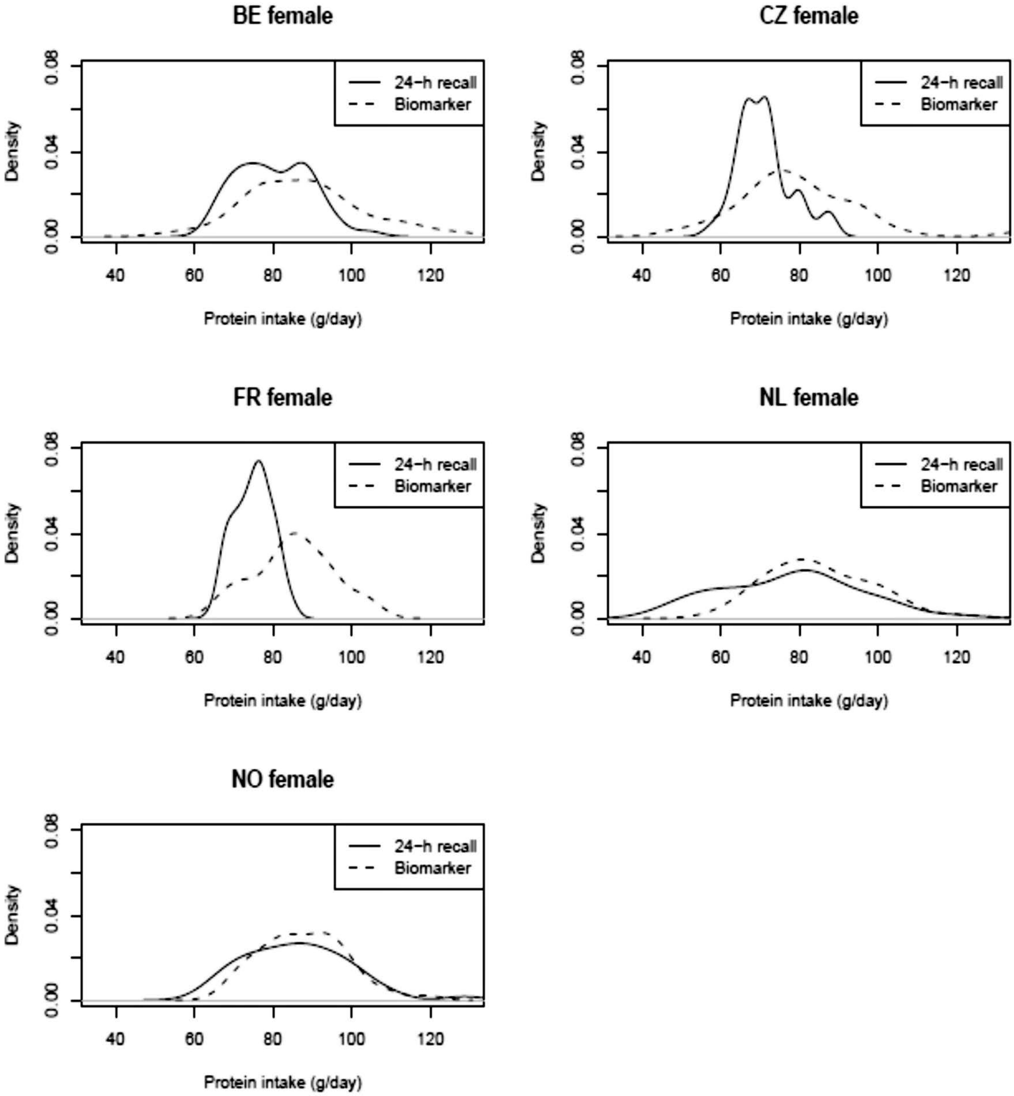

Figure 2 – Estimated distribution of usual protein intake in women, based on the 2x24-h dietary recall and biomarker for five European centres in the EFCOVAL validation study BE=Belgium, CZ=Czech Republic, FR=France, NL=the Netherlands, NO=Norway

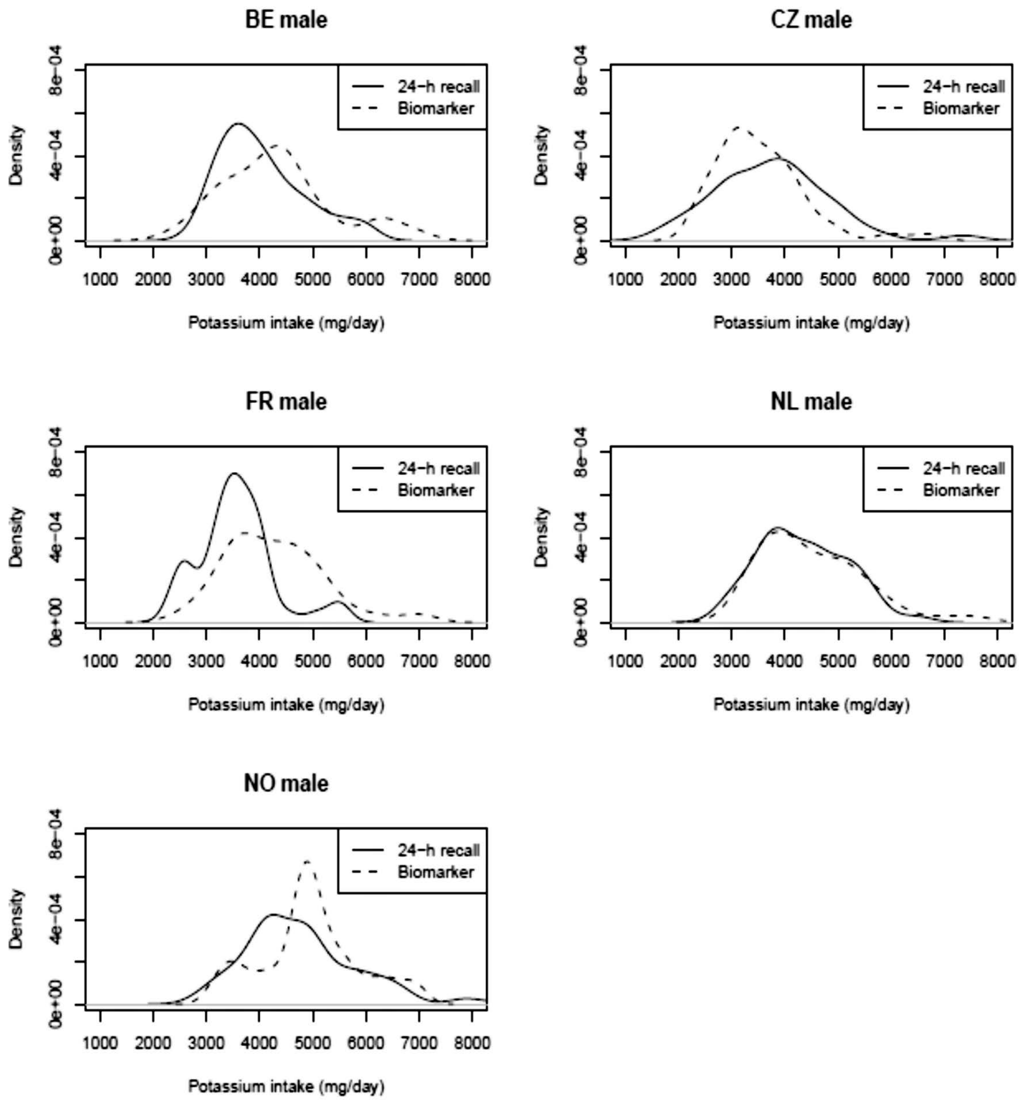

Figure 3 – Estimated distribution of usual potassium intake in men, based on the 2x24-h dietary recall and biomarker for five European centres in the EFCOVAL validation study BE=Belgium, CZ=Czech Republic, FR=France, NL=the Netherlands, NO=Norway

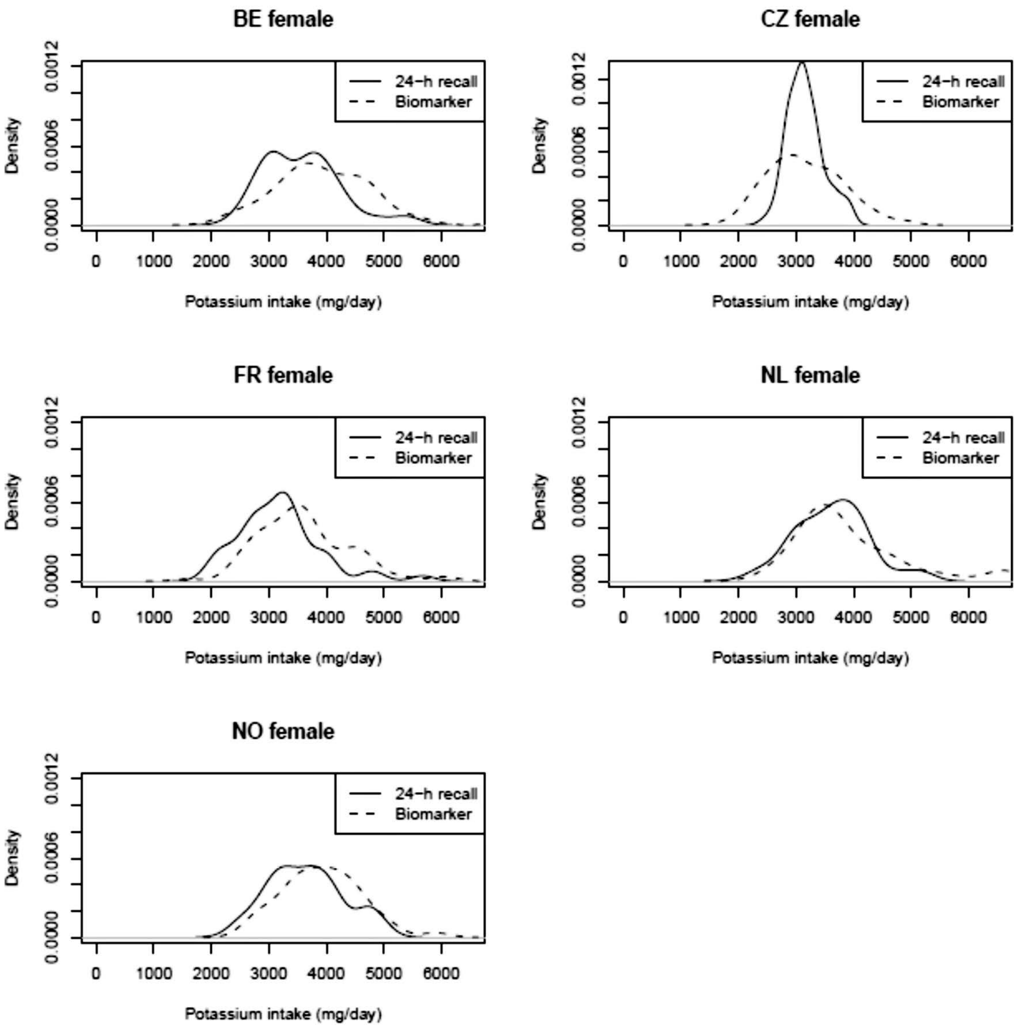

Figure 4 – Estimated distribution of usual potassium intake in women, based on the 2x24-h dietary recall and biomarker for five European centres in the EFCOVAL validation study BE=Belgium, CZ=Czech Republic, FR=France, NL=the Netherlands, NO=Norway

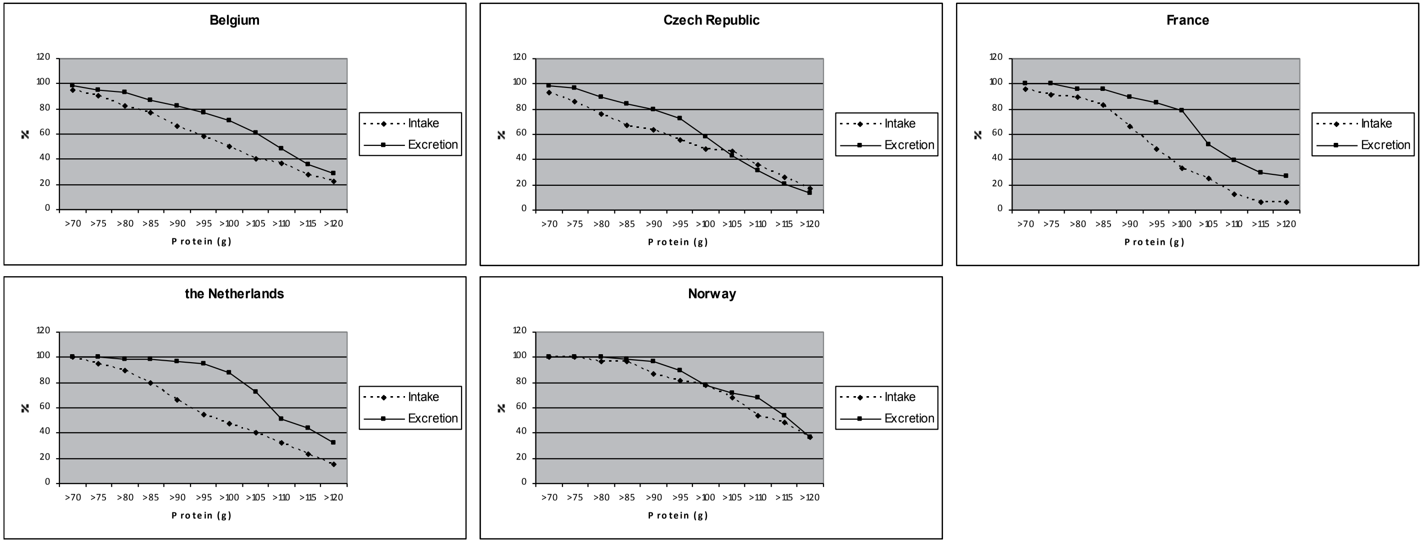

Figure 5– Prevalence of men consuming above specific amounts of protein as estimated by usual intake distributions from 24-h dietary recalls (intake) and biomarkers (excretion) for five European centres in the EFCOVAL validation study. Usual intake/excretion distributions estimated by MSM method.

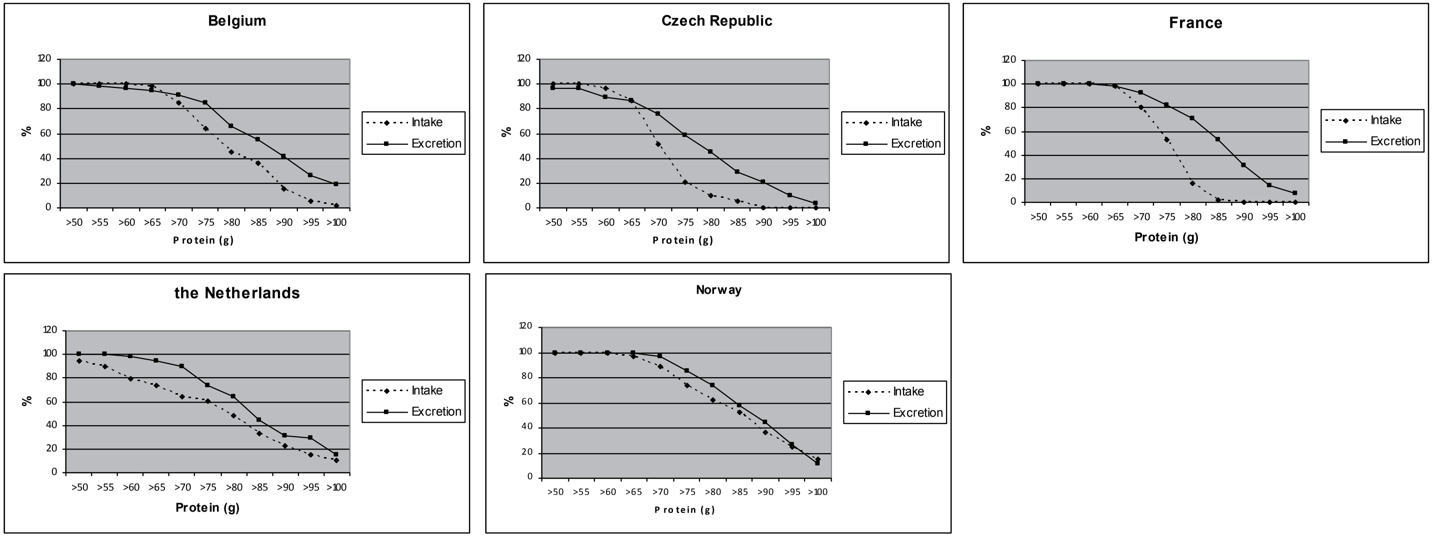

Figure 6 – Prevalence of women consuming above specific amounts of protein as estimated by usual distributions from dietary recalls (intake) and biomarkers (excretion) for five European centres in the EFCOVAL validation study. Usual intake/excretion distributions estimated by MSM method.

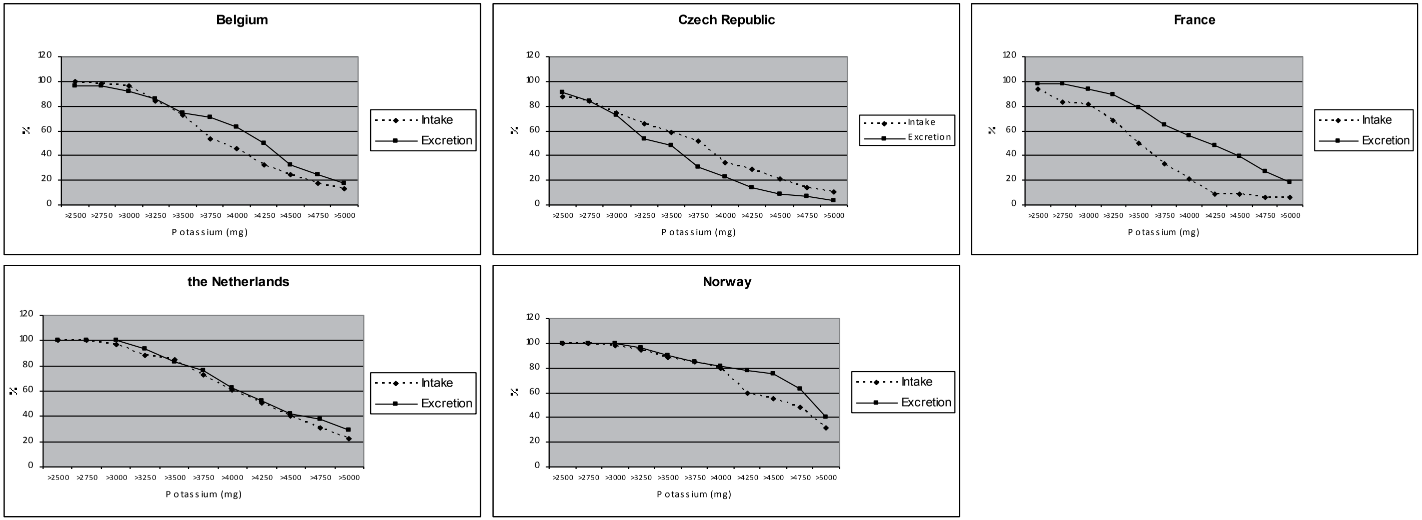

Figure 7– Prevalence of men consuming above specific amounts of potassium as estimated by usual intake distributions from dietary recalls (intake) and biomarkers (excretion) for five European centres in the EFCOVAL validation study. Usual intake/excretion distributions estimated by MSM method.

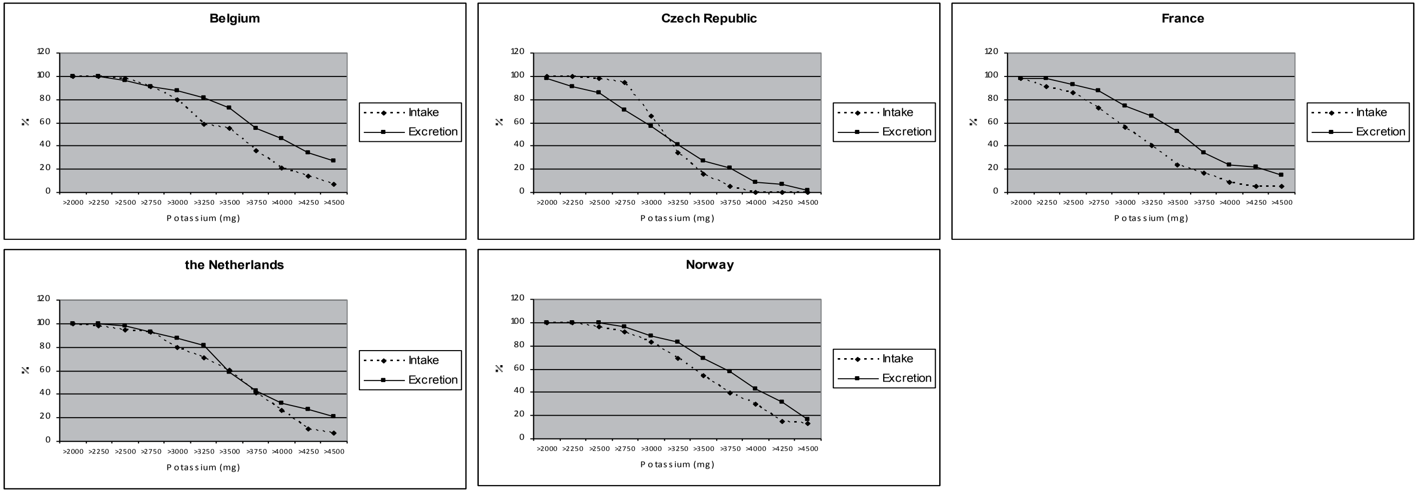

Figure 8 – Prevalence of women consuming above specific amounts of potassium as estimated by usual intake distributions from dietary recalls (intake) and biomarkers (excretion) for five European centres in the EFCOVAL validation study. Usual intake/excretion distributions estimated by MSM method.

Table 3: Pearson coefficients of correlation (confidence interval) between protein intake and urinary excretion* for five European centres in the EFCOVAL validation study†

PROTEIN								
	Men				Women			
Centres	*n*	*Unadjusted*	*Adjusted ‡*	*Energy-Adjusted §*	*n*	*Unadjusted*	*Adjusted ‡*	*Energy-Adjusted §*
Belgium	58	0.48 (0.27,0.65)	0.49 (0.27,0.67)	0.48 (0.26, 0.66)	62	0.57 (0.37,0.72)	0.57 (0.35,0.72)	0.35 (0.13,0.59)
Czech Republic	58	0.50 (0.28,0.67)	0.43 (0.18,0.62)	0.25 (-0.01, 0.49)	58	0.56 (0.35,0.71)	0.57 (0.35,0.72)	0.49 (0.29,0.69)
France	55	0.65 (0.46,0.78)	0.67 (0.47,0.81)	0.65 (0.44, 0.79)	48	0.46 (0.23,0.64)	0.39 (0.13,0.60)	0.51 (0.27,0.69)
the Neth-erlands	58	0.42 (0.18,0.61)	0.51 (0.29,0.68)	0.47 (0.24, 0.65)	59	0.51 (0.29,0.67)	0.63 (0.44,0.77)	0.34 (0.15,0.60)
Norway	61	0.52 (0.32,0.69)	0.47 (0.24,0.65)	0.50 (0.27, 0.67)	60	0.53 (0.33,0.69)	0.52 (0.30,0.68)	0.41 (0.20,0.62)
Pooled**	290	0.52 (0.40, 0.63)	0.51 (0.39,0.63)	0.50 (0.38, 0.62)	287	0.53 (0.41,0.64)	0.60 (0.42,0.66)	0.45 (0.33,0.57)
POTASSIUM								
	Men				Women			
Centres	*n*	*Unadjusted*	*Adjusted ‡*	*Energy-Adjusted §*	*n*	*Unadjusted*	*Adjusted ‡*	*Energy-Adjusted §*
Belgium	58	0.54 (0.33,0.69)	0.53 (0.32, 0.69)	0.42 (0.18, 0.61)	62	0.69 (0.53,0.81)	0.68 (0.51,0..80)	0.60 (0.40, 0.75)
Czech Republic	58	0.45 (0.21,0.63)	0.40 (0.15, 0.60)	0.37 (0.12, 0.58)	58	0.31 (0.01,0.52)	0.37 (0.12-0.58)	0.36 (0.11, 0.57)
France	55	0.62 (0.42,0.76)	0.64 (0.42, 0.78)	0.63 (0.42, 0.78)	48	0.61 (0.42,0.75)	0.63 (0.43, 0.77)	0.62 (0.41, 0.76)
the Neth-erlands	58	0.65 (0.47,0.76)	0.69 (0.52, 0.80)	0.66 (0.48, 0.79)	59	0.61 (0.42,0.74)	0.60 (0.40, 0.75)	0.36 (0.10, 0.57)
Norway	61	0.50 (0.28,0.67)	0.50 (0.28, 0.68)	0.62 (0.43, 0.76)	60	0.49 (0.28,0.66)	0.51 (0.29, 0.68)	0.49 (0.26, 0.66)
Pooled	290	0.55 (0.44,0.62)	0.56 (0.44, 0.68)	0.56 (0.44, 0.68)	287	0.55 (0.44,0.67)	0.57 (0.45, 0.68)	0.51 (0.40, 0.63)

* Average intake and excretion based on two days of collection
† Pairwise comparisons between countries (by Fisher Z transformation) suggested differences for: unadjusted correlations between Belgium and Czech Republic in females; and
between France and Czech Republic for energy-adjusted correlations in males.
‡ Adjusted for the within person variability using the usual intake/excretion data as estimated by MSM method (see methods section); and adjusted for age, BMI, and educational level
using Partial Pearson correlations.
§ Same adjustments as previous correlation plus energy-adjustment by residual method.
** Mean values for heterogeneity were not significant for all the analyses (p>0.05).

Discussion

In the present study, we compared the validity of usual protein and potassium intake estimated from two non-consecutive standardized 24-HDR between five selected centres in Europe. On average, men and women under-reported protein intake from the two 24-HDR by 8%. For potassium intake, average underestimation was 7% for men and 4% for women.

Protein intake was markedly underestimated (~12%) in French and Dutch men, especially when compared with Czech Republic men. The same is true for potassium intake in French men. In women, underestimation of mean protein intake was present in all the centres and appeared to be comparable across the centres. For potassium intake, however, the underestimation observed in the French centre was not comparable to that of the other centres, particularly to the overestimation observed in the Czech Republic. Furthermore, we assessed the agreement between the percentage of subjects above a certain cut-off point based on 24-HDR and biomarker data. We found a fair agreement for cut-off points at the lower end of the distribution (less than 10% difference), but larger differences at other points of the intake distribution (up to 55% difference for protein in French females). Finally, we observed moderate correlations for the ranking of individuals, which were likely to be comparable across the centres.

The results from the EPIC study, using EPIC-Soft in different centres, revealed a similar or even higher underestimation of protein intake collected from a single day (average of 13% in men and 19% in women) (Slimani et al., 2003). The OPEN study in the United States, which assessed the structure of dietary measurement error in duplicate 24-HDR, has also shown a similar underestimation of protein intake (11-15%) (Subar et al., 2003). A few other studies indicated overestimation of protein (about 7% for the whole population) (Kahn et al., 1995). For potassium, studies indicated overestimation of intake up to 20% (Bingham, S. A. & Day, 1997; Heerstrass, Ocké, Bueno-de-Mesquita, Peeters, & Seidell, 1998; Freedman et al., 2004), similar to what we observed in the Czech Republic. Nevertheless, because of methodological differences, the comparison of bias estimates between the present study and other studies is not straightforward. For example, adjustment of nitrogen and potassium excretions to extra-renal losses was not consistently performed among the studies. In addition, the completeness of 24-h urine collections was not always assessed. Although we acknowledge the differences in methodology between the studies, the performance of these two standardized 24-HDR on assessing the mean protein and potassium intake appeared to provide similar or even more accurate results than what have been presented in the literature so far.

In terms of assessing the whole distribution of intake, two 24-HDR used in the study by Freedman et al. (2004) underestimated the usual protein intake in all points of the distribution, especially at the lower end. Moreover, they found a good agreement between potassium intake and excretion in the whole range of percentiles. In contrast, moderate to large discrepancies were found between 24-HDR and biomarker data distributions in the present study, but not at the lower end of the distribution. The present results suggest that the assessment of protein and potassium inadequacy at the population level by two non-consecutive 24-recalls in healthy European populations is, therefore, appropriate.

Independent of the size of the bias, the correct classification of individuals according to their intake is also informative on the quality of the dietary assessment. The correlations in the present study are considerably higher compared with many other studies (Bingham, S. A. et al., 1997; Subar et al., 2003; Shai et al., 2005; Olafsdottir, Thorsdottir, Gunnarsdottir, Thorgeirsdottir, & Steingrimsdottir, 2006). Based on this, we conclude that the method performed sufficiently for the ranking of individuals, adding evidence to the use of this standardized 24-HDR. When we adjusted the nutrient values for energy intake, this changed the correlations in both directions and resulted in more noticeable differences across the centres. We doubt, however, whether energy-adjusted values will be our main exposure of interest in future monitoring surveys and whether individual energy intake was correctly estimated using only two days of 24-recall. Therefore, we do not base the conclusions of the present study on the energy-adjusted results.

We suppose that the differences found in the size and direction of the bias (i.e. overestimation of potassium intake in the Czech Republic and underestimation of both potassium and protein in the other centres) between the centres may be explained by reasons related to characteristics of the population and of the method itself. We have controlled our statistical analyses for the influence of age, education level and BMI. As a result, BMI was the only factor significantly influencing the differences between the countries. This is in accordance with our expectations since other studies have revealed a differential under-reporting of dietary intake by subgroups of BMI, more specifically, under-reporting increases with BMI. (Heerstrass et al., 1998; Lissner et al., 2007). Nevertheless, other aspects of the population could have affected the validity of the method between the centres in a different manner, i.e. factors related to the food pattern of the centres. Due to cultural differences in food pattern, it is expected that predominant food items contributing to protein and potassium intake across European countries will be different (Slimani et al., 2002; Halkjaer et al., 2009). For example, the food group 'dairy products' was one of the major contributors (>22%) to the protein intake in The Netherlands and Norway (in males only) whereas in the other three centres 'meat products' was distinctly the major contributor (>30%). Knowing that the errors in the assessment of different food groups differ, as for instance in the portion size estimation (Rumpler, Kramer, Rhodes, Moshfegh, & Paul, 2008), differences in validity between the centres could be expected. Likewise, differences in the consumption of composite foods could have had an effect since it is more difficult to recall all ingredients of composite foods than a single food item (O'Brien, Kiely, Galvin, & Flynn, 2003; Cosgrove, Flynn, & Kiely, 2005).

Another important factor that could explain the difference between countries is the use of non-harmonized FCT across the centres. Use of different conversion factors as well as of distinct laboratory analyses to produce food nutrient contents across the tables are just some examples which could have caused biases not to be comparable. For instance, for three of the FCT used in EFCOVAL, protein figures were calculated from nitrogen contents using the so-called "Jones conversion factors" (Jones, 1941) or slight modifications of them. However, in the Dutch tables only two of these factors were used (6.38 for milk products and 6.25 for all other foods) and in the compiled Czech table only one factor (6.25) was applied (Slovakian tables). Since errors attributed to these differences can be proportional to the level of intake, it is impossible to conclude on the influence of using different conversion factors in the comparison between the countries. Nevertheless, further investigation about the use of these conversion factors in FCT for comparisons of nutrient intake between countries is warranted.

The present study adds value to the current knowledge of collecting dietary information using standardized 24-HDR for possible use in national nutrition surveys. An important strength of the present study was the collection of two days of both dietary intake and biomarkers allowing the quantification of the within-person variability and to estimate the usual intake distributions. A potential limitation of the present study is that a health-conscious sample may have been included, hampering the extrapolation of the results to the general population. However, the present results suggested that extrapolation to other populations could be done irrespective of their education level. In addition, the generalizability of protein and potassium results to other nutrients of interest should be done with care. Although we might want to assume that the validation results of a single nutrient can be used as a proxy to other nutrients, there is evidence nowadays that some foods and consequently related nutrients might be selectively misreported (Pryer, Vrijheid, Nichols, Kiggins, & Elliott, 1997; Rumpler et al., 2008). Besides, only two days of 24-HDR were used in our assessment while the inclusion of more than two days may be necessary to improve the use of this 24-HDR in the assessment of other nutrient intake distributions, particularly the infrequently consumed ones (Palaniappan, Cue, Payette, & Gray-Donald, 2003). The statistical adjustments performed with the MSM intended to remove the day-to-day variation in intakes and assess the usual distributions of intake. But, if the variance of the nutrient intake is not reliably estimated from two days of intake, then the observed intake may shrink too much or too little toward the group mean intake, resulting in an inaccurate usual intake distribution (Carriquiry, 2003). The use of food frequency questionnaires combined with 24-HDR may be an option in future monitoring surveys for the calculation of usual intakes of infrequently consumed nutrients, as more days of 24-HDR are demanding and expensive. Furthermore, the reliability of the conversion factors used to adjust urinary protein and potassium in our analyses can be questioned. With the assumption that subjects were in nitrogen balance, these factors have been based on rigorously controlled feeding studies (Bingham, S. A. & Cummings, 1985; Tasevska et al., 2006) and in the case of protein confirmed by Kipnis et al (2001). Lastly, we have collected data in The Netherlands six months before the other centres and this may have influenced the results. Nevertheless, while the data for the Netherlands were collected in spring/summer, the data for the other countries were collected in the winter/spring. However, since minor adjustments were done in the study protocols, and differences in the seasonality were small for protein and potassium intakes, it is unlikely that a different period influences the present results.

Conclusions

To conclude, first, the ability of the two non-consecutive standardized 24-HDR using EPIC-Soft software appears to be sufficiently valid for assessing and comparing the mean protein and potassium intake across the centres. When comparing populations in a future nutrition monitoring system, the variability in the nutrient biases of 4-7% across the centres needs to be considered. Second, the method seems to be sufficiently valid for assessing and comparing the protein and potassium inadequacy of healthy populations across the centres, and less appropriate to assess other points of the intake distribution. Third, the ability to rank the individuals according to protein and potassium intakes within the centres is comparable between them, which substantiates the validity of the method. Therefore, two non-consecutive 24-HDR, further adapted and validated in the EFCOVAL project, are appropriate for use in the context of a future pan-European dietary monitoring system. Built on EFCOVAL and EPIC experiences, improvements may be possible for the employment of this methodology standardization (e.g. conversion factors), which could result in an enhanced validity of the method, and thus comparability between the countries.

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Chapter 5
Reporting accuracy of population dietary sodium intake using duplicate 24-hour dietary recalls and a salt questionnaire

High dietary sodium intake is associated with multiple health risks. Therefore, accurate assessment of population sodium intake is critical. In this chapter, reporting accuracy of dietary sodium intake using the EPIC-Soft 24-h dietary recall (24HDR) is evaluated using 24-h urinary sodium excretions. Participants from a subsample of the EFCOVAL study (n= 365; countries: Belgium, Norway and Czech Republic), aged 45-65 years, delivered two 24-h urine collections and two 24HDR during the same period. Reporting accuracy was calculated as the ratio of reported sodium intake to that estimated from the urinary biomarker (24-h urinary sodium/0.9). A questionnaire on salt use was completed to assess discretionary table and cooking salt use. Two scenarios are reported, one using a salt adjustment procedure with data from the salt questionnaire and one without adjustment. Overall, reporting accuracy improved when data from the salt questionnaire was included into the analysis. Mean reporting accuracy (95% CI) was 0.67 (0.62, 0.72), 0.73 (0.68, 0.79), and 0.79 (0.74, 0.85) for Belgium (n= 123), Norway (n= 124) and Czech Republic (n= 118), respectively. Reporting accuracy decreased with increasing BMI among male subjects in all countries. For women from Belgium and Norway only, reporting accuracy was higher in those classified as obese [body mass index (in kg/m^2) >= 30]: 0.73 (0.67, 0.81) and 0.81 (0.77, 0.86), respectively. Findings from this study showed considerable underestimation of dietary sodium intake assessed with two 24-HDR using the EPIC-Soft version evaluated in EFCOVAL. The use of a salt adjustment procedure based on data from a questionnaire improved reporting accuracy; however, further development of both the questionnaire and the EPIC-Soft databases (e.g. inclusion of facet concerning salt content) is necessary to estimate population dietary sodium intakes accurately.

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Background

Current WHO guidelines strongly recommend a reduction in sodium intake to <2 g/day sodium (5 g salt/day) (WHO, 2012). There is conclusive evidence that sodium reduction reduces blood pressure (He & MacGregor, 2004; Dickinson et al., 2006; Dietary Guidelines Advisory Committee, 2010; Graudal, Hubeck-Graudal, & Jurgens, 2011). The relation between sodium consumption and the risk for cardiovascular disease and stroke is less clear than that for hypertension. One systematic review of RCTs found no relationship between sodium intake and cardiovascular disease (Taylor, Ashton, Moxham, Hooper, & Ebrahim, 2011), however, in a meta-analysis of 13 cohort studies it was concluded that there was a direct relationship between increased sodium consumption and subsequent risk of cardiovascular disease and stroke (Strazzullo, D'Elia, Kandala, & Cappuccio, 2009).

Data from the INTERMAP study show that sources of dietary sodium can vary considerable. For instance, processed foods contribute heavily to sodium intake in the Unites States and the United Kingdom (70-95%), whereas in China, most dietary sodium (76%) was from salt added during home cooking (Anderson et al., 2010). In another study, lithium was used as a marker to assess intake of household salt and showed that in a Danish population, median contribution of household salt was 8-10% of the total salt intake (Andersen, Rasmussen, Larsen, & Jakobsen, 2009).

Given the important health associated risks of high sodium intakes, monitoring of sodium consumption is essential and should be integrated in national surveillance programs. There is European consensus that two non-consecutive 24HDR using EPIC-Soft are the preferred method for population-level or group intake estimations (Brussaard et al., 2002). Although the methods to collect food consumption data have been improved over time, validation studies show that underestimation of protein (2-13%) and potassium (4-17%) intakes are present (see chapter 4) (Crispim, S. P. et al., 2011), however, bias is comparable across European countries (Crispim, S. et al., 2012). To date, the reporting accuracy of dietary sodium intake estimation using the EPIC-Soft 24HDR has not been assessed. Therefore, the objective of this chapter is to compare the estimated sodium intake from self-reported dietary recalls using EPIC-Soft with 24-h urinary sodium excretions. In addition, a salt adjustment procedure, using information from a questionnaire on discretionary salt use during food preparation or at the table, will be evaluated in terms of reporting accuracy also.

Methods

Design

The present study was performed as part of the European Food Consumption Validation (EFCOVAL) study which was completed in five European countries. The EFCOVAL Project aimed to further develop and validate the use of repeated 24-HDR using EPIC-Soft for the intake assessment of foods, nutrients and potentially hazardous chemicals for surveillance purposes relevant to health and safety policies in Europe (de Boer et al., 2011). For standardization purposes, all study procedures, i.e. on recruitment and fieldwork conditions, data processing formats, quality-control aspects and specimen collection, storage and transport details, were described in protocols. The fieldwork was performed from October 2007 to April 2008.

At the beginning of the study, the subjects had their body weight (kg) and height (cm) measured at the study centres before the first urine collection (wearing light clothes and no shoes). Then, a 24-h recall and a 24-h urine collection were obtained covering the same reference day. Subjects were aware of the days of data collection but not of the purpose of the interviews. The second recall and urine collection was obtained at least one month after the first one.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethical committees in each country involved in the data collection. Written informed consent was obtained from all subjects.

Subjects

The study group comprised a subsample of 365 healthy European adults (183 males and 182 females aged 45-65 y) participating in the European Food Consumption Validation (EFCOVAL) study. Data was collected in three European countries: Belgium, the Czech Republic, and Norway. In all countries, a convenience sample was recruited targeting equal numbers of men and women, and inclusion of subjects from lower, intermediate and higher educational levels. Exclusion criteria comprised use of diuretics, simultaneous participation in another study, pregnancy or lactation, having diabetes mellitus or a kidney disease. In addition, because of PABA administration during urine collections, use of sulphonamide-based antibiotics or acetaminophen painkillers (e.g. paracetamol) was not allowed and subjects hypersensitive to sulphonamides or PABA were also excluded.

Dietary sodium

Two 24-h recalls were collected using EPIC-Soft software (version 9.16). The structure and standardization procedure of EPIC-Soft have been described elsewhere (Slimani et al., 1999; Slimani et al., 2000). Briefly, EPIC-Soft is a computer-assisted dietary intake assessment tool that follows standardized steps when describing, quantifying, probing and calculating food intakes across countries (Slimani et al., 1999). A concept of facets (questions: e.g. source) and descriptors (answer options: e.g. cow, goat, sheep, pork, etc.) is used to describe the foods and recipes recalled during the 24-h recall interview. Two modes of administration were used: one by phone and one face-to-face at the centre. The order of administration mode and the day of the week were randomly allocated among the subjects. Interviewers in each centre were nutritionists or dietitians who were trained in interviewing skills and working with EPIC-Soft in the context of a validation study. All the participating countries had an existing version of EPIC-Soft available, except the Czech Republic for which a new country-specific version was developed. In addition, EPIC-Soft databases were adapted for each centre in terms of some common specifications for the EFCOVAL study (e.g., soups were treated as recipes rather than food items). Furthermore, the centres generated or updated a list of the single food items and recipes expected to be consumed by their participants. Modifications of such lists were needed afterwards based on notes made during the interview. It is noteworthy that the EPIC-Soft versions used in EFCOVAL did not include any particular questions regarding sodium content/intake (no facet was foreseen for salt content of foods/recipes).

The methods of estimation of portion size included household measures, weight/volume, standard units and portions, drawings of bread shapes and photographs. The set of photographs was developed in the context of the EPIC study (van Kappel, Amoyel, Slimani, Vozar, & Riboli, 1995). Each centre chose from the EPIC portfolio of photographs the pictures that best represented their national food habits. Given the absence of harmonized recent food composition tables (FCT) including all countries of our assessment, sodium contents in foods were calculated using country-specific FCT (NUBEL, 2004; MVT-06, 2006; NEVO-TABEL, 2006). In the Czech Republic, the national FCT was published about 20 years ago. Therefore, a FCT was compiled for EFCOVAL purposes in the Czech Republic with composition of most foods based on the Slovakian tables (Food Research Institute, 1997-2002). In all the centres, missing nutrient data for a food was imputed from a similar food or another FCT, based on country-specific decisions.

Two different approaches were used to calculate dietary sodium intake. First, sodium was calculated by using sodium concentrations reported in food composition tables, i.e., only sodium naturally present in foods or sodium added during food processing reported as such in the food composition tables is counted (SODIUM). Second, for culinary treated food items (e.g. meat, fish, potatoes, cooked vegetables), sodium contents were increased to reflect sodium levels of foods prepared using salt (SODIUMSALT). For Belgium, the amounts used for adding were extracted from the USDA database and for Czech Republic, local salt addition factors where available and used. Salt addition factors for Norwegian foods were not available and therefore not used in the present analysis.

EFCOVAL salt use questionnaire

Participants were requested to complete a short salt use questionnaire (see **addendum 4**) and asked whether they were on a low salt diet (yes/no), and if they usually use salt (a. No, salt is not used, neither during preparation of meals nor by adding salt during consumption/b. Yes, salt is added to meals during consumption, not during preparation of meals/c. Yes, salt is used during preparation of meals, no salt is added to meals during consumption/d. Yes, salt is used during preparation of meals and to meals during consumption). In addition, respondents were asked about the frequency of salt addition to their meals at the table (a. never/ b. occasionally/c. often/d. always).

Urinary sodium

All subjects were carefully instructed to keep two 24h urine collections according to a standardized protocol. Subjects were asked to urinate upon rising in the morning; this micturition was completely discarded and the time was registered. This time was taken as starting point of the 24-h urine collection. Subsequently, all urine produced during the next 24 hours was collected up to, and including, the first voiding of the following day. Subjects were provided a diary to register time of rising, medication use and possible deviations (e.g. missing urine) from the urine collection protocol. All urine voidings were stored in light protected recipients containing boric acid (3 g/2 L bottle) as a preservative. In order to verify completeness of urine collections, an 80 mg PABA tablet (PABAcheck, Laboratories for Applied Biology, London, United Kingdom) was taken three times over the day, orally during a meal. The underlying assumption to use PABA as a marker for detection of incomplete urine collections is that it is excreted almost quantitatively in 24 hours. Hence, we expected that approximately 240 mg of PABA would be present in every 24h urine sample (Bingham & Cummings, 1983). After one month, the same procedure was repeated so every subject yielded two 24h urine collections.

At the study centre urine samples were weighed and well mixed before aliquoting into 10 ml cryo-storage tubes. Aliquots were then frozen at -20°C until shipment on dry ice to a central laboratory, where they were kept at the same temperature. Analyses were performed according to standardized protocols and following high standards of quality control. On the day of chemical analysis, aliquots were rapidly thawed at room temperature. PABA was measured using the colorimetric diazocoupling method described by Bingham and Cummings (Bingham & Cummings, 1983). The method is based on total quantification of aromatic amines derived from PABA and its metabolites after alkaline hydrolysis. Sodium concentrations were determined by indirect potentiometry on a Synchron LX20 (Beckman Coulter, Fullerton, USA).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows (IBM Corp. Released 2011. Version 20.0. Armonk, NY: IBM Corp.). Because of methodological differences between countries in calculating dietary sodium intake, data is presented by country.

Reporting accuracy of dietary sodium intake is assessed using two scenarios. In the first scenario, no post-collection data processing step is applied with respect to salt addition. Therefore, individual values for SODIUM are aggregated to calculate total sodium intake. The second scenario presents reporting accuracy of sodium intake after salt adjustment based on the respondent's reply to a question about the use of salt during food preparation or at the table. For respondents that don't add salt to their food (answer option a), salt adjustment is not performed and total sodium values equal those from the first scenario. Respondents who indicated that usually salt is used during cooking (answer option d and e), total sodium intake is calculated by summing the values for SODIUMSALT. Finally, for respondents who indicated that in general, salt is added to their meal during consumption using a salt shaker (answer option b and e), a standard amount of sodium is added to reflect salt addition. The amounts of sodium added are based on the respondent's answer to the question on the frequency of salt added to meals (a. 0 mg/ b. 25mg/ c. 50mg and d. 100mg).

Dietary sodium intake (DRNA) and urinary sodium excretion (URNA) was log transformed to improve distribution toward normality. To account for serial correlations between individual subject dietary recalls and between individual urinary excretions, the sample within-subject variance and SD were estimated from a linear mixed model of dietary sodium intake and urinary sodium excretion with random intercepts and all fixed effects for up to 2 dietary recalls and urinary excretions. Within sex and country, 24-h sodium subgroup means and 95% CIs were estimated using the estimated marginal means subcommand. Logarithmic means and 95% CIs were back transformed to geometric means and 95% CIs on the original scale.

Reporting accuracy was calculated from subgroup geometric means as a ratio of dietary sodium to excreted urinary sodium (DRNA:URNA). The 95% confidence limits of the ratio were calculated by adding

$$\pm 1.96 \sqrt{\frac{\sigma^2_{wDRNA}}{d} + \frac{\sigma^2_{wURNA}}{d} - 2r\frac{\sigma^2_{wDRNA}\sigma^2_{wURNA}}{d}}$$

where σ_{wDRNA} is the within-subject SD for the log of 24-h dietary sodium intake, *d* is the number of days of dietary sodium intake, σ_{wURNA} is the within-subject SD for the log of urinary sodium, and *r* is the correlation between the log of dietary and urinary sodium (Rhodes et al., 2013).

Assuming independence for the two 24-h recalls and 2 urinary sodium measurements, σ_{wDRNA} and σ_{wURNA} can be estimated as one-half of the dietary sodium intake sample variance of ($\log_{DRNA1} - \log_{DRNA2}$) and half the urinary sodium excretion sample variance of ($\log_{URNA1} - \log_{URNA2}$), respectively, in a design with 2 dietary sodium intake DRNA (d = 2) and 2 urinary sodium excretion measurements per subject (Julious, 2004). On the original scale, the 95% confidence limits are given by the exponential of the limits on the log scale.

Results

Demographic characteristics of the sample (n=365) are presented in **Table 1**. Subjects were distributed evenly by sex and age; 57% were highly educated. A significant difference in education category across countries was present for women (Chi^2 13.204, df: 4; p=0.01). More women (58%) than men (29%) were considered normal weight (BMI in $kg/m^2 < 25.0$).

All participants collected their urine the first time; but two participants failed to perform the second collection. Urine samples with PABA recoveries <50% were treated as incomplete and excluded from the data analysis (n=9). As described before (Johansson, Bingham, & Vahter, 1999), specimens containing between 50 and 85% of PABA recovery (n=57) had their urinary concentrations proportionally adjusted to 93% of PABA recovery. Recoveries >85% were included in data analyses without adjustments (n=662).

Geometric means for sodium as measured by urinary biomarker and as self-reported from the EPIC-Soft 24-HDR are shown in **Table 2**. Mean dietary sodium, calculated by using individual subject means for the 2 recalls from Belgium, represented 61% and 59% of the mean sodium biomarker for men and women, respectively. For data from Norway, this was 75% and 70%, and for Czech Republic 67% and 66%, for men and women respectively. Reporting accuracy was higher after data was adjusted for salt intake during preparation and consumption of foods. Reporting accuracy increased by 7% for Belgium, 1% for Norway and 13% for Czech Republic.

Table 1: Demographic characteristics of the sample (n = 365)

		Belgium		Norway		Czech Republic	
		Men (*n* = 63)	Women (*n* = 60)	Men (*n* = 62)	Women (*n* = 62)	Men (*n* = 58)	Women (*n* = 60)
Age (years)	mean	54,5	54,9	54,1	53,7	55,0	54,8
	SD	5,5	5,0	5,9	6,0	6,9	6,1
Weight (kg)	mean	84,1	66,9	85,7	68,4	85,6	66,7
	SD	13,3	11,9	9,9	11,4	13,3	9,7
Height (cm)	mean	176	163	180	166	175	164
	SD	7,0	6,7	7,2	6,8	6,1	6,1
BMI (kg/m²)	mean	27,2	25,0	26,4	24,8	27,8	24,9
	SD	3,6	4,1	2,5	3,7	4,2	3,9
Age							
	45-54 y	46%	48%	50%	56%	50%	52%
	55-65y	54%	52%	50%	44%	50%	48%
Education							
	Low	16%	17%	3%	16%	21%	17%
	Intermediate	24%	25%	31%	19%	24%	47%
	High	60%	58%	66%	65%	55%	37%
BMI category							
	<25 kg/m², normal weight	27%	62%	29%	56%	31%	55%
	25-29.9 kg/m², overweight	56%	25%	63%	32%	41%	35%
	>=30 kg/m², obese	17%	13%	8%	11%	28%	10%
Salt use							
	No	26%	18%	6%	8%	2%	7%
	Only salt at table	9%	12%	6%	15%	0%	2%
	Only salt for preparation	57%	71%	49%	44%	69%	63%
	Both for preparation and at table	8%	0%	40%	33%	29%	28%

Some percentages do not total 100 because of rounding

Table 2: Daily sodium measured in male and female subjects according to country

	Belgium (*n* = 123)				Norway (*n* = 124)				Czech Republic (*n* = 118)			
	Men		Women		Men		Women		Men		Women	
	Geom. mean[1]	95% CI	Geom. mean[1]	95% CI	Geom. mean[1]	95% CI	Geom. mean[1]	95% CI	Geom. mean[1]	95% CI	Geom. mean[1]	95% CI
DRNA - SODIUM[2]												
Recall no. 1 (mg/d)	2904	2600 - 3245	2274	2028 - 2550	3585	3206 - 4009	2481	2218 - 2774	4141	3685 - 4652	2890	2580 - 3237
Recall no. 2 (mg/d)	2949	2640 - 3295	2458	2188 - 2761	3479	3106 - 3896	2356	2105 - 2637	4081	3632 - 4585	2936	2616 - 3295
Mean recall (mg/d)	2927	2676 - 3200	2365	2155 - 2595	3532	3226 - 3867	2418	2209 - 2646	4111	3742 - 4516	2913	2656 - 3194
DRNA - SODIUMSALT[3]		-		-		-		-		-		-
Recall no. 1 (mg/d)	3225	2904 - 3580	2576	2312 - 2870	3618	3256 - 4020	2524	2272 - 2805	4906	4395 - 5476	3470	3117 - 3862
Recall no. 2 (mg/d)	3256	2932 - 3615	2703	2422 - 3017	3512	3156 - 3909	2397	2156 - 2666	4840	4336 - 5402	3558	3191 - 3967
Mean recall (mg/d)	3240	2975 - 3529	2639	2414 - 2884	3564	3269 - 3887	2460	2256 - 2682	4873	4454 - 5331	3513	3217 - 3837
URNA[4]		-		-		-		-		-		-
Biomarker no. 1 (mg/d)	4507	4158 - 4886	3879	3570 - 4214	4924	4542 - 5338	3435	3169 - 3724	6203	5702 - 6748	4339	3997 - 4711
Biomarker no. 2 (mg/d)	5102	4709 - 5528	4076	3748 - 4433	4469	4118 - 4851	3494	3221 - 3791	6055	5566 - 6588	4508	4148 - 4900
Mean biomarker (mg/d)	4796	4484 - 5129	3976	3709 - 4263	4691	4383 - 5021	3465	3238 - 3708	6129	5712 - 6576	4423	4128 - 4739
Reporting accuracy[5]		-		-		-		-		-		-
SODIUM	0,61	0,57 - 0,66	0,59	0,55 - 0,64	0,75	0,70 - 0,81	0,70	0,65 - 0,75	0,67	0,62 - 0,72	0,66	0,61 - 0,71
SODIUMSALT	0,68	0,63 - 0,73	0,66	0,61 - 0,72	0,76	0,71 - 0,82	0,71	0,66 - 0,76	0,80	0,74 - 0,85	0,79	0,74 - 0,85

[1] Geometric mean (and 95% CIs) based on sex- and country-specific 24-h dietary recall or biomarker least-squares means and CI lower and upper limits generated by a linear mixed model for repeated measures.
[2] DRNA: dietary sodium intake; SODIUM: unadjusted sodium values.
[3] DRNA: dietary sodium intake; SODIUMSALT: adjusted for salt use based on salt questionnaire.
[4] URNA: urinary sodium excretion; calculated as 24-h urinary sodium divided by 0.9, with the assumption that 90% of sodium consumed is excreted in the urine.
[5] Ratio of sodium intake estimated from dietary recall to that estimated from biomarker (DRNA:URNA).

Table 3: Daily sodium measured in male and female subjects by BMI and country

	Belgium (*n* = 123)				Norway (*n* = 124)				Czech Republic (*n* = 118)			
	Men		Women		Men		Women		Men		Women	
BMI category	**Geom. mean[1]**	*95% CI*	**Geom. mean[1]**	*95% CI*	**Geom. mean[1]**	*95% CI*	**Geom. mean[1]**	*95% CI*	**Geom. mean[1]**	*95% CI*	**Geom. mean[1]**	*95% CI*
DRNA - SODIUMSALT[2]												
<25 kg/m², normal weight	3314	*2809 - 3911*	2594	*2317 - 2904*	3781	*3214 - 4448*	2413	*2149 - 2710*	4988	*4247 - 5859*	3523	*3128 - 3967*
25-29.9 kg/m², overweight	3393	*3023 - 3808*	2618	*2195 - 3122*	3516	*3152 - 3922*	2381	*2044 - 2773*	4719	*4093 - 5441*	3481	*2993 - 4050*
>=30 kg/m², obese	2702	*2199 - 3319*	2938	*2256 - 3827*	3210	*2341 - 4401*	2980	*2302 - 3857*	4969	*4190 - 5894*	3557	*2692 - 4701*
URNA[3]												
<25 kg/m², normal weight	4121	*3634 - 4674*	3749	*3442 - 4085*	4393	*3883 - 4970*	3287	*3442 - 4085*	5913	*5232 - 6682*	4036	*3688 - 4417*
25-29.9 kg/m², overweight	4910	*4498 - 5360*	4571	*3998 - 5226*	4801	*4418 - 5217*	3724	*3998 - 5226*	6053	*5433 - 6744*	4933	*4397 - 5534*
>=30 kg/m², obese	5670	*4838 - 6645*	4000	*3273 - 4889*	5029	*3957 - 6391*	3662	*3273 - 4889*	6496	*5706 - 7396*	5027	*4068 - 6213*
Reporting accuracy[4]												
<25 kg/m², normal weight	0,80	*0,74 - 0,87*	0,69	*0,64 - 0,74*	0,86	*0,80 - 0,93*	0,73	*0,68 - 0,79*	0,84	*0,79 - 0,90*	0,87	*0,82 - 0,93*
25-29.9 kg/m², overweight	0,69	*0,64 - 0,74*	0,57	*0,54 - 0,61*	0,73	*0,68 - 0,79*	0,64	*0,59 - 0,69*	0,78	*0,72 - 0,84*	0,71	*0,66 - 0,75*
>=30 kg/m², obese	0,48	*0,44 - 0,51*	0,73	*0,67 - 0,81*	0,64	*0,59 - 0,69*	0,81	*0,77 - 0,86*	0,76	*0,72 - 0,81*	0,71	*0,66 - 0,76*

[1] Geometric mean (and 95% CIs) based on sex-, country- and BMI-specific 24-h dietary recall or biomarker least-squares means and CI lower and upper limits generated by a linear mixed model for repeated measures.

[2] DRNA: dietary sodium intake; SODIUMSALT: adjusted for salt use based on salt questionnaire.

[3] URNA: urinary sodium excretion; calculated as 24-h urinary sodium divided by 0.9, with the assumption that 90% of sodium consumed is excreted in the urine.

[4] Ratio of sodium intake estimated from dietary recall to that estimated from biomarker (DRNA:URNA).

Reporting accuracy was highest among normal-weight subjects, except for women from Belgium and Norway where reporting accuracy was highest among obese subjects, as shown in **Table 3**. Among normal-weight subjects (BMI <25 kg/m²), reporting accuracy in Belgium and Norway was higher for men compared to women (0.80 and 0.69; 0.86 and 0.73 respectively). For Czech Republic, reporting accuracy was similar for normal-weight men and women, 0.84 and 0.87 respectively. No consistent differences were found between educational level and reporting accuracy by country and gender (data not shown).

The male and female subjects were classified into tertiles of urinary sodium excretion (mg/d) per MJ of dietary energy intake. Arithmetic means, standard deviations, medians en tertiles are presented in **Table 4.** Median energy-adjusted sodium excretion is higher for women compared to men in Belgium and Czech Republic; 476 mg/MJ and 432 mg/MJ (Belgium); 569 mg/MJ and 538 mg/MJ Norway) for women and men, respectively.

Table 4: Energy-adjusted sodium excretion of the subjects by gender and country

	Belgium		Norway		Czech Republic	
Sodium excretion (mg/MJ)[1]	Men (*n* = 63)	Women (*n* = 60)	Men (*n* = 62)	Women (*n* = 62)	Men (*n* = 58)	Women (*n* = 60)
Mean	484	515	457	456	597	602
SD	211	212	236	182	275	233
Median	432	476	410	411	538	569
1st Tertile	379	419	354	350	473	474
2nd Tertile	531	533	484	505	650	676

[1] Tertiles of urinary sodium (mg/d) per MJ of dietary energy intake estimated from EPIC-Soft 24-h recall.

Sodium measurements and reporting accuracy for tertiles of energy-adjusted sodium excretion are shown in **Table 5**. For subjects among the lowest tertile of sodium/MJ, reporting accuracy was highest in all genders and countries. For subjects from Czech Republic with low sodium excretion per MJ, reporting of dietary sodium intake was overestimated by 22% to 24% for men and women, respectively.

Table 5: Daily sodium measured in male and female subjects by tertile of energy-adjusted sodium intake and country

		Belgium (*n* = 123)				Norway (*n* = 124)				Czech Republic (*n* = 118)			
		Men		Women		Men		Women		Men		Women	
	tertile URNA/MJ[1]	Geom. mean[2]	95% CI	Geom. mean[2]	95% CI	Geom. mean[2]	95% CI	Geom. mean[2]	95% CI	Geom. mean[2]	95% CI	Geom. mean[2]	95% CI
DRNA - SODIUMSALT[3]													
	t1	3268	*2896 - 3687*	2811	*2441 - 3237*	3846	*3422 - 4324*	2686	*2389 - 3020*	6674	*5610 - 7939*	3843	*3235 - 4564*
	t2	3379	*2945 - 3875*	2574	*2285 - 2901*	3558	*3115 - 4063*	2407	*2081 - 2784*	4513	*3962 - 5141*	3830	*3333 - 4401*
	t3	3067	*2677 - 3514*	2558	*2203 - 2972*	3077	*2612 - 3625*	2160	*1859 - 2510*	4525	*4007 - 5109*	3229	*2887 - 3612*
URNA[4]													
	t1	3850	*3573 - 4150*	3077	*2822 - 3355*	3720	*3460 - 4000*	2854	*2653 - 3070*	5375	*4835 - 5976*	3150	*2836 - 3500*
	t2	4975	*4573 - 5413*	3969	*3686 - 4274*	5091	*4690 - 5526*	3670	*3354 - 4015*	5527	*5100 - 5989*	4071	*3739 - 4433*
	t3	6268	*5766 - 6813*	5267	*4804 - 5774*	6611	*5975 - 7314*	4578	*4174 - 5022*	7082	*6568 - 7636*	5270	*4914 - 5651*
Reporting accuracy[5]													
	t1	0,85	*0,78 - 0,92*	0,91	*0,85 - 0,98*	1,03	*0,96 - 1,11*	0,94	*0,88 - 1,00*	1,24	*1,18 - 1,31*	1,22	*1,15 - 1,30*
	t2	0,68	*0,63 - 0,73*	0,65	*0,61 - 0,69*	0,70	*0,66 - 0,74*	0,66	*0,62 - 0,69*	0,82	*0,77 - 0,87*	0,94	*0,88 - 1,00*
	t3	0,49	*0,46 - 0,52*	0,49	*0,46 - 0,52*	0,47	*0,44 - 0,50*	0,47	*0,44 - 0,50*	0,64	*0,60 - 0,68*	0,61	*0,58 - 0,65*

[1] Tertiles of urinary sodium (mg/d) per MJ of dietary energy intake.
[2] Geometric mean (and 95% CIs) based on sex-, country- and tertile of energy-adjusted sodium intake-specific 24-h dietary recall or biomarker least-squares means and CI lower and upper limits generated by a linear mixed model for repeated measures.
[3] DRNA: dietary sodium intake; SODIUMSALT: adjusted for salt use based on salt questionnaire.
[4] URNA: urinary sodium excretion; calculated as 24-h urinary sodium divided by 0.9, with the assumption that 90% of sodium consumed is excreted in the urine.
[5] Ratio of sodium intake estimated from dietary recall to that estimated from biomarker (DRNA:URNA).

Discussion

The present study is the first to investigate reporting accuracy of dietary sodium estimated by the EPIC-Soft guided 24-HDR method which did not specifically ask for salt contents or use. Since 24-h urine collections were provided during the EFCOVAL–study, analysis of urinary sodium excretion provided a unique opportunity to assess reporting accuracy of dietary sodium intake. It is worth mentioning that at the time the EFCOVAL study was performed, sodium was not a nutrient of interest, hence, procedures to link sodium to foods and recipes were different across participating countries. Nevertheless, although it was not the intention to assess dietary sodium intake a priori, the available data is scientifically very interesting to explore and to allow further optimizations of the dietary intake assessment methods under study.

Reporting accuracy of dietary sodium intake without salt adjustment (SODIUM scenario) tended to be lowest for Belgium and highest for Czech Republic. This is probably because in the Belgian version of EPIC-Soft, no salt is added to composite meals. Only in recipes of soups, the sodium present in stock cubes is taken into account. All other recipes and composite meals are treated as if no salt is added. The EPIC-Soft version of Czech Republic has salt included in standard recipes; therefore, dietary sodium intake estimations are higher and closer to urinary sodium excretion resulting in higher reporting accuracy.

The salt adjustment procedure used information from the salt questionnaire to take into account discretionary use of cooking or table salt (SODIUMSALT scenario). The salt adjustment procedure improved reporting accuracy among subjects from both Belgium and Czech Republic. Only 1% increase in reporting accuracy was found for Norway. This can be explained because, for Norwegian data, no salt addition factors were available for culinary treated food items. Since 89% and 77% of Norwegian men and women, respectively, reported to use salt during cooking, a considerable part of the Norwegian sample should have had their sodium intake being increased during the salt adjustment procedure. From the Norwegian data it can also be concluded that the correction of sodium intake based on the question of table salt use only minimally improves reporting accuracy by 1%. Therefore, in future analysis, the effect of higher standard amounts of sodium added to reflect discretionary table salt use should be investigated. Nevertheless, it is believed that the contribution of household salt to total salt intake is limited. In a Danish study using a lithium-marker technique, Andersen et al. (2009) found that the median contribution of household salt was 8-10% of total salt intake.

Sodium intake is highly correlated with energy intake; however, because discretionary table and cooking salt is not included in the EPIC-Soft 24-HDR and no salt-facet was foreseen in the EFCOVAL versions of EPIC-Soft, a lower reporting accuracy for sodium might be expected. A previous study has indicated that extreme energy underreporting is present in men and women; 10% en 14% respectively (Ferrari et al., 2002). On average, men and women underreport protein intake from the two 24-h recalls by 8% (Crispim, S. et al., 2012). When urinary sodium excretion was adjusted for dietary energy intake, it was found that reporting accuracy was highest among those subjects from the lowest tertile, in all countries and both sexes. Therefore, it can be concluded that as sodium density of a daily diet increases, reporting accuracy of sodium decreases. Sodium intake was overestimated by 22% and 24% of Czech Republic males and females among the lowest tertile of urinary sodium per MJ of energy intake. When the SODIUM scenario was used, reporting accuracy was 1.10 and 0.98 for men and women respectively (data not shown). Further analysis of salt addition factors for culinary treated foods revealed that these factors were considerably higher in Czech Republic compared to those used in Belgium. It is assumed that these higher addition factors are responsible for the large overestimation of sodium intake among subjects of the lowest tertile of urinary sodium per MJ of energy intake.

In a study of 465 American subjects aged 30-69 years, the overall reporting accuracy of dietary sodium intake using the Automated Multiple-Pass Method (AMPM) compared to 24-h urinary excretion was 0.93 for men and 0.90 for women (Rhodes et al., 2013). Larger underestimation of sodium intake was found with increasing BMI. Among normal-weight subjects, sodium was accurately reported in both genders.

The sample of the present study was highly motivated, only two subjects failed to collect their second urine sample. PABA was used to verify completeness of urine collections. Based on the recovery of PABA, only 1% was treated as incomplete (PABA recovery below 50%) and 8% of collections were proportionally adjusted to 93% of PABA (50% < PABA recovery < 85%). When proportionally adjusted collections were excluded from the analysis, overall reporting accuracy did not differ from that reported.

The correction factor used for estimating sodium intake from 24h-urine collections should be taken into account when results of this study are interpreted. Since the fieldwork of the urine collections was during winter, a correction factor of 90% was chosen. Holbrook and colleagues have shown that seasonal variation in urinary sodium excretion is present probably associated with sweating (Holbrook et al., 1984). In the study performed by Rhodes et al. (2013), a correction factor of 86% was used, other studies have used 95% (Vandevijvere et al., 2010). The use of other correction factors or, no correction factor, would influence the magnitude of misreporting.

Dietary sodium intake is challenging to assess in free-living individuals due to its high day-to-day variation, and, its diversity in sources (naturally present, added by the industry or discretionary salt use at home) and varying sodium (salt) content over time. Indeed, sodium reduction intervention plans have led to considerable commitment of the food industry to lower the sodium content of processed foods. Consequently, the large diversity of foods available on the food market and the change of sodium content due to reformulation of foods require a continuous updating of food composition databases.

Conclusions

The present study shows considerable underestimation of dietary sodium intake both at population and group level when using the EPIC-Soft 24-h recall versions that do not include any specific questions regarding salt content/use. The salt adjustment procedure presented here increased reporting accuracy, however, not to satisfying levels. Given that during the EPIC-Soft guided 24-h dietary recall, discretionary use of table or cooking salt is not assessed and not salt-facet was foreseen, the low reporting accuracy is not surprising. Reporting accuracy tended to be highest in Czech Republic with considerable overestimation of sodium intake among subjects with low urinary sodium excretion per MJ of energy intake. Data from Belgium showed lowest reporting accuracy. Therefore, inclusion of salt use in composite meals and recipes should be considered in future. Finally, in order to accurately estimate population dietary sodium intake, using the EPIC-Soft 24-HDR method, future development of facets and descriptors related to discretionary salt use is necessary.

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Chapter 6
Predicting urinary creatinine excretion and its usefulness to identify incomplete 24-h urine collections

Studies using 24-h urine collections need to incorporate ways to validate the completeness of the urine samples. Models to predict urinary creatinine excretion (UCE) have been developed for this purpose, however, information on their usefulness to identify incomplete urine collections is limited. The aim of this chapter is to develop a model for predicting UCE and to assess the performance of a creatinine index using *para*-Aminobenzoic acid (PABA) as a reference. Data was taken from the EFCOVAL study comprising two non-consecutive 24-h urine collections from 600 subjects in five European countries. Data from one collection was used to build a multiple linear regression model to predict UCE, and data from the other collection was used for performance testing of a creatinine index-based strategy to identify incomplete collections. Multiple linear regression (n= 458) of UCE showed a significant positive association for body weight (β= 0.07), the interaction term gender*weight (β= 0.09, ref women), and protein intake (β= 0.02). A significant negative association was found for age (β= -0.09) and gender (β= -3.14, ref women) (adjusted r^2= 0.76). An index of observed to predicted creatinine resulted in a sensitivity to identify incomplete collections of 0.06 (95% CI: 0.01-0.20) and 0.11 (95% CI: 0.03-0.22) in men and women, respectively. Specificity was 0.97 (95% CI: 0.97-0.98) in men and 0.98 (95% CI: 0.98-0.99) in women. The present study shows that UCE can be predicted from weight, age and gender. However, the results revealed that a creatinine index based on these predictions is not sufficiently sensitive to exclude incomplete 24-h urine collections.

Chapter based on:

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Part of this work was presented at the 2nd World congress of Public Health Nutrition & the 1st Latin American congress of Community Nutrition in Porto, Portugal, September 2010.

Background

When biomarkers from 24-h urine collections are used in validation studies of dietary assessment methods or in clinical investigations, it is clearly inappropriate to use incomplete urine collections since this may result in systematic bias and an underestimate of excretion rates (Williams & Bingham), 1986. Currently, two markers are available to check for a complete urine collection; urinary creatinine excretion (UCE) and *para*-Aminobenzoic acid (PABA).

The use of creatinine as a check on the completeness of 24-h urine collections is based on the assumption that excretion per kg body mass is constant (Bingham & Cummings, 1985). Nevertheless, by progressing age, total body potassium reflecting metabolically active body tissue has been shown to decline indicating loss of lean body mass (Driver & McAlevy, 1980). Furthermore, cooked meat contains creatine and creatinine which increases UCE (Bingham & Cummings, 1985), and, since arginine and glycine are amino acid precursors of creatinine, protein-rich foods are able to influence UCE (Gibson, 2005).

In the past decades, scientific disagreement has been reported on the appropriateness of UCE to serve as a marker for identifying incomplete urine collections (Edwards, Bayliss, & Millen, 1969; Bingham & Cummings, 1985; Knuiman et al., 1986; Williams & Bingham, 1986; Remer, Neubert, & Maser-Gluth, 2002; Murakami et al., 2008). Furthermore, different strategies for excluding urine samples based on creatinine excretion have been published (Joossens & Geboers, 1984; WHO, 1984; Malekshah et al., 2006; Reinivuo, Valsta, Laatikainen, Tuomilehto, & Pietinen, 2006; Murakami et al., 2008). One strategy to exclude specimens is based on the ratio of observed over expected UCE (creatinine index) (Joossens & Geboers, 1984). Expected UCE ($mg \cdot d^{-1}$) is derived from the observed weight of the person and calculated as: body weight (kg) x 24 (males) or 21 (females) (Joossens & Geboers, 1984). According to Joossens & Geboers, urine collections with a creatinine index falling outside the range of 0.6-1.4 should be discarded.

Because some investigators argued that creatinine excretion is not a reliable marker to detect incomplete urine collections, due to its large day-to-day variation (Edwards, Bayliss, & Millen, 1969), use of the exogenous marker PABA has been proposed (Bingham, S. & Cummings, 1983). As PABA is actively absorbed and rapidly and completely excreted in urine, it is suitable to verify completeness of urine collections based on the simple principle of an expected minimal PABA recovery in sampled urine (Bingham, S. A., 2003).

Currently, there is no recent data available on creatinine excretion in a large European sample, nor on its potential value to serve as a marker for detection of incomplete urine collections. Also, models to predict UCE have been published before, although, information on their performance to correctly identify incomplete urine samples is limited.

The objective of the present chapter is, firstly, to develop a multiple linear regression model which is able to predict UCE using readily available subject information and, secondly, to investigate the suitability of UCE as a marker for identifying incomplete 24h urine collections using PABA as a reference.

Methods

Subjects

The study group comprised 600 healthy European adults (297 males and 303 females aged 45-65 y) participating in the European Food Consumption Validation (EFCOVAL) study. Data was collected in five European countries: Belgium, the Czech Republic, France (Southern part), the Netherlands and Norway. In all countries, a convenience sample was recruited targeting equal numbers of men and women, and inclusion of subjects from lower, intermediate and higher educational levels. Exclusion criteria comprised use of diuretics, receiving diet therapy, simultaneous participation in another study, pregnancy or lactation, having diabetes mellitus or a kidney disease and donation of blood or plasma during (or less than four weeks prior) the study. In addition, because of PABA administration during urine collections, use of sulphonamide-based antibiotics or acetaminophen painkillers (e.g. paracetamol) was not allowed and subjects hypersensitive to sulphonamides or PABA were also excluded.

Urine collections

All subjects were carefully instructed to keep two 24h urine collections according to a standardized protocol. Days of urine collection were randomly assigned, though with a time interval of at least four weeks between the two collections. Subjects were asked to urinate upon rising in the morning; this micturition was completely discarded and the time was registered. This time was taken as starting point of the 24-h urine collection. Subsequently, all urine produced during the next 24 hours was collected up to, and including, the first voiding of the following day. Subjects were provided a diary to register time of rising, observations (e.g. use of medication) and possible deviations (e.g. missing urine) from the urine collection protocol. All urine voidings were stored in light protected recipients containing boric acid (3 g/2 L bottle) as a preservative. In order to verify completeness of urine collections, an 80 mg PABA tablet (PABAcheck, Laboratories for Applied Biology, London, United Kingdom) was taken three times over the day, orally during a meal. The underlying assumption to use PABA as a marker for detection of incomplete urine collections is that it is excreted almost quantitatively in 24 hours. Hence, we expected that approximately 240 mg of PABA would be present in every 24h urine sample (Bingham, S. & Cummings, 1983). After one month, the same procedure was repeated so every subject yielded two 24h urine collections. Subjects' body weight (kg) and height (cm) was measured at the study centres before the first urine collection (wearing light clothes and no shoes). This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethical committees in each country involved in the data collection. Written informed consent was obtained from all subjects.

Quantification of urinary analytes

At the study centre, urine samples were weighed and well mixed before aliquoting into 10 ml cryo-storage tubes. Aliquots were then frozen at -20°C until shipment on dry ice to the central laboratory at Wageningen University (the Netherlands), where they were kept at the same temperature. On the day of chemical analysis, aliquots were rapidly thawed at room temperature. PABA was measured using the colorimetric diazocoupling method described by Bingham and Cummings (Bingham, S. & Cummings, 1983). The method is based on total quantification of aromatic amines derived from PABA and its metabolites after alkaline hydrolysis. Urinary creatinine concentrations were measured at 520 nm on a Synchron LX20 (Beckman Coulter, Fullerton, USA) using a commercial kit which is a modification of the kinetic Jaffé procedure (Cook, 1975).

Stability of PABA in urine was verified by storing urine samples of three participants at four different temperatures (-20, 6, 20 and 30°C) for 8 d. PABA concentrations were measured at five moments (days 0, 1, 2, 4 and 7). No significant changes in PABA concentrations were observed during the storage period at each temperature. In addition, previous studies have shown that in all but extreme cases (e.g. storage at 55°C for 30 days), urinary creatinine is virtually unaffected by storage time and temperature in both acidified as in unpreserved urine samples (Spierto, Hannon, Gunter, & Smith, 1997; Miki & Sudo, 1998).

Dietary data

Two 24-h recalls (24-HDR) were collected using EPIC-Soft software (version 9.16). The structure and standardization procedure of EPIC-Soft have been described elsewhere (Slimani et al., 1999; Slimani et al., 2000). Briefly, EPIC-Soft is an assisted dietary tool that follows standardized steps when describing, quantifying, probing and calculating food intakes across countries (Slimani et al., 1999). Dietary recalls followed a randomized schedule, which included all days of the week. Protein intake was calculated using mainly the country-specific Food composition tables (FCT) and missing information from a food was gathered from another similar food or another FCT. The protein coverage of national FCT was 100% for all foods reported.

Statistical analysis

A stepwise regression approach was used for developing and validating a model for creatinine prediction. Data from the second urine collection was used for model development, and data from the first collection for model validation. The first collection was chosen to validate the model because this corresponds with data that is available if only one urine collection would be performed. When the first urine collection was used for model development, results did not differ significantly from those presented here.

First, multiple regression with UCE from the second urine collection as dependent variable was performed. The independent variables age, gender, weight, height and an interaction term gender*weight were entered in the model. The interaction term was included because regression of weight to UCE showed different slopes for both genders. Because protein-rich foods are able to influence UCE, mean protein intake derived from the dietary intake data was also included as explanatory variable. Only cases with complete urine collections according to PABA recovery ≥ 85% were used to develop a model for predicting UCE. Cook's distance and studentized residuals were used to analyze residuals and to assess the influence of outliers.

Second, the predictive ability of the model was evaluated. Therefore, expected UCE was calculated for every participant by using the regression equation of the model. The standard error of the model was used to calculate 95% CI around predicted UCE. Next, the percentage of actual values for UCE from collection one that were located within 95% CI of the predicted UCE was calculated.

Subsequently, the suitability of creatinine to serve as a marker for identifying incomplete urine collections was investigated. Therefore, the performance of the ratio observed over expected UCE was tested using PABA recovery as a reference. Two ratios were calculated and compared. For one, expected UCE was body weight-derived as proposed by Joossens & Geboers (Joossens & Geboers, 1984). In the second ratio, expected UCE was derived from the regression equation of the final regression model. For both ratios, collections were classified as incomplete using the cut-off by Murakami *et al.* (Murakami et al., 2008) (creatinine index < 0.7 = incomplete collection). Finally, sensitivity was calculated as the proportion of participants with incomplete urine collections correctly classified, and specificity as the proportion of participants with complete urine collections correctly classified. For comparison of groups, the likelihood ratio of a positive test was also calculated (sensitivity/(1-specificity)). For all figures, 95% CI are reported.

Results

Participant characteristics are listed in **Table 1**. The mean (SD) age of the participants was 55.2 (5.7) years for men and 54.7 (5.8) years for women. Mean (SD) BMI was 26.7 (3.5) and 24.7 (4.1) for men and women, respectively. In men, 34% of the participants had a BMI below 25 kg/m², and in women this was 61%. All participants (n= 600) collected their urine the first time. Two participants failed to perform the second collection. Diaries were analysed to inventory deviations from the urine collection protocol. Four and ten participants reported not having taken all three PABA tablets during collection one and two, respectively. Prohibited medication intake during urine collection one and two was reported by two and six participants, respectively. During collection one and two, respectively 54 and 58 participants reported that not all urine could be collected. Finally, in three urine specimens (two from collection one; one from collection two) creatinine could not be determined.

Table 1: Characteristics of participants

	Men (*n*= 297)				Women (*n*= 303)			
	Mean	SD	n	%	Mean	SD	n	%
Age *(years)*	55.2	5.7			54.7	5.8		
Weight *(kg)*	83.6	12.5			67.0	11.9		
Height *(cm)*	177	7.5			165	7.4		
BMI *(kg/m²)*	26.7	3.5			24.7	4.1		
BMI category								
<25 kg/m²			100	34			185	61
25-29.9 kg/m²			151	51			89	29
>=30 kg/m²			46	15			29	10
Educational level								
Low			50	17			66	22
Intermediate			73	24			96	32
High			174	59			141	47

Table 2: Characteristics of urine collections*

	Urine collection															
	First								Second							
	Men (*n*= 278)				Women (*n*= 263)				Men (*n*= 267)				Women (*n*= 261)			
	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%
Total urine volume (*mL/d*)	2114	849			2336	911			2105	817			2313	944		
Reported collection time (*h*)	23.9	1.1			23.9	1.1			23.9	1.0			24.0	0.7		
Urinary PABA (*mg/d*)	245.2	28.0			239.5	30.9			240.3	39.0			234.5	37.0		
PABA recovery (%)	102.2	11.7			99.6	13.2			100.1	16.2			98.0	15.6		
< 85%			18	6.5			19	7.2			26	9.7			36	13.8
>= 85%			260	93.5			244	92.8			241	90.3			225	86.2
Urinary creatinine (*mmol/L*)	8.6	3.6			5.0	2.5			8.5	3.6			5.0	2.3		
Total urinary creatinine (*mmol/d*)	15.7	3.2			9.9	1.9			15.6	3.3			9.9	2.0		
Urinary creatinine to body weight (*mg/kg*)	21.4	3.6			17.1	3.2			21.2	3.6			17.1	3.5		

PABA; para-aminobenzoic acid

*Only collections that fully complied with the protocol are presented (total n_{first}= 541, total n_{second}= 528)

Taking all deviations from the first and second urine collection and analysis protocol into account, respectively 541 (90.2%) and 528 (88.3%) specimens were available for data analysis. Mean self-reported collection time was close to 24 h (23.9 h for men during both collections, 23.9 h and 24.0 h during first and second collection for women) (**Table 2**). PABA recovery was proximate to 100% (range of means (SD): 98.0 (15.6) % to 102.2 (11.7) %). 86.2% (women during second urine collection) to 93.5% (men during first urine collection) of PABA recoveries had values equal to or above 85%. Mean weight-adjusted creatinine excretion was 21 mg/kg in men and 17 mg/kg in women.

For the prediction of UCE, the multiple regression model showed a significant positive association for the interaction term gender*weight (β= 0.09, *P* <0.001, ref women), weight (β= 0.07, *P* <0.001) and protein intake (β= 0.02, *P* <0.001). A significant negative association was found for age (β= -0.09, *P* <0.001) and gender (β= -3.14, *P* = 0.006, ref women) (**Table 3**). The variables in the model explained more than three-quarter (adjusted R^2= 0.76) of the variance in predicted UCE with a correlation coefficient of 0.87. The standard error of the estimate was 1.884 mmol/d. UCE values from seven participants were identified as outlier and excluded before model development, and from one participant no dietary intake data was available (n= 458).

Table 3: Model coefficients of multiple linear regression

	β				
UCE (mmol/d)†	β	SE	95% CI		*P*
Constant	9.36	1.132	7.136	11.585	<0.001
Gender‡	-3.14	1.141	-5.377	-0.892	0.006
Weight (kg)	0.07	0.011	0.048	0.093	<0.001
Gender*Weight	0.09	0.015	0.058	0.118	<0.001
Age (years)	-0.09	0.015	-0.123	-0.063	<0.001
Protein (g/d)	0.02	0.003	0.009	0.021	<0.001

UCE; Urinary Creatinine Excretion
Model based on data from second urine collection. Only collections that fully complied with the protocol and PABA recoveries equal to or above 85% were included. Seven cases were identified as outliers based on studentized residuals and Cook's distance and excluded from the model.
† Model summary: R 0.87, Adj. R^2 0.76, SE estim. 1.884 mmol/d, n= 458
‡ Gender = 0 for females, 1 for males

When UCE measurements from the first collection were compared to the predicted UCE using the regression equation, 93.5% of the measurements fell within the 95% CI of the prediction.

Table 4: Number of participants with incomplete and complete 24-h urine collections by PABA and two test strategies, and sensitivity, specificity and positive likelihood ratio of both test strategies for identifying incomplete 24-h urine collections

		Completeness of 24-h urine collection by PABA											
		Incomplete		Complete									
		Completeness of 24-h urine collection by test strategy		Completeness of 24-h urine collection by test strategy									
Test strategy		Incomplete	Complete	Incomplete	Complete	n	Sensitivity	(95% CI)	Specificity	(95% CI)	LR+	(95% CI)
Murakami *et al.* (10) *												
	all	18	19	61	443	541	0.49	(0.34-0.63)	0.88	(0.87-0.89)	4.0	(2.6-5.7)
	male	6	12	15	245	278	0.33	(0.17-0.53)	0.94	(0.93-0.96)	5.8	(2.5-11.9)
	female	12	7	46	198	263	0.63	(0.42-0.80)	0.81	(0.80-0.83)	3.4	(2.1-4.6)
Regression model †												
	all	3	34	11	493	541	0.08	(0.03-0.17)	0.98	(0.97-0.99)	3.7	(1.1-11.6)
	male	1	17	7	253	278	0.06	(0.01-0.20)	0.97	(0.97-0.98)	2.1	(0.3-11.7)
	female	2	17	4	240	263	0.11	(0.03-0.22)	0.98	(0.98-0.99)	6.4	(1.4-28.3)

PABA; para-aminobenzoic acid, LR+; Likelihood Ratio of a Positive test

* Participants with a value for (urinary creatinine [mg·d^{-1}]/(G x body weight [kg]) of <0.7 were identified as having incomplete urine collections. G = 21 for females and 24 for males.

† Ratio observed/expected urinary creatinine excretion. Expected urinary creatinine excretion was calculated as (9.36 - 3.14·gender + 0.07 weight + 0.09·gender*weight - 0.09·age + 0.02·protein intake). Participants with a ratio <0.7 were identified as having incomplete urine collections.

Sensitivity and specificity of UCE and the likelihood ratio of a positive test for identification of incomplete urine collections are reported in **Table 4** using different ratios. First, the performance of the strategy proposed by Murakami *et al.* (Murakami et al., 2008) is presented. When a cut-off of 0.7 was used for the creatinine index, sensitivity and specificity (95% CI) was respectively 0.49 (0.34-0.63) and 0.88 (0.84-0.89). For females, sensitivity was higher (0.63) and specificity lower (0.81) compared to the total group. In males, sensitivity was markedly lower (0.33) and specificity slightly higher (0.94) compared to total group figures. The overall likelihood of an incomplete urine collection was increased four-fold given a positive test result (5.8 and 3.4 for males and females respectively). Second, the estimated UCE was calculated using the regression equation and the same cut-off for detection of incomplete urine collections was used. Overall, sensitivity was very low (0.08) and specificity almost excellent (0.98).

Explorations of other cut-offs accompanied with their respective measures for sensitivity, specificity and positive likelihood ratios are presented in **Table 5**. Finally, **Figure 1** shows a scatter plot from observations for PABA recoveries and ratios of observed to predicted creatinine. Both cut-offs for detection of incomplete urine collections by PABA and creatinine ratio are indicated by a horizontal and vertical line respectively. The large scatter shows that shifting the cut-off of the ratio observed over expected creatinine to right (i.e. using a higher cut-off) will lead to an important increase of false positive results.

Table 5: Sensitivity, specificity and positive likelihood ratios from a range of cut-offs from observed to expected creatinine calculated by the regression model*

		All			Male			Female	
Cut-off	SE	SP	LR+	SE	SP	LR+	SE	SP	LR+
0.50	0.00	1.00	0.0	0.00	1.00	0.0	0.00	1.00	-
0.55	0.00	0.99	0.0	0.00	0.99	0.0	0.00	1.00	0.0
0.60	0.05	0.99	6.8	0.00	0.99	0.0	0.05	1.00	12.8
0.65	0.05	0.99	4.5	0.00	0.98	0.0	0.11	1.00	25.6
0.70	0.08	0.98	4.5	0.06	0.97	0.0	0.11	0.98	12.8
0.75	0.22	0.97	6.8	0.17	0.97	5.4	0.26	0.97	8.0
0.80	0.38	0.93	5.6	0.33	0.93	4.8	0.42	0.94	6.8
0.85	0.49	0.87	3.9	0.39	0.88	3.3	0.58	0.87	4.4
0.90	0.65	0.77	2.8	0.56	0.81	2.9	0.74	0.73	2.7
0.95	0.81	0.61	2.1	0.78	0.62	2.1	0.84	0.60	2.1
1.00	0.89	0.47	1.7	0.94	0.49	1.9	0.84	0.45	1.5
1.05	0.95	0.33	1.4	0.94	0.34	1.4	0.95	0.32	1.4
1.10	0.97	0.22	1.3	0.94	0.22	1.2	1.00	0.23	1.3

* Regression equation of the model: expected urinary creatinine excretion [mg·d-1] = 9.36 - 3.14·gender + 0.07 weight + 0.09·gender*weight - 0.09·age + 0.02·protein intake (gender: male = 1, female = 0; weight (kg); age (years); protein intake (g/d)).SE; Sensitivity, SP; Specificity, LR+; Likelihood Ratio of a Positive test

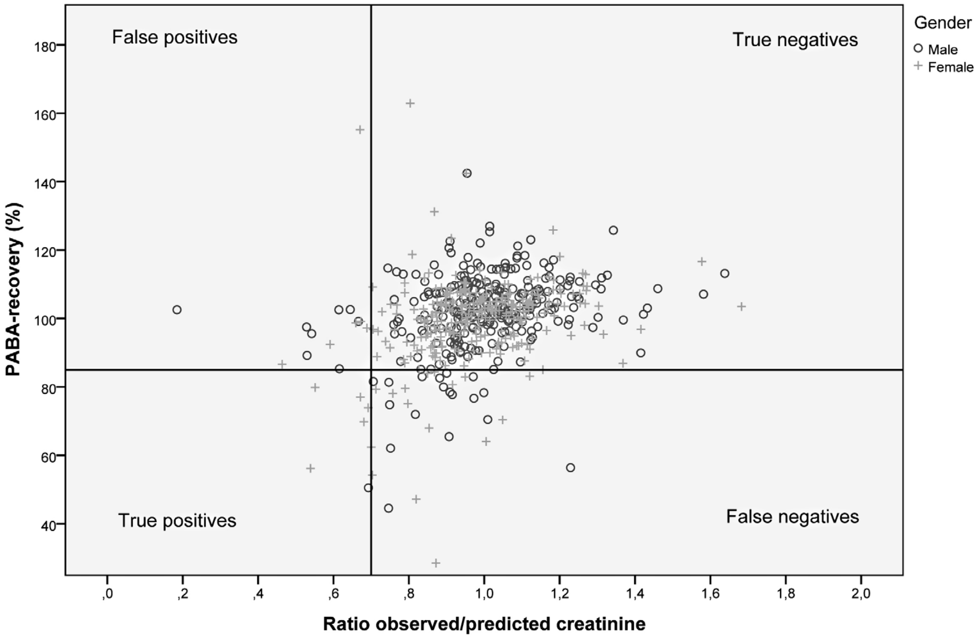

Figure 1 - Comparison of PABA-recovery and creatinine ratio cut-offs in their ability to identify incomplete urine collections in our sample of 541 adults. Horizontal line marks 85% PABA-recovery, vertical line represents the cut-off for ratio of observed to predicted creatinine <0.7 from Murakami et al. (2003)

Discussion

In the present study, measures from duplicate 24-h urine collections are used to develop a prediction model for estimating urinary creatinine excretion on one hand and to test the performance of urinary creatinine to serve as an indicator for detecting incomplete urine collections on the other hand. For the latter, PABA is used as a reference and is assumed to correctly identify incomplete urines. The model presented in this paper is able to explain up to 76% of the variance in urinary creatinine excretion when using gender, age, weight and gender*weight as independent variables. Although 93.5% of the observed urinary creatinine values from urine collection one fell within 95% CI of the model predictions from urine collection two, the sensitivity of the ratio observed to predicted creatinine was very low when using traditional cut-offs for the creatinine index. Sensitivity improved after increasing the cut-off (e.g. to 0.95), however, given the trade-off between sensitivity and specificity, this also decreases specificity.

In a study, performed by Murakami *et al.* (Murakami et al., 2008), sensitivity and specificity of different strategies using creatinine as an indicator for identification of incomplete urine collections against PABA were investigated. The strategy using a creatinine index with a cut-off of 0.7 was identified as potentially useful for identifying incomplete 24-h urine collections. The sensitivity and specificity among 654 Japanese girls (mean age 19.7 years, SD 1.1 years) were respectively 0.47 and 0.99. In the present study, sensitivity and specificity in females using the strategy by Murakami *et al.* (Murakami et al., 2008) was 0.63 and 0.81 respectively. The sample characteristics from this latter study are different than those from the present sample in terms of age, ethnicity and educational diversity.

The sensitivity in men (0.33) was roughly half the sensitivity in women (0.63) in the present study. A lower sensitivity in men compared to women was also demonstrated in a small scale study (n= 83) comprising data from six European countries performed by Knuiman *et al.* (Knuiman et al., 1986) where sensitivity was 0.07 for men compared to 0.13 for women. It is noteworthy to mention that in their study a different cut-off (i.e. 0.6) was used. When a cut-off of 0.6 was used on the present data, sensitivity was 0.05 for men and 0.36 in women (data not shown). Regardless of cut-off or study sample, it is clear that when exclusion of collections is based on UCE, a large part of incomplete collections remains unidentified because of low sensitivity, resulting in an underestimation of urine-based analytes used during further analysis.

In this study, the fraction of incomplete collections defined as PABA recovery below 85%, was 6.5% and 9.7% for the first and second collection in men, and 7.2% and 13.8% in women respectively. Earlier studies have reported prevalences of incomplete collections similar to the ones reported here (Williams & Bingham, 1986; Leclercq, Maiani, Polito, & Ferro-Luzzi, 1991; Toft et al., 2007; Murakami et al., 2008). The higher prevalence of incomplete urines during the second collection might be attributed to survey fatigue. Also, the collection protocol was not explained again to participants before the second collection which might have decreased attention or motivation of participants to collect all urine. Therefore, repetition of instructions stressing the necessity of complete urine collections is advised when multiple collections are requested. Mean PABA recoveries (ranging from 98.0% in women to 102.2% in men) were close to 100% and in agreement with those from past observations in a European sample (Knuiman et al., 1986) and somewhat lower than the one reported by Murakami *et al.* (Murakami et al., 2008) in a Japanese sample (103.8% after adjustment for self-reported missing urine and collection time).

In the literature, models to predict creatinine have been described before (Dodge, Travis, & Daeschner, 1967; Turner, 1975; Kawasaki, Uezono, Itoh, & Ueno, 1991;

Kroos, Mays, & Harris, 2010) and reported correlations between observed and predicted UCE range from 0.50 to 0.64 (Dodge et al., 1967; Turner, 1975; Kawasaki et al., 1991). However, no reference method was used to assess the performance of these models. From the present study, it can be concluded that when an internal standard like PABA is used to check for completeness of urine collections, sensitivity of urinary creatinine to identify incomplete urine collections is very disappointing. This is the case for both cut-offs based on simple calculations as for more advanced predictions based on multiple regression modelling. However, both the ratios of observed to predicted creatinine and observed to total UCE from incomplete collections are significantly lower than those from complete collections (data not shown).

For model development, data from the second urine collection was used. Subsequently, UCE from the first urine collection was compared to the predicted UCE using the equation generated by the model. This way, both model development sample and model validation sample were large, comprising 458 and 504 cases respectively. As mentioned before, there was only a difference in prevalence of incomplete collections between the first and second urine collection. Because incomplete urine collections were excluded during both model development and validation, this difference was removed making both collections equal. Due to the fact that between-person variance in UCE is higher than within-person variance, the high number of participants in the present study is a major strength ($CV_{between}$: 19.1% for males, 18.3% for females; CV_{within}: 9.1% for males, 9.2% for females in the present study). Also, body weight of participants was accurately weighed instead of self-reported. In addition, an internal standard (PABA) was used to identify incomplete urine collections.

Nevertheless, PABA has also some limitations. Firstly, over-collection of urine cannot be detected. For instance, participants might collect the first urine voiding instead of discarding it. This will dilute urine concentration leading to underestimations of its constituents. Secondly, impaired renal function leads to under-collection. Therefore, kidney disease was an exclusion criterion for enrolment in the study. Thirdly, it has been suggested that late night meals interfere with PABA-resorption due to decreasing of metabolism and excretion of PABA (Knuiman et al., 1986). This problem was overcome in the present study by asking participants to take the PABA tablet before seven o'clock in the evening. Fourthly, when the colorimetric method is used for PABA-analysis, aromatic amines are also determined (Jakobsen, Ovesen, Fagt, & Pedersen, 1997). Because these compounds can originate from drugs like paracetamol and sulphonamide, use of these drugs was prohibited during study participation. Fifthly, previous studies (Bingham, S. & Cummings, 1983; Joossens & Geboers, 1984) have shown excretions of PABA (15 – 24 mg) originating from foods, so determination of baseline PABA excretion, at least in a subsample, is advised because any natural presence of PABA can result in an underestimation of incomplete urine collections. Sixthly, a major drawback of PABA-use is that intake can be refused or forgotten by study participants. Also, it can be considered inappropriate because of unknown interferences with biological samples of interest (e.g. genetic studies).

No self-reported dietary assessment method is capable of capturing all protein intakes. When comparing protein intake to urinary nitrogen, the EFCOVAL study found an underestimation of the EPIC-Soft guided 24-HDR varying from 2.7% up to 12.4% in men and 2.3% up to 12.8% in women after adjusting for age, BMI and education level (Crispim et al., 2011). Because of the small influence of dietary protein intake on UCE (Gibson, 2005), and the fact that underestimation of protein intake is not large, the anticipated consequences for the present results are assumed to be limited.

Development of a model for the prediction of urinary creatinine based on anthropometrics logically implies the inclusion of participants expected to deliver complete urine collections only. Application of this method while assessing the performance of a test strategy, however, will yield a lower prevalence of incomplete urine collections, thereby potentially affecting sensitivity and specificity calculations. Additional analyses of our data nevertheless demonstrated a limited impact of including 54 participants reporting incomplete urine collections during the first collection, as only four of these also showed to be catalogued as such by the reference method (data not shown).

Finally, adjustments for missed urine have been proposed elsewhere (Murakami et al., 2008), as have corrections for collections with PABA recoveries below 85% (Johansson, Bingham, & Vahter, 1999). Given that one of the objectives of the present study was to report on performance of strategies to deal with suspicious urine collections in terms of completeness, it was chosen not to adjust nor correct data and to keep them as straightforward as possible so consequences for inferences could be minimized.

Conclusions

The present study has shown that UCE can be predicted from readily available subject information like gender, weight and age. For the first time the performance of a prediction-based creatinine index in terms of sensitivity and specificity was assessed against a reference method. When such a creatinine index is used to exclude incomplete urines, sensitivity analysis showed that 94% to 89% of incomplete 24-h urine collections remain unidentified in males and females respectively. Also, in this European sample, sensitivity (95% CI) to identify incomplete urine collections of a traditional creatinine index was only 0.33 (0.17-0.53) and 0.66 (0.42-0.80) in males and females respectively. Therefore, based on the present findings, both the prediction-based as the traditional creatinine index, can be considered as an unreliable marker for detection of incomplete urine collections when compared to PABA.

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PART 3

Overview of dietary assessment methods used in nutritional surveillance

Chapter 7
Inventory of experiences from national/regional dietary monitoring surveys using EPIC-Soft

The EPIC-Soft 24-h recall (the software developed to conduct 24-h dietary recalls (24-HDR) in the European Prospective Investigation into Cancer and Nutrition (EPIC-Study) has been used in several regional/national dietary nutrition surveys. The main objective of this chapter is to present and discuss design, settings, logistics, data management and quality controls of dietary monitoring surveys that used EPIC-Soft for the collection of food consumption data. Within European Food Consumption Validation (EFCOVAL), a questionnaire including questions on current/past EPIC-Soft experiences and requirements for the future was developed and sent to all institutes that used EPIC-Soft in their food consumption survey(s) (five surveys in four different countries). EPIC-Soft was used in the national food consumption survey in Belgium (≥15–97 years), Germany (14–80 years), the Netherlands (19–30 years and 2–6 years) and Spain (regional only; 4–18 years). Participation rates in these surveys were 46% (Belgium), 42% (Germany), 42% (Dutch survey in adults), 79% (Dutch survey in children) and 77% (Basque survey). Two 24-HDR were collected by conducting face-to-face interviews in Belgium and Spain, and through telephone interviews in Germany and the Netherlands. Except the Netherlands (19–30 years), where the study was conducted only in autumn, in all other countries the study was conducted throughout the four seasons, including all days of the week. Interviews were conducted by dietitians, except in Germany and Spain. Mean EPIC-Soft interview time was 20–34 min. The dropout rate between the first and second interviews was low (<7.5%) in all surveys. EPIC-Soft has been used in different study settings and populations for nutritional exposure assessments. To guarantee the comparability of data across countries, recommendations for the design of future pan-European dietary monitoring surveys using EPIC-Soft should be drawn.

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Huybrechts, I., Casagrande, C., Nicolas, G., Geelen, A., Crispim, S. P., De Keyzer, W., Freisling, H., De Henauw, S., De Maeyer, M., Krems, C., Amiano, P., de Boer, E. J., Ocke, M. C., de Vries, J. H., & Slimani, N. (2011). Inventory of experiences from national/regional dietary monitoring surveys using EPIC-Soft. Eur J Clin Nutr, 65(S1), S16-S28.

Background

Different methods and study designs are currently being used in national food consumption surveys conducted in Europe, undermining the between-country comparability. Therefore, the availability of detailed, harmonized and high quality food consumption data at European level is a primary long-term objective for the European Food Safety Authority (EFSA) (EFSA, 2009). In agreement with the European Food Consumption Survey Method (EFCOSUM) recommendations (Biro et al, 2002), EFSA recently recommended the use of the 24-HDR method including two non-consecutive days for dietary surveys in adults (except those older than 75 years) (EFSA, 2009). This is considered the most cost-effective method and the main arguments in favour of this choice are that the 24-HDR method is less of a burden for the subjects and thus will increase the participation rate, and, since it is independent of literacy rates, it can be better implemented in different parts of the population (EFSA, 2009). In addition, the EFCOSUM group advised to use EPIC-Soft to standardize the 24-HDR as the best way forward for future pan-European dietary monitoring surveys (Brussaard et al, 2002). EPIC-Soft is a computer-assisted 24-HDR method that was developed by the International Agency for Research on Cancer (IARC) as calibration method for the food frequency questionnaire data obtained in the European Prospective Investigation into Cancer and Nutrition (EPIC) study (Slimani et al, 1999; Slimani et al, 2000). It provided the opportunity to collect dietary data in a standardized manner (Slimani & Valsta, 2002) and was validated for between population comparisons (Slimani et al, 2003). More recently, the software has been used and adapted for national/regional nutrition monitoring surveys in a few countries (Netherlands, Belgium, Germany and Spain). As it appears to be a promising method for between-population comparisons of dietary intakes and patterns, the validation study of the European Food Consumption Validation (EFCOVAL) project aimed to further develop and validate the use of duplicate 24-HDR using EPIC-Soft for the intake assessment of foods, nutrients and potentially hazardous chemicals for nutrition surveillance purposes relevant to health and safety policy in Europe. Experiences from previous studies using EPIC-Soft can be used for the optimization of the EPIC-Soft program and for the development of guidelines for the use of EPIC-Soft in future dietary monitoring surveys. Therefore, in the frame of the EFCOVAL project, an inventory was performed about the experiences of the use of EPIC-Soft in national/regional dietary monitoring surveys in Europe. This inventory aided in the development of specifications (an explicit set of requirements) for an optimal EPIC-Soft program to assess dietary intakes in different European countries. An in depth description about the EPIC-Soft specifications obtained from this inventory and the prioritization and implementation procedures of these specifications are given in another paper (Slimani et al, 2011). Also the specifications about the EPIC-Soft databases and guidelines are discussed elsewhere (Ocke et al, 2011). In addition, this inventory provided important information related to the study design, setting and logistics, data management and analyses and quality control procedures of the dietary monitoring surveys that used EPIC-Soft in the past. An in depth comparison of the study characteristics of the surveys in which EPIC-Soft has been used for monitoring dietary intake is an important step in the preparation of a future pan-European dietary monitoring survey. Therefore, the aim of this study is to present and discuss the experiences, the study designs, setting and logistics, data management and analyses and the quality control and evaluation procedures used in the dietary monitoring surveys that used EPIC-Soft in the past.

Methods

An ad-hoc EPIC-Soft specifications questionnaire was developed and used to assess the views and requirements of all current and past EPIC-Soft users (users within and outside EFCOVAL).

The main contents of the specifications questionnaire included (1) questions focusing on current/past experiences with the use of EPIC-Soft and (2) questions about their requirements for the future. In addition, other questions related to the study design and logistics, data management and analyses and quality control procedures were included. Mainly these latter questions were used for the inventory presented in this chapter.

The questionnaire included a combination of open and closed questions and was divided in different sections according to the topic of the questions (see highlighted headings in **addendum 5**). After pilot testing (by few EPIC-Soft users to evaluate the comprehensibility and completeness of the questionnaire), the specifications questionnaire was distributed to all the institutes that used EPIC-Soft in their dietary monitoring survey: Belgium (De Vriese et al, 2006) (Flemish centres and Walloon centre), The Netherlands (Hulshof et al, 2004; Ocke et al, 2004; Ocke et al, 2005) (coordinating centre in combination with subcontracted private company), Germany (Max Rubner-Institut (MRI), 2008) (coordinating centre and subcontracted private company who was in charge of the fieldwork) and Spain (Larrañaga et al, 2006) (coordinating centre).

All four coordinating centres completed the questionnaire and sent it back (via email) to the contact person at IARC who checked the answers in the questionnaire.

The data from the specifications questionnaires were then analysed and categorized (according to their topic):

1) EPIC-Soft software specifications
2) EPIC-Soft database specifications
3) Other specifications (e.g. food classification system used for analysing data)
4) Descriptive information about the design, setting, logistics and evaluation procedures used in these dietary monitoring surveys that used EPIC-Soft

The descriptive, logistical and evaluation information about monitoring surveys that used EPIC-Soft were collated in tables that were sent back to the different respondents for a second quality check (whether it was correctly interpreted). The results derived from the summary tables are presented and discussed in this chapter.

Results

The answers from the specifications questionnaire obtained from the coordinating centre of the Belgian, German, Dutch and Basque food consumption survey are summarized in Tables 1 to 6. These surveys used EPIC-Soft as one of the main dietary intake assessment methods. A comparison of these studies (design, settings, logistics, data management, etc.) is given below.

Study design and target population

From **Table 1** it can be concluded that EPIC-Soft was used in five different study designs (including for instance different sampling designs) and target populations in the frame of a national/regional food consumption survey: in Belgium (≥15 y old (oldest subject was 97 years old); n=3200), Germany (14-80 y; n=19329), the Netherlands (19-30 y; n=750 and 2-6 y; n=1279), and Spain (regional only; 4-18y; n=1178). A multistage sampling design was used in all surveys. All these dietary monitoring surveys are cross-sectional surveys.

Although for all surveys the target sample size had been estimated via sample size calculations, the rationale for these sample size calculations differed between the surveys:

– Belgian food consumption survey: sample size calculations were based on an estimated mean intake for different nutrients to fall within a 5% interval around the true population mean with a 95% probability.

- German food consumption survey: the total number of about 20,000 participants of the German food consumption survey was determined to permit a sufficiently high number of cases for subgroups (e. g. region or age groups).
- Basque food consumption survey in children: sample size calculations were based on an estimated mean intake for different nutrients to fall within a 5% interval around the true population mean with a 95% probability.
- The Dutch food consumption survey in children: the sample size of the study population was based to be able to estimate the 97.5 % percentile of intake distribution (food safety aims).
- The Dutch food consumption survey in adults: the study should have sufficient power to estimate mean intake of energy and nutrients with at least 5 percent precision for each gender, and mean intake of vegetables and fruits with 10-15 percent precision for men and women combined.

Recruitment of participants

Belgium (participation rate (PR): 46%), Germany (PR: 42%) and Spain (PR: 77%) used the national or regional registers as sampling frame while consumer panels were used in the Netherlands (PR: 42% for 19-30 y and 79% for 2-6 y). Belgium and Germany used general and personal feedback from the study results as an incentive to motivate the respondents to participate in the survey, while participants in Spain received a little present and in The Netherlands bonus points to select a present (**Table 2**). All surveys mentioned specific problems in the recruitment of respondents: in Belgium and the Netherlands it was more difficult to recruit young adults (working population), while in the Basque country and Germany it was hard to interview people on Fridays and Saturdays and in Germany also during the Christmas period.

EPIC-Soft utilization

Two non-consecutive 24-HDR were collected via face-to-face interviews in the study centre in Belgium and The Basque country, and telephone interviews in Germany and the Netherlands (except for 2-6 y old for whom a data-entry system of parentally reported food diaries was used) (**Table 3**). Interviews were conducted by trained interviewers (see section 'Training and recruitment of the interviewers'). Mean EPIC-Soft interview time ranged between 20 and 34 minutes (**Table 4**). A selection of the EPIC-Soft picture book was used to help the respondents in estimating portion sizes of food items and recipes, while only in Belgium the complete EPIC-Soft picture book was used (Table 1). Except for Belgium, all countries used pictures for household measures. All countries used a ruler to help in the portion size estimation and Belgium, Germany and The Basque country also used drawings of bread shapes to identify the type and size of bread that the respondent consumed.

Additional methods used

In Belgium, the Netherlands and The Basque country, a qualitative Food Frequency Questionnaire was used while in Germany a diet-history and dietary weighing records were used in addition to the repeated EPIC-Soft 24-HDR (Table 1). In The Basque country and in the Dutch survey among 2-6 year old children, an extra questionnaire was used to investigate dietary supplement intake. Body weight and height were measured in The Basque country, the Netherlands (only in the children 2-6 y old) and in Germany. In Belgium, waist circumference and in Germany waist and hip circumferences were measured (Table 1). No biological samples were collected in these dietary monitoring surveys.

Training and recruitment of the interviewers

In Belgium and The Basque country, the coordinator of the food consumption survey was responsible for the recruitment of the interviewers, while in the other countries a subcontractor was responsible for this task. Except from The Basque country and Germany, it was mandatory that the interviewers were dietitians (Table 3). Country specific manuals were used to inform the interviewers about the EPIC-Soft procedures. Most of these manuals were adapted from the original EPIC-Soft manual developed at IARC. The payment procedure of the interviewers differed between countries: monthly salary payment in all countries except from Belgium where interviewers were paid per interview. In Belgium and the Netherlands, a large staff turnover was considered as an important problem/burden for the survey (this caused extra administrative work (new contracts) and extra trainings) and was mainly due to payment/workload imbalance in Belgium and job insecurity (temporary contracts) in The Netherlands.

Fieldwork and quality control procedures during the fieldwork

The fieldwork ran over a whole year in all countries, except for the survey among 19-30 y old adults in the Netherlands where the fieldwork took place in autumn (Table 4). Interviews were collected about the seven days of the week (Monday until Sunday), though, in countries where interviewers were not allowed to conduct the interviews on Sundays or holidays (The Netherlands and the Basque country), the 24-HDR could also be performed two days later (e.g. on Monday to recall the food intake of

Saturday). The coordination of the fieldwork took place via different procedures. In Belgium and the Netherlands the communication with the interviewers mainly took place via supervisors and a regular newsletter. In all countries, except from Belgium, at least one extra training was organized during the fieldwork to check and discuss possible problems that appeared during the fieldwork. In Belgium, the Netherlands and The Basque country, random quality controls were performed during the fieldwork. In the Netherlands a ghost interviewee was used to check the professionalism of the interviewers and the quality of the conducted interviews. In Germany an external quality management system was implemented to ensure the anticipated data quality.

In the Dutch children 2-6 y old, dietary records (on two non-consecutive days) were used to assess the dietary intake of the children. All the dietary intake data were entered in the EPIC-Soft program to allow the same approach of data handling for this age group as for the other age groups in the Netherlands for whom 24-HDR were conducted with EPIC-Soft.

Data-analyses

Different methods were used to categorize and analyse the 24-HDR data exported from EPIC-Soft (**Table 5**). All countries used a national food classification system to categorize their food items reported with EPIC-Soft. However, in Belgium, the Netherlands and the Basque country, the food items were analysed via the food categories provided in the EPIC-Soft program as well. All countries used their national food composition database to link with the EPIC-Soft food items, though very often complemented with data from other countries when data for a particular food item was not available in the national food composition database. Statistical methods used to correct for within-person variability differed also between countries (Table 5). Furthermore, the Goldberg method was used in all countries to identify misreporters in adults (this was done after the food consumption data obtained with EPIC-Soft had been linked with the food composition tables to calculate the energy intake). Both, the Goldberg cutoffs at the population level ("cut-off 1") as well as those at the individual level ("cut-off 2") were applied.

In the Belgian food consumption survey, 20% of the subjects were identified as underreporter when using the cut-off values developed by Goldberg. When using the Goldberg cut-offs for group means, an underreporting of 15% of total energy-intake was found. When using the individual Goldberg cutoffs to identify under- and overreporters in the Basque survey among children, 9% of the subjects were identified as underreporters and 0.6% as overreporters.

In the Dutch food consumption survey among adults (DFCS), the ratio of energy intake to basal metabolic rate (EI:BMR) was calculated to check for underestimation of energy intake. In the total population of the DFCS-2003, an underestimation of energy intake of about 11% was observed (no information was available on the exact number of individuals under the used cut-off level of the basal metabolic rate). In the Dutch food consumption survey in children, gross underreporting of energy intake at the group level was evaluated by means of the ratio of reported energy intake and estimated energy requirement for basal metabolic rate. The expected ratios were 1.64 for boys and 1.57 for girls of this age with a sedentary lifestyle. The observed mean ratios were 1.63 and 1.62 for boys and girls, respectively. No information is available yet about the degree of misreporting in the German survey.

Underreporters were not excluded from the data analyses, except from the survey in the Basque country.

Evaluations

In Germany and the Basque country, Fridays and Saturdays were underrepresented. Respondent evaluation questionnaires were used in the Dutch surveys which in general yielded positive feedback for the EPIC-Soft 24-HDR interviews and the 2 day diary records (**Table 6**).

An interviewer evaluation in Belgium revealed some complaints about the work-load and unbalance of workload/salary among the interviewers and also about the time needed to get in contact with the respondents. The interviewer evaluations in the Netherlands revealed a positive feedback in general except from some similar complaints about the time that was needed to get in contact with the respondents. The other countries did not assess the interviewers' viewpoint. More details about the evaluations can be found in Table 6.

Table 1: Study design and methods of the monitoring surveys where EPIC-soft was used as (one of the) dietary method(s)

Survey(s)	**Belgian National Food Consumption Survey** (2004)	**German National Food Consumption Survey** (2005-2007)	**Dutch National Food Consumption Survey** (2003)	**Dutch Food Consumption Survey in Children** (2005/2006)	**Basque Country Food Consumption Survey in children** (2004-2005)
Country	**BE**	**GE**	**NL**	**NL**	**SP**
Institution[1]	**UGent**	**MRI**	**RIVM**	**RIVM**	**PHGI**
Target population					
N	3200	19329	750	1279	1178
Sex	M & W	M & W	M & W	M & W	M & W
Age	≥ 15	14-80	19-30	2-6	4-18
Extra Criteria	Exclusion criteria: - institutionalized individuals[2] - not speaking one of the three national languages (Dutch, French or German) - individuals who are physically or mentally not able to be interviewed[3]	Exclusion criteria: - not German speaking - institutionalized individuals	Exclusion criteria: - not Dutch speaking; - pregnant or giving breastfeeding - institutionalized individuals	Exclusion criteria: - parent/carer not Dutch speaking; - institutionalized individuals	Exclusion criteria: - not living in private household. - Individuals who are mentally not able to be interviewed. - not Spanish or Euskera speaking
Sampling Frame	National register	local registration offices of 500 randomly chosen sample points	consumer panel	consumer panel	Regional register
Methods					
EPIC-soft					
Administration	- Face-to-face	- Telephone	- Telephone - Recall food intake day before & two days before (for Sunday or holiday)	- Data-entry of diaries	- Face-to-face - Recall food intake two days before for Saturdays or days before a holiday

Table 1: continued

Survey(s)	Belgian National Food Consumption Survey (2004)	German National Food Consumption Survey (2005-2007)	Dutch National Food Consumption Survey (2003)	Dutch Food Consumption Survey in Children (2005/2006)	Basque Country Food Consumption Survey in children (2004-2005)
Recalls	2 non-consecutive days (4-6 weeks apart)	2 non-consecutive days (2-8 weeks apart)	2 non-consecutive days (8-13 days apart)	2 non-consecutive days (8-13 days apart)	2 non-consecutive days (7-10 days apart)
Visual aids	- part of EPIC picture book (only a few photos excluded) - ruler - own bread shapes but no household measures - pictures for spreadable fat on bread	- EPIC picture book (selection) - pictures of household measurements - bread shapes - pictures for spreadable fat on bread	- EPIC picture book (selection) - pictures of household measurements	- EPIC picture book (selection) - pictures of household measurements	EPIC picture book (selection) household measurements - ruler - bread shapes
Additional diet questionnaires					
FFQ[4]	- qualitative - self-administered	No	- qualitative - self-administered	- qualitative - self-administered	FFQ: Qualitative Frequency Questionnaire Interview face-to-face Frequency questions: never, per day, per week, per month, occasional.
Other		- Diet History interviews (15371) - Dietary weighing records (sub-sample of 1,000 participants)			Questionnaire measuring in the last year intake of dietary supplements
Measured anthropo-metrics	waist circumference	- weight - height - waist circumference - hip circumference		- weight - height	- weight - height

Table 1: continued

Survey(s)	Belgian National Food Consumption Survey (2004)	German National Food Consumption Survey (2005-2007)	Dutch National Food Consumption Survey (2003)	Dutch Food Consumption Survey in Children (2005/2006)	Basque Country Food Consumption Survey in children (2004-2005)
Other methods/ questionnaires	- physical activity - sociodemographic information - illnesses - physical activity - special diets and eating behaviours - smoking - alcohol consumption - food safety (household) questionnaire	- physical activity - sociodemographic information - nutritional behaviour - shopping behaviour - health aspects (e.g. smoking, illnesses) - sleeping behaviour - use of dietary supplements	- physical activity - smoking - alcohol consumption - socio-demographic information	- physical activity - socio-demographic information - purchase of biologic products -volume of cups etc	- physical activity - smoking use - alcohol intake - knowledge attitude to food and nutrition socio-demographic information

[1] UGent: Ghent University; MRI: Max Rubner-Institut; RIVM: Rijksinstituut voor Volksgezondheid en Milieu; PHGI: Public Health Division of Gipuzkoa

[2] These non-eligible persons were excluded from the samples at the doorstep

[3] because of a reduced freedom in food choice

[4] Three main types of Food Frequency Questionnaires can be considered: qualitative FFQ (without any information about portion sizes), quantitative FFQ (asking detailed portion size estimations), semi-quantitative FFQ (asking less detailed portion size information)

Table 2: Recruitment of the participants in the monitoring surveys where EPIC-soft was used as (one of the) dietary method(s)

Survey(s)	**Belgian National Food Consumption Survey (2004)**	**German National Food Consumption Survey (2005-2007)**	**Dutch National Food Consumption Survey (2003)**	**Dutch Food Consumption Survey in Children (2005/2006)**	**Basque Country Food Consumption Survey in children (2004-2005)**
Invitation type	- First: Letter - Secondly: telephone or face-to-face	- First: Letter - Secondly: telephone	Letter	Letter	First letter Secondly telephone
Incentives		A personal analysis of their nutritional habits	bonus points to choose presents from catalog	bonus points to choose presents from catalog & small present for child	A little present
Number of subjects approached	7000	46587	1794	1634	1535
Number of participants	3200	19329	750	1279	1178
Participation rate	-Total: 46% - 24-HDR: 50% (of invited)	- Total: 42 % - 24-HDR: 78% (of total participants)	- Total: 42% - 24-HDR: 96% (of persons that filled out general questionnaire)	- Total: 79% - 24-HDR: same	- Total: 77% - 24-HDR: 99% (of participants)
Dropout after first EPIC interview	1.4%	7.5 %	5%	not applicable	1 %
Problems in participants recruitment	Age and region were limiting factors to approach: - working population: most difficult to approach and motivate - Brussels: major problem for approaching and motivating individuals	Difficulties to approach during certain days in the year (from 24/12 - 01/01) subjects with low graduation were difficult to motivate	Young adults: very difficult to approach (often away from home) and difficult to motivate	None	Difficulties to approach subjects restricted to certain days of the week (Friday & Saturday were the most difficult days)

Abbreviations: 24-HDR, 24-h dietary recall; EPIC-Soft, the software developed to conduct 24-HDRs in the European Prospective Investigation into Cancer and Nutrition Study.

Table 3: Recruitment and training of the interviewers in the monitoring surveys where EPIC-soft was used as (one of the) dietary method(s)

Survey(s)		Belgian Food Consumption Survey (2004)	German Food Consumption Survey (2005-2007)	Dutch Food Consumption Survey (2003)	Dutch Food Consumption Survey in Children (2005/2006)	Basque Country Food Consumption Survey in children (2004-2005)
$N_{subjects}$ ($N_{24\text{-}HDR}$)		3200 (6400)	19329 participants (13926 two 24-HDR)	750 (1500)	1279 (1558)	1000 (2000)
Recruitment criteria interviewers		- dietitians - living in geographical area of study sample	- non dietitians (permanent employees of the market research company, experienced in conducting telephone interviews)	- dietitians	- not applicable because record method was used	- not necessarily dietitians (dietitians, nurses or people with experience in other surveys, specifically Health Surveys or other surveys in relation with Social and Health characteristics realized in the Basque Country. The interviewers must speak the two languages in the Basque Country)
Training interviewers	***materials***	- Country specific training manual (with original EPIC-manual in annex)	- Country specific training manual	- Country specific training manual	- not applicable	- Country specific training manual
	duration	1.5 days course (8-12h)	2.5 days course (20-24h)	2 days course (12-16h)	- not applicable	3 days course (>24h)
	interviewers/ training session	more than 20 interviewers/course	> 20 interviewers/course	10-20 interviewers/course	- not applicable	10-20 interviews/course
Interviewers	***Total number during fieldwork***	140	80	15	- not applicable	14
	Number of subjects (interviews) per interviewer	23 (46)	NA	50 (100)		71 (142)
	Interviews/ week	2-3		11	- not applicable	8
	Supervision			field work supervisor	- not applicable	
	Payment	Amount per interview	Salary	Salary	- not applicable	Salary
	Problems encountered	- Interviewer turnover: because of payment/ workload inbalance - staff turnover: because of payment/workload inbalance and short contracts	- Interviews on all days of the week and official holidays	- no interviews on Sundays or official holidays	many resigning dietitians who did data-input in EPIC-soft (because of short term contracts and part-time work)	- no interviews on Sundays or official holidays

Abbreviations: EPIC-Soft, the software developed to conduct 24-h dietary recalls in the European Prospective Investigation into Cancer and Nutrition Study

Table 4: Fieldwork characteristics of the monitoring surveys where EPIC-soft was used as (one of the) dietary method(s)

Survey(s)	Belgian Food Consumption Survey (2004)	German Food Consumption Survey (2005-2007)	Dutch Food Consumption Survey (2003)	Dutch Food Consumption Survey in Children (2005/2006)	Basque Country Food Consumption Survey in children (2004-2005)
Location subject during interviews	At respondent's home	Face-to-face interviews (diet-history interviews were conducted at local study centres) 24-HDR were conducted by telephone	At respondent's home	not applicable	At respondent's home
Time-span fieldwork	- All 4 seasons (1 year) - All days of week	- All 4 seasons (1 year) - All days of week	- Autumn only - All days of week (day before Sunday & holidays: recall 2 days later)	- All 4 seasons (1 year) - All days of week	- All 4 seasons (1 year) - All days of week (day before Sunday & holidays: recall 2 days later)
Data sending	Interviews sent daily/ weekly by email to coordinator	- using File Transfer Protocol (FTP) - sent to coordinator each 3 months	Interviews sent by email from market research organisation to coordinator (2-weekly or monthly)	not applicable	Interviews sent by email to coordination center
Intermediate controls	Intermediary random controls by dietitians		- Telephone contact with some respondents - Fake interviewee	Double data-entry by different dietitians	Telephone contact with some respondents
Final data controls	- EI/BMR - extreme values for some nutrients and food groups calculated		- EI/BMR - extreme values for all nutrients and food groups calculated	- EI/BMR - extreme values for all nutrients and food groups calculated	- EI / BMR Extreme values for food groups and nutrients
Mean interview time	- Mean 24-HDR: 30 min	- Mean 24-HDR: 22 min	- Mean 24-HDR: 34 min	not applicable	- Mean 24-HDR: 20 min
Problems	Oldest age group (>60 y) more problems for answering questions: longer interview time				

Abbreviations: 24-HDR, 24-h dietary recall; BMR, basal metabolic rate; EI, energy intake; EPIC-Soft, the software developed to conduct 24-h dietary recalls in the European Prospective Investigation into Cancer and Nutrition Study.

Table 5: Data analyses in the monitoring surveys where EPIC-soft was used as (one of the) dietary method(s)

Survey(s)		Belgian Food Consumption Survey (2004)	German Food Consumption Survey (2005-2007)	Dutch Food Consumption Survey (2003)	Dutch Food Consumption Survey in Children (2005/2006)	Basque Country Food Consumption Survey in children (2004-2005)
Food classification system used		EPIC, DAFNE & national classification	National classification	EPIC & national classification	EPIC classification	EPIC & national classification
Linking databases	***nutrients***	NUBEL, NEVO, Mc&Widdowson, USDA, IPL	German Nutrient Database (BLS)	NEVO	NEVO	EPIC Spain FCT 1991, 1996 CESNID 2003
	Raw agricultural crops	Database developed by ISP		KAP	KAP	Database developed by CESNID & PGHI
	Other			not applicable	Ad hoc databases based on data from Dutch food safety authority (e.g. label information)	Ad hoc databases based on data from CESNID
Statistical procedures/ adjustments (&Software packages)		NUSSER-method (C-Side)		AGE MODE (Soft-package developed at RIVM)	NUSSER-method (C-Side)	NUSSER-method (C-Side)
Method for calculating under- or overreporters		Goldberg cut-offs for under- and over-reporters	Goldberg cut-offs for under- and over-reporters	Goldberg cut-offs for under-reporters only	Goldberg cut-offs for under-reporters only	Goldberg cut-offs for under- and over-reporters

Abbreviations: AGE MOD, age-dependent model; CESNID, Centro de Ensen˜anza Superior de Nutricio´n y Diete´tica (Centre for Higher Studies in Nutrition and Dietetics); DAFNE, Data Food Networking; EPIC-Soft, the software developed to conduct 24-h dietary recalls in the European Prospective Investigation into Cancer (EPIC) and Nutrition Study; KAP, Quality Agricultural Products Database (Dutch database on the normal occurring background levels in feed and food products); NEVO, Nederlands Voedingsstoffenbestand (The Dutch Food Composition Database); NUSSER, a statistical modelling method developed by Sarah NUSSER

Table 6: Evaluations of the 24-HDR data (from EPIC-soft) in regional and national monitoring surveys where EPIC-soft was used as (one of the) dietary method(s)

Survey(s)		Belgian Food Consumption Survey (2004)	German Food Consumption Survey (2005-2007)	Dutch Food Consumption Survey (2003)	Dutch Food Consumption Survey in Children (2005/2006)	Basque Country Food Consumption Survey in children (2004-2005)
Respondents' evaluations				positive results from respondent evaluation forms	positive results from respondent evaluation forms	
Interviewers' evaluations	***intermediar***	Intermediate evaluation meeting: - complaints about workload - problems to approach respondents				
	final/post	Exit meeting: - complaints about unbalance workload/salary - complaints about time needed to get in contact with respondents		Interviewer evaluation forms: - generally positive results - complaints about time needed to get in contact with respondent	Interviewer evaluation forms: - generally positive results - complaints about heavy materials (e.g. scales) interviewers had to carry	
Evaluation studies	***Type***	- Pilot study - Validation study	Pilot study	Pilot study	Pilot study	Pilot study
	Reference method	7-day diary and accelerometry				
	Special documents/ questionnaires used for evaluating the study	- interviewer evaluation forms - diet diary and physical activity diary		Special documents used, but not yet received	Special documents used, but not yet received	Interviewer evaluation forms
	Results	- Recall of 2 days ago was not feasible in the study population - 2-day 24h-DR-interviews had less under-reporting than 7-day diaries. When taking only 2 days of diary, results were similar to 2 days 24h-DR		interviews of 7-11 years old & their caretaker are feasible	interviews of 12-15 years old & their caretaker are feasible	

Abbreviations: 24-HDR, 24-h dietary recall; EPIC-Soft, the software developed to conduct 24-h dietary recalls in the European Prospective Investigation into Cancer and Nutrition Study.

Discussion

In the present chapter we present and discuss the experiences from different dietary monitoring surveys in Europe in which the EPIC-Soft program was used as one of the main dietary intake assessment methods. EPIC-Soft was used in the national food consumption survey in Belgium (≥15 y), Germany (14-80 y), the Netherlands (19-30 y and 2-6 y), and The Basque country (regional only; 4-18y) and a completed specifications questionnaire was obtained from all these surveys. From the results obtained from these specifications questionnaires (Tables 1-6) it could be concluded that EPIC-Soft had already been used in diverse study designs and settings and in different study population groups ranging from children (2-6 y in the Netherlands) to elderly people (oldest subject in Belgium was 97 years old). In the Dutch food consumption survey among children, EPIC-Soft was used as a data entry system for food diaries obtained from the parents of the children.

The most important barrier for measuring dietary intake in children is the fact that they are not able to complete questionnaires on their own and that they have a limited cognitive ability to recall, estimate, and otherwise cooperate. Therefore, a food diary that can be completed by different proxy persons (e.g. the (grand)parents, school staff, care taker) could be a better method to assess children's dietary intake than the 24-HDR method which is recommended for measuring adults' food intake. However, to optimize the comparability with the other age groups, it is important to handle these food diaries in the same way as the adult 24-HDR. Therefore, it was decided to use the EPIC-Soft system as a data entry system for the food diaries of the Dutch children. Since the structure of EPIC-Soft was not conceptualised for this purpose, the time required for entering a dietary record was large which resulted in an important workload. However, this new approach had many advantages, e.g. standardized procedures for data entry, possibility to compare the outcome with other surveys using EPIC-Soft. Therefore it was recommended to develop an additional EPIC-Soft version that is more user-friendly for data-entry of food diaries. An adapted EPIC-Soft version for data entry of food diaries is developed and tested in the "PANCAKE" project funded by the European Food Safety Authority (EFSA).

Within the other four food consumption surveys included in this study (in adults and adolescents), repeated face-to-face or telephone interviews (on 2 non-consecutive days at least 2 weeks apart (Table 1)) were used to conduct their EPIC-Soft 24-HDR interviews. As shown in Table 6, all these methods have been pilot tested or validated and confirmed the feasibility and user-friendliness of the EPIC-Soft 24-HDR method. In a publication based upon the EFCOVAL respondent evaluation questionnaire, it was shown that most of the respondents do not have a strong preference for the face-to-face or telephone administration method, though some differences in preference could be seen between the different countries (Huybrechts et al, 2011). Differences between the telephone vs. face-to-face interview conducted with the EPIC-Soft program were studied in the Norwegian subsample of the EPIC-study (Brustad et al., 2003). From this study it could be concluded that the distribution of energy-contributing nutrients was not significantly different between the two modes of administration, except for reported energy percentage from protein, which was significantly higher in the face-to-face group (Brustad et al., 2003). It could also be concluded that the drop-out of respondents (after the first 24-HDR interview) was low in all surveys (<7.5%) which indicates that respondent burden is not too high. More details about the respondent burden and evaluation are given in the paper by Huybrechts et al. (Huybrechts et al, 2011).

It was remarkable that considerable differences were found in the recruitment and training of the interviewers. While most of the countries were only using dietitians as interviewers, Germany and The Basque country used non-dietitians. Also the duration of the interviewer trainings differed considerably between countries (from 1.5 to 3 days) and also the number of interviewers per training session and the total number of interviewers recruited for the fieldwork (from 14 in The Basque country to 140 in Belgium). In addition the payment procedures and the work permissions of the interviewers differed between countries (e.g. in some countries they were not allowed to work on Sundays). Unfortunately, this comparison of surveys that used EPIC-Soft did not allow any judgements about the preference of method/design that should be used in future dietary monitoring surveys. Neither does it allows to describe the impact of these different study designs on the accuracy of international comparisons between countries. Therefore, it should be further investigated to what extend these differences in training and background of the interviewers (e.g. dietitians or not) are leading to different degrees of accuracy of the 24-HDR data collected. From this inventory, for instance, it could be hypothesized that mean 24-HDR interview time differed between the countries in which dietitians were responsible for the 24-HDR interviews (30-34 min.) as compared to the countries where no dietitian degree was required (20-22 min.).

Furthermore, it should be investigated whether a 24-HDR interview about two days in the past (in countries where interviews on Sundays and holidays are not performed) are as accurate as a 24-HDR about the day before. Concerning the accuracy of portion size estimations, De Keyzer et al. concluded from a validation study in Belgium that the use of food photographs for portion size estimation of bread and beverages is acceptable for use in nutrition surveys. Though, for photographs of margarine on bread, further validation using smaller amounts corresponding to actual consumption is recommended (De Keyzer et al, 2010).

To guarantee the comparability of the collected data between countries it will be necessary to harmonize the study designs and logistics in future surveys by providing recommendations for future international food consumption surveys using EPIC-Soft. However, a certain level of flexibility in study design will be necessary in a pan-European food consumption survey.

Conclusions

Apart from the EPIC-study, EPIC-Soft has been used in different study settings and population groups, for both the assessment of nutrition and chemical substances in foods. Repeated face-to-face or telephone interviews (on 2 non-consecutive days) were used to conduct the EPIC-Soft 24-HDR interviews. These interviews have been pilot tested or validated and this inventory confirmed the feasibility and user-friendliness of the EPIC-Soft 24-HDR method (drop-out <7.5%). However, some recommendations regarding study design and logistics for the implementation of the EPIC-Soft programme in future pan-European dietary monitoring surveys should be drawn to guarantee the comparability of the data obtained across countries.

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Chapter 8
Cross-continental comparison of national food consumption survey methods

Food consumption surveys are performed in many countries. Comparison of results from those surveys across nations is difficult because of differences in methodological approach. Also, consensus about the preferred methodology associated with national food consumption surveys is increasing; nevertheless, no inventory of methodological aspects across continents is available. The aims of the present chapter are 1) to develop a framework of key methodological elements related to national food consumption surveys, and, 2) to inventory these properties of surveys performed in the continents North-America, South-America, Africa, Asia and Australasia. The framework for the inventory was based on an earlier developed one used to inventory national food consumption surveys in Europe. A literature search was performed using a fixed set of search terms in the databases MEDLINE (PubMed) and Web of Science. Reports and information available on websites of government agencies were used in addition to the peer-review articles. The inventory was then completed with all accessible information from the retrieved publications and corresponding authors were requested to provide additional information where missing. Surveys from eleven individual countries, originating from five continents are listed in the inventory. The results are presented into six major aspects of food consumption surveys: 1) target population, survey design and sampling, 2) dietary intake and other assessments, 3) recruitment of participants, 4) fieldwork characteristics, 5) data/nutrient analyses, and 6) recruitment and training of interviewers. The most common dietary intake assessment method used in food consumption surveys worldwide is the 24-h dietary recall interview, occasionally administered repeatedly, mostly using interview software. Some countries have incorporated their national food consumption surveys into continuous national health and nutrition examination surveys.

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Background

Food consumption surveys (FCS) are used to estimate intakes of foods and nutrients by a certain target population from a specified region. Usually, they are initiated by governmental organisations to 1) identify deficient or excessive intakes of nutrients, 2) assess accordance with food based dietary guidelines, or 3) estimate food safety related risks (e.g. contaminant exposures), using national representative samples.

In Europe, efforts have been made to harmonize methodological aspects related to dietary intake assessment (DIA) in the context of national nutrition surveys. Briefly, in the European Food Consumption Survey Method project (EFCOSUM) it was agreed that two non-consecutive 24-HDR are the most suitable to get internationally comparable data on population means and distributions of actual intake (Brussaard et al., 2002). Also, the menu-driven standardized 24-HDR program EPIC-Soft was considered to be the most appropriate software for standardized data collection in a pan-European survey. Following the EFCOSUM project, in the European Food Consumption Validation (EFCOVAL) project, EPIC-Soft was upgraded and adapted, and the two non-consecutive 24-HDRs using EPIC-Soft were validated (de Boer et al., 2011). Finally, a guideline on general principles to collect dietary information was developed by the European Food Safety Authority (EFSA) Expert Group on Food Consumption Data (European Food Safety Authority (EFSA), 2009), and in 2010, members of the EFSA Advisory Forum signed a declaration supporting the establishment of the EU Menu project, a pan-European food consumption survey among EU member states (EFSA, 2010).

As for Europe, other parts of the world have a shared methodology when conducting FCS. An in-depth description regarding experiences, study designs, setting and logistics, data management and analyses, along with quality control and evaluation procedures used in dietary monitoring surveys in Europe that used EPIC-Soft was presented previously (EFSA, 2009; Huybrechts, Casagrande, et al., 2011; Le Donne, Piccinelli, Sette, Leclercq, & European Food Consumption Validation, 2011). In light of comparability of results from future pan-European surveys with results from FCS performed elsewhere in the world, a thorough overview of methodological elements associated with these surveys is requested. Therefore, the aims of the present paper are 1) to develop a framework of key parameters describing methodological aspects of FCS, and, 2) to inventory methodological properties of national food consumption surveys performed on the continents North-America, South-America, Africa, Asia and Australasia.

Methods

Development of the inventory framework

First, key methodological properties of FCS were identified in order to construct a framework available for presenting the inventory. This framework was based on the one used by Huybrechts and co-workers (2011). After author debate it was decided to categorize the properties into six aspects of conducting a FCS: 1) target population, survey design and sampling, 2) dietary intake and other assessments, 3) recruitment of participants, 4) fieldwork characteristics, 5) data/nutrient analyses, and 6) recruitment and training of the interviewers. The framework was designed as a table listing FCS in the rows and property fields in the columns. In total, twenty nine fields were created. The fields to be completed per survey are presented in **Table 1**.

Table 1: Overview of inventory framework

General items	**Recruitment of participants**
Continent	Invitation type
Country	Incentives
Survey	Number of participants (*n*)
Institution	Participation rate (%)
Year(s)	Problems in recruitment/recruitment notes
	Place of DIA administration
Target population, survey design and sampling	**Fieldwork characteristics**
Sex	Time-span fieldwork
Age (years)	Intermediate controls
Sampling method and design	Final data controls
Sampling frame	
Dietary intake and other assessments	**Data/Nutrient analyses**
Method	Food classification system
Total recalls (n)	Food composition databases
Administration	Statistical procedures/ adjustment (software)
Portion size estimation	Methods for calculating under- or overreporters
Interview aids/software	**Recruitment and training of interviewers**
Other methods/ questionnaires	Recruitment criteria interviewers
Measured anthropometrics	Number of interviewers
Biological samples	Training material/Training topics
	Duration training

DIA: dietary intake assessment

Search strategy

As proposed by Blanquer et al. (2009) a combined strategy for data acquisition was used. First, a systematic literature search was performed, second, experts were contacted to complete missing information which could not be found in the literature from step one. We used the electronic database MEDLINE (PubMed) and Web of Science to identify studies reporting on food consumption surveys from 1985 to December 2011. Text terms with appropriate truncations, Boolean operators and relevant indexing terms were used. The reference lists in the articles, reviews and textbooks retrieved were also investigated for additional publications yielding a substantial amount of grey literature like reports available on websites of governmental bodies. The key words used in the search were: 'national nutrition survey'; 'food and nutrition survey'; 'dietary consumption survey'; 'dietary intake'; 'nutrition examination'; 'nutrition survey'; and 'dietary intake assessment'. Additional terms referring to a country or continent were added to this search query for obtaining region specific information. The selection of continents was based on the seven-continent model excluding Europe (pan-European methodology and inventory of experiences are reported elsewhere (see chapter 7; EFSA, 2009; Huybrechts, Casagrande, et al., 2011; Le Donne et al., 2011)) and Antarctica (no permanent living).

The exclusion criteria that were used to withdraw retrieved surveys were: 1) age (nutrition surveys in children only were excluded); 2) indirect or ecological measurement of food intake (e.g. food balance sheets or household budget surveys); 3) absence of dietary intake assessment (e.g. nutritional assessment based on anthropometric or clinical measurements), 4) publications or reports not available in English and/or not accessible online.

Once the table was completed based on the information available from the retrieved publications, it was e-mailed to principal investigators or corresponding authors of studies reporting on the food consumption survey with an accompanying request to fill in the blanks. This additional information was then merged with the tables and the inventory was distributed to all collaborators for final review.

Results

The first step of the search strategy yielded a total of 12,605 articles. From this, 4,511 articles met at least one of the exclusion criteria. In the remaining articles, single surveys from individual countries were identified. A total of eleven countries from five continents were retained: Africa: Nigeria; North-America: Canada, United States (US), Mexico; South-America: Brazil; Asia: China, Japan, Korea (South), Malaysia;

Australasia: Australia, New Zealand. In total, data from 29 FCS are presented in the overview.

Target population, survey design and sampling method

Table 2 summarizes study design aspects and methods of the selected surveys. The ages of the target populations ranged from less than 1 year of age to over 80 years. Surveys including all age categories were from Canada, US, Mexico (MHNS-06), China (1991 and onwards), Japan, Korea and Australia. In all surveys both genders were included except for Nigeria and Mexico (NNS-1999) that included only women. In all surveys a multistage sampling design was used to select study participants. The sampling frames used for selection of sampling units were based either on census data (US, Mexico, Brazil, Korea and New Zealand), a combination of frames like healthcare registries and labour force data (Canada) or strata from agroecological zones (Nigeria), counties (China) or enumeration blocks (Malaysia). For Canada, US, Mexico, China and Korea the national food consumption survey was also part of a health (examination) survey. The dietary monitoring surveys were cross-sectional, some of which having a continuing character since they are repeated annually or biennially (US, China, Japan and Korea). For US and China, participants are included in a cohort for tracking over time.

Numbers of participants and participation rates

In **Table 3**, recruitment aspects of all selected surveys are listed. Sample sizes of single surveys ranged from 2,596 (Mexico; NNS-1999) to over 30,000 (Canada and Brazil). This latter figure was transgressed when taking into account the totals of all samples in the continuous programs in US, China and Korea. Participation rates were above 90% in Korea (KNHANES 1998) and Malaysia; between 80.0-89.9% in Nigeria, US (NHANES 2001, 2005), Mexico (NNS-1999), Brazil, China and Korea; between 70.0-79.9% in Canada, US (NHANES 2003, 2007 and 2009), and Australia (for the FFQ); and below 70% in Japan, Australia (for the 24-HDR) and New Zealand.

Dietary intake assessment methods

Most surveys used 24-HDR as principal DIA method to assess dietary intakes (**Table 4**). Multiple recalls for all participants were available in US (2 recalls in NHANES 2003 and onwards) and China (3 recalls). In some countries duplicate recalls were available in a subsample only (Canada, Korea, Australia and New Zealand). A computer assisted personal interview (CAPI) was performed in US (NHANES 2001), Malaysia, Australia and New Zealand. In Canada and US (NHANES 2003 and onwards), a CAPI was performed during the first recall and a computer assisted telephone interview (CATI) during the second recall. In the surveys from Nigeria and China the 24-HDR was performed by paper and pencil in a face-to-face interview. In Korea, a face-to-face interview was performed, no interview software was reported, and in Mexico, the administration of the 24-HDR was also not reported in the study report. Only in Brazil and Japan a prospective DIA method was used (2-day EDR and 1- or 3-day semiweighed DR respectively). Finally, Mexico (MHNS-06) used only a semiquantitative FFQ to report on frequencies of intake during the past seven days. An FFQ was also used in addition to a principal DIA method to identify frequencies of consumption and non-consumers of various food groups in Canada, US (formerly called Food Propensity Questionnaire), Japan, Korea, Malaysia, Australia and New Zealand (NNS97).

Fieldwork characteristics

In **Table 5** fieldwork aspects of the nutrition surveys are presented. Looking at the available data, all surveys reported that interviews were conducted when the participant was at home. For surveys with multiple interviews, at least one was conducted at home. Interviews could either be a face-to-face or a telephone interview. In cases where the DIA was a dietary record, interviews were performed to review the participant's records and to check for completeness (Brazil and Japan). Another place for administrating the DIA was a mobile examination centres (MEC) (US, NHANES). The time-span of the fieldwork was at least one year (all seasons) in Canada, US, Brazil, Korea (KNHANES 2008 and onwards), Malaysia, Australia and New Zealand.

Data and nutrient analyses

Table 6 summarizes features related to data analyses of the nutrition surveys. Surveys using multiple measures of intake are able to correct for within-person variability. Most surveys used the Nusser method (using SIDE or C-SIDE) developed at the Iowa State University (ISU) to calculate distributions of usual intake (Canada, US NHANES 2003, Brazil, Korea and New Zealand). For US, from NHANES 2005 and onwards, the NCI method developed by the National Cancer Institute was used. Finally, in the Australian survey, an equation by the US National Academy of Science (NAS) was used to adjust for within-person variance. Furthermore, misreporting of energy intake was assessed using either the Goldberg method (1991) ($EI{:}BMR_{est}$) (US, Malaysia and Australia) or the equations by Black and Cole (2001) (Canada). Four surveys indicated that no calculation of misreporting was performed (Brazil, Korea and New Zealand).

Recruitment and training of field staff

In **Table 7** recruitment and training of the interviewers and field staff in the nutrition surveys are listed. In China, Japan, Korea, Malaysia and Australia, it was mandatory that the interviewers be nutritionists or dietitians. In other countries interviews were performed by trained interviewers familiar with local food customs (New Zealand) or professional interviewers working on a variety of surveys (Canada). For interviewers in US, a high school diploma was considered to be the minimum education as this is required for government jobs. Training was provided on a variety of topics like interviewing (and probing) skills (Canada, US, Brazil, China, Korea, Malaysia, Australia and New Zealand), training on contacting participants and software training. The duration of these trainings ranged from three days (China) to 15 days (Korea, KNHANES 2009). The average duration of reported training programs for interviewers was around seven days.

Table 2: Target population, survey design and sampling method of national nutrition surveys per continent

Continent *Country*	**References**	**Survey name**	**Institution**	**Year(s)**
Africa				
Nigeria	Maziya-Dixon et al., 2004; Harris, Dixon, Oguntona, & Jackson, 2010	Nigeria Food Consumption and Nutrition Survey (NFCNS)	International Institute of Tropical Agriculture (IITA)	2001-2003
North-America				
Canada	Statistics Canada, 2009; Health and Statistics Division Canada, 2012	Canadian Community Health Survey - Nutrition (CCHS)	Statistics Canada	2004
United States	Centers for Disease Control and Prevention, 2012; USDA, 2012	What we Eat in America (WWEIA), National Health and Nutrition Examination Survey (Continuous NHANES)	National Center for Health Statistics (NCHS) from the Centers for Disease Control and Prevention (CDC)	2001-2002 2003-2004 2005-2006 2007-2008 2009-2010
Mexico	Simón Barquera et al., 2003; Resano-Pérez, Méndez-Ramírez, Shamah-Levy, Rivera, & Sepúlveda-Amor, 2003; Rivera & Sepúlveda Amor, 2003; S. Barquera et al., 2008; S. Barquera et al., 2010	National Nutrition Survey 1999 (NNS-1999)	Instituto Nacional de Salud Pública (INSP)	1998-1999
		Encuesta Nacional de Salud y Nutrición 2006 (ENSANUT 2006), Mexican Health and Nutrition Survey 2006 (MHNS-06)	Instituto Nacional de Salud Pública (INSP)	2005-2006
South-America				
Brazil	Pereira, Duffey, Sichieri, & Popkin, 2012	Brazilian Individual Dietary Survey (IDS 2008-2009)	Instituto Brasileiro de Geografia e Estatistica (IBGE)	2008-2009

M: male; F: female n/a: not available
“: ditto

Sex	Age (years)	Sampling method and design	Sampling frame	Notes
Adults: F Subsample: pregnant F	≥ 18 n/a	Multistage, stratified cluster sample: state > local government area > enumeration area > household	Stratification according to major agroecological zones and predominant food crops	
M and F	All age categories (< 1 - 71+)	Two-step strategy: 1) 80 units in 14 age/sex groups per province 2) power allocation scheme for remaining anticipated units	4 frames: Labour Force Survey (LFS) area frame, CCHS 2.1 dwellings, Prince Edward Island and Manitoba Health-care registries	
M and F	All age categories (< 1 - 80+)	Stratified, multistage probability sample: Primary Sampling Units (PSUs) (counties) > segments within PSUs (blocks containing a cluster of households) > households within segments > one or more participants within households	PSU samples were selected from a frame of all U.S. counties, using the 2000 census data and associated estimates and projections	What We Eat in America is the dietary component of NHANES, both surveys are integrated as of 2001-2002. As of 1999 the NHANES became a continuous program and is performed every two years.
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
Adolescents and adults: F Children: M and F	12 - 49 < 12	Probabilistic, multistage, stratified cluster sample: basic geographical statistical area (BGSA) > household block > household	Census data (1995), stratification of BGSA by socioeconomic status index	
Children: M and F Adults: M and F	< 19 ≥ 19	Multistage, stratified cluster sample	n/a	
M and F	≥ 10	Probabilistic two-stage complex cluster sampling: census tracts > households	Census data (2000), a subsample (25%) of households selected in the Household Budget Survey was randomly selected to participate in the IDS	

Table 2: continued

Continent *Country*	References	Survey name	Institution	Year(s)
Asia				
China	Popkin, Du, Zhai, & Zhang, 2010; Chinese Center for Disease Control and Prevention, 2012	China Health and Nutrition Survey (CHNS)	National Institute of Nutrition and Food Safety (NINFS) from the China Center for Disease Control and Prevention (CCDC)	1989
				1991
				1993
				1997
				2000
				2004
				2006
				2009
Japan	National Institute of Health and Nutrition Japan, 2012; Tokudome et al., 2012	National Nutrition Survey in Japan (NNS-J)	National Institute of Health and Nutrition (NIHN)	2004-2007
Korea	Kim et al., 2011; Lee, 2012	Korean National Health and Nutrition Examination Survey (KNHANES)	Korean Institute for Health and Social Affairs (KIHASA) and the Korea Health Industry Development Institute (KHIDI)	1998
			"	2001
			KIHASA, KHIDI and the Korean Centers for Disease Control and Prevention (KCDC)	2005
			KCDC	2007
			"	2008
			"	2009
Malaysia	Mirnalini et al., 2008; Norimah et al., 2008	Malaysian Adult Nutrition Survey (MANS)	Ministry of Health Malaysia (MOH-M)	2004
Australasia				
Australia	McLennan & Podger, 1997; Cook, Rutishauser, & Seelig, 2001	National Nutrition Survey (NNS)	Australian Bureau of Statistics (ABS) and Commonwealth Department of Health and Family Services (HFS)	1995
New Zealand	Quigley & Watts, 1997; Parnell, Wilson, & Russell, 2001; Ministry of Health, 2012	New Zealand National Nutrition Survey (NNS97)	New Zealand Ministry of Health (MOH-NZ)	1996-1997
		New Zealand Adult Nutrition Survey (NZANS)	"	2008-2009

Sex	Age (years)	Sampling method and design	Sampling frame	Notes
Children: M and F Adults: M and F	1-6 20-45	Multistage, random cluster sample: province > county > PSUs (n=190) > household	Stratification of counties by income (low, middle, and high), four counties per province were selected, PSUs are urban neighborhoods, suburban neighborhoods, towns, and rural villages	CHNS is an ongoing open cohort International collaboration of NINFS with Carolina Population Center at the University of North Carolina at Chapel Hill
M and F	All age categories	"	"	
"	"	"	"	
"	"	"	"	
"	"	Multistage, random cluster sample: province > county > PSUs (n=216) > household	"	
"	"	"	"	
"	"	"	"	
"	"	"	"	
M and F	≥ 1 - 70+	Stratified random sample: survey district units (n=300) > households	n/a	The methods will change to 24HDR,NNS-J is an ongoing study undertaken annualy
M and F	≥ 1 - 70+	Stratified, multistage probability sample: PSUs (n=600) > households	Census data, population register	National Health and Nutrition Survey (NHNS) was conducted for the first time in 1998 and replaced the National Nutrition Survey
"	"	"	"	
"	"	"	"	
"	"	"	"	
"	"	"	"	
"	"	"	"	
M and F	18-59	Stratified random sample with proportional allocation	Enumeration Blocks (EB) and Living Quarters (LQ) were sampled proportionate to population size	
M and F	≥ 2	Multistage area sample	n/a	
M and F	≥ 15	Multistage, stratified sample: PSUs (n=18,000) > households > participant	Area based, census data (1991)	
"	"	Multistage, stratified, probability-proportional-to-size (PPS) sample	Area based, New Zealand census meshblocks (2006)	

Table 3: Dietary intake and other assessments of national nutrition surveys per continent

Continent			Dietary intake assesment			
Country	**Survey name**	**Year(s)**	**Method**	**Total recalls (n)**	**Administration of method**	**Portion size estimation**
Africa						
Nigeria	Nigeria Food Consumption and Nutrition Survey (NFCNS)	2001-2003	24-HDR	1	Face-to-face, paper pencil	Cups, spoons, thickness sticks, rulers
North-America						
Canada	Canadian Community Health Survey - Nutrition (CCHS)	2004	24-HDR (children: 6-11 yrs assisted by parents; <6 yrs reported by parents)/ FFQ (fruit and vegetables)	1 (70% of sample) 2 (30% of sample)	Face-to-face (first interview) Telephone (recall)/ Paper-pencil	Food model booklet, volume measures (tablespoon, cup, etc.), weight measures (ounce, gram, etc.), dimensions (length, width, etc.), general measures (relative sizes, container units)
United States	What we Eat in America (WWEIA), National Health and Nutrition Examination Survey (Continuous NHANES)	2001-2002	24-HDR (children < 16 yrs proxy provided information)/ FFQ	1	Face-to-face/ Paper-pencil	Three-dimensional food models for first interview.
		2003-2004	"	2 (3-10 d interval)	Face-to-face (first interview) Telephone (recall)	Three-dimensional food models for first interview. USDA's Food Model Booklet (two-dimensional drawings of glasses, mugs, bowls, mounds, circles, etc.) and three-dimensional models (measuring cups and spoons, a ruler, and two household spoons) for telephone interview.
		2005-2006	"	"	"	"
		2007-2008	"	"	"	"
		2009-2010	"	"	"	"
Mexico	National Nutrition Survey 1999 (NNS-1999)	1998-1999	24-HDR	1	n/a	n/a
	Encuesta Nacional de Salud y Nutrición 2006 (ENSANUT 2006), Mexican Health and Nutrition Survey 2006 (MHNS-06)	2005-2006	semiquantitative FFQ (past 7 days, 101 foods, 14 food groups)		n/a	n/a
South-America						
Brazil	Brazilian Individual Dietary Survey (IDS 2008-2009)	2008-2009	2-day EDR (non-consecutive on pre-determined days spanning one week)		Paper pencil, face-to-face interview to review food records	Picture book (pictures of plates, glasses, bottles and cutlery)
Asia						
China	China Health and Nutrition Survey (CHNS)	1989	24-HDR (children < 12 yrs proxy provided information)	3 (consecutive on pre-determined days spanning one week)	Paper pencil, face-to-face interview	Food models and picture aids
		1991	"	"	"	"
		1993	"	"	"	"
		1997	"	"	"	"
		2000	"	"	"	"

Interview aids/ software	Other methods/ questionnaires	Measured anthropometrics	Biological samples
Food instruction booklet with types of foods and quantities (adopted from USDA)	Household/demographic information, socioeconomic characteristics of households, food availability and affordability, food consumed away from home, food-related coping strategies, health and care	BMI	Blood: vitamin E and E, iron, zinc Urine: iodine Blood and urine was also collected from children (n= ca. 3000) aged < 5 years
CAI software, developed by Statistics Canada (adopted from AMPM, USDA)	General health components including chronic conditions, consumption of vitamin and mineral supplements, physical and sedentary activities, smoking and alcohol consumption and socio-demographic characteristics	Weight and height	n/a
CAI software, developed by USDA: Automated Multiple-Pass Method (AMPM)	For a complete list of questionnaire components of NHANES 1999–2012 visit http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Health examinations are conducted in mobile examination centers (MECs).	Body composition and bone density (Dual energy x-ray absorptiometry), body measurements.	For a complete list of laboratory components of NHANES 1999–2012 visit http://www.cdc.gov/nchs/nhanes/about_nhanes.htm.
“	“	“	“
“	“	“	“
“	“	“	“
“	“	“	“
n/a	Socioeconomic and demographic family characteristics, acute and chronic morbidity, obstetric history, physical activity, and use of tobacco and alcohol	Weight and height (in women, waist and hip circumferences)	Capillary blood: concentration of hemoglobin Venous blood and urine: assessment of micronutrient status
n/a			
CAPI software	Socioeconomic and demographic information (household questionnaire), food security questionnaire	Weight and height	n/a
n/a	Household survey, health survey, physical activity, elderly component, body image and mass media behaviors and practices, ever-married women survey, community survey, food market survey, and health and family planning facility surveys For a complete overview of surveys per year visit http://www.cpc.unc.edu/projects/china/design/datacoll and http://www.cpc.unc.edu/projects/china/data/questionnaires	Weight and height, head circumference, arm circumfeence, and waist-hip ratio	None
“	“	“	“
“	“	“	“
“	“	“	“
“	“	“	“

Table 3: continued

Continent *Country*	Survey name	Year(s)	Dietary intake assesment Method	Total recalls (n)	Administration of method	Portion size estimation
		2004	"	"	"	"
		2006	"	"	"	"
		2009	"	"	"	"
Japan	National Nutrition Survey in Japan (NNS-J)	2004-2007	1- or 3-day semiweighed DR/ FFQ (≥ 20 yrs)		Paper pencil, face-to-face interview to review food records/ Paper-pencil	Kitchen scale
Korea	Korean National Health and Nutrition Examination Survey (KNHANES)	1998	24-HDR (in 200 PSUs)/ FFQ	1	Face-to-face/ Paper-pencil	Three-dimensional food models and a picture book with color photographs of foods
		2001	"	"	"	"
		2005	"	"	"	"
		2007	"	"	"	"
		2008	"	"	"	"
		2009	"	"	"	"
Malaysia	Malaysian Adult Nutrition Survey (MANS)	2004	24-HDR/ FFQ (126 foods, 15 food groups)	1	Face-to-face/ Paper-pencil	Album of food pictures and household measures
Australasia						
Australia	National Nutrition Survey (NNS)	1995	24-HDR (children: 2-4 yrs reported by adult; 5-11 yrs assisted by adult)/ FFQ (≥ 12 yrs, 107 foods)	1 (90% of sample) 2 (10% of sample)	Face-to-face/ Paper-pencil	n/a
New Zealand	New Zealand National Nutrition Survey (NNS97)	1996-1997	24-HDR/ FFQ	1 2 (n=695)	Face-to-face/ Paper-pencil	Cups, spoons, thickness sticks (thickness of meat, fish, poultry and cheese), photographs , grids and concentric circles, balls (to estimate apples and oranges), beans bags (to describe mashed potato and rice), standard serving sizes of foods and weights
	New Zealand Adult Nutrition Survey (NZANS)	2008-2009	24-HDR/ dietary habits questionnaire	1 (75% of sample) 2 (25% of sample)	Face-to-face/ Paper-pencil	Food photographs, shape dimensions, food portion assessment aids (e.g. dried beans) and packaging information

": ditto
n/a: not available
EDR: Estimated dietary record
CAI: computer assisted interview
CAPI: computer assisted personal interview
AMPM: Automated Multiple-Pass Method

Interview aids/ software	Other methods/ questionnaires	Measured anthro-pometrics	Biological samples
"	"	"	"
"	"	"	"
"	"	"	Blood collection
n/a	Blood pressure, daily physical activity and lifestyle questionnaire (eating habits, physical activity, physical exercise, sleep, alcohol intake, smoking, and dental health) (subjects aged 15 years or older)	Weight and height (subjects aged 1 year or older), abdominal circumference (subjects aged 6 year or older)	Blood collection (subjects aged 20 years or older)
n/a	Socio-economic and demographic information (household questionaire), physical activity questionnaire	Weight and height	Blood and urine collection
n/a		"	"
n/a		"	"
n/a		"	"
n/a		"	"
n/a		"	"
Nutritionist Pro™ Nutrition Analysis Software (for data entry)	Socio-demographic questionnaire, physical activity questionnaire and 24-hour physical activity recall	Weight and height	n/a
Australian Nutrition Survey System (ANSURS) (Australian version of Survey Net which was developed by USDA)	Socio-economic and demographic information, physical activity questionnaire, lifestyle questionnaire, health questionnaire, food habits questionnaire, food security questionnaire, blood pressure (≥ 16 yrs)	Weight and height, waist and hip circumference	n/a
CAPI software, LINZ24© (analogous to AMPM, USDA)	Blood pressure, socio-economic and demographic information, food safety questionnaire, food habits questionnaire, dietary supplements questionnaire, food security questionnaire	Weight and height, circumference of waist, hip and arm, waist-hip ratio, triceps and subscapular skinfold thickness, elbow breadth	Non-fasting blood sample: cellular evaluation, blood lipids, iron
"	Socio-economic and demographic information, general health questionnaire, food habits questionnaire, dietary supplements questionnaire, food security questionnaire	Weight and height, waist circumference	Non-fasting blood sample: cellular evaluation, blood lipids, iron, HbA1c Spot urine sample: sodium, potassium, iodine, creatinine

Table 4: Recruitment of the participants in national nutrition surveys per continent

Continent *Country*	**Survey name**	**Year(s)**	**Invitation type**
Africa			
Nigeria	Nigeria Food Consumption and Nutrition Survey (NFCNS)	2001-2003	n/a
North-America			
Canada	Canadian Community Health Survey - Nutrition (CCHS)	2004	Invitation letter and telephone invitation
United States	What we Eat in America (WWEIA), National Health and Nutrition Examination Survey (Continuous NHANES)	2001-2002	Invitation letter, personal visit at home
		2003-2004	"
		2005-2006	"
		2007-2008	"
		2009-2010	"
Mexico	National Nutrition Survey 1999 (NNS-1999)	1998-1999	n/a
	Encuesta Nacional de Salud y Nutrición 2006 (ENSANUT 2006), Mexican Health and Nutrition Survey 2006 (MHNS-06)	2005-2006	n/a
South-America			
Brazil	Brazilian Individual Dietary Survey (IDS 2008-2009)	2008-2009	Personal visit at home
Asia			
China	China Health and Nutrition Survey (CHNS)	1989	Personal visit at home
		1991	"
		1993	"
		1997	"
		2000	"
		2004	"
		2006	"
		2009	"
Japan	National Nutrition Survey in Japan (NNS-J)	2004-2007	n/a
Korea	Korean National Health and Nutrition Examination Survey (KNHANES)	1998	Invitation letter
		2001	"
		2005	"
		2007	"
		2008	"
		2009	"
Malaysia	Malaysian Adult Nutrition Survey (MANS)	2004	n/a
Australasia			
Australia	National Nutrition Survey (NNS)	1995	n/a
New Zealand	New Zealand National Nutrition Survey (NNS97)	1996-1997	Telephone invitation and/or personal visit at home
	New Zealand Adult Nutrition Survey (NZANS)	2008-2009	Personal visit at home

F: female
": ditto
n/a: not available

Incentives	Number of participants (n)	Participation rate (%)	Problems in recruitment/ recruitment notes
n/a	F: 5,325 subsample pregnant F: 960	81.2	n/a
None	35,107	76.5	Difficulties in approaching target population, participation was experienced as burdensome
Participants receive remuneration as well as reimbursement for transportation and child/elder care expenses	11,039	84.0	NHANES is designed to sample larger numbers of certain subgroups of particular public health interest. Oversampling is done to increase the reliability and precision of estimates of health status indicators for these population subgroups.
"	10,122	79.0	"
"	10,348	80.5	"
"	10,149	78.4	"
"	10,537	79.4	"
n/a	Adolescent F: 416 Adult F: 2,596	82.4	n/a
n/a	Adolescents: 7,464 Adults: 21,113	n/a	n/a
None	34,032	81.0	The burden of participating in a survey was reported as a recruitment problem
n/a	15,927	n/a	Participants leaving in one survey and moving back in a later year, migration of participants, natural disasters and major redevelopment of housing in all large urban centres
"	14,789	88.1	"
"	13,893	88.2	"
"	15,874	80.9	"
"	17,054	83.0	"
"	16,129	80.2	"
"	18,764	88.0	"
"	n/a	n/a	"
n/a	8,762 (2004) 8,885 (2007)	≈ 60.0 (a)	n/a
Small present	11,525	95.9	n/a
"	10,051	81.0	
Small present and a letter with individual results from examination	9,047	80.5	The burden of participating in a survey and motovation pf participants were reported as recruitment problems
"	4,099	80.6	"
"	8,641	82.0	"
"	9,397	82.2	"
n/a	6,886	93.6 (24-HDR) 92.0 (FFQ)	n/a
n/a	13,858	61.4 (24-HDR) 76.0 (FFQ)	n/a
Small present	4,636	50.1	Participants of the Health Survey were asked if they would further consent to the Nutrition Survey which badly affected the response rate since added respondent burden and time lapse between both surveys
Grocery voucher (if blood collected) and a letter with individual results from examination	4,721	61.0	"

Table 5: Fieldwork characteristics of national nutrition surveys per continent

Continent *Country*	**Survey name**	**Year(s)**	**Place of DIA administration**
Africa			
Nigeria	Nigeria Food Consumption and Nutrition Survey (NFCNS)	2001-2003	n/a
North-America			
Canada	Canadian Community Health Survey - Nutrition (CCHS)	2004	Participant's home
United States	What we Eat in America (WWEIA), National Health and Nutrition Examination Survey (Continuous NHANES)	2001-2002	First interview: Mobile Examination Center (MEC)
		2003-2004	First interview: MEC Second interview: participant's home
		2005-2006	"
		2007-2008	"
		2009-2010	"
Mexico	National Nutrition Survey 1999 (NNS-1999)	1998-1999	n/a
	Encuesta Nacional de Salud y Nutrición 2006 (ENSANUT 2006), Mexican Health and Nutrition Survey 2006 (MHNS-06)	2005-2006	n/a
South-America			
Brazil	Brazilian Individual Dietary Survey (IDS 2008-2009)	2008-2009	Participant's home
Asia			
China	China Health and Nutrition Survey (CHNS)	1989	Participant's home
		1991	"
		1993	"
		1997	"
		2000	"
		2004	"
		2006	"
		2009	
Japan	National Nutrition Survey in Japan (NNS-J)	2004-2007	Participant's home
Korea	Korean National Health and Nutrition Examination Survey (KNHANES)	1998	Participant's home
		2001	"
		2005	"
		2007	"
		2008	"
		2009	"
Malaysia	Malaysian Adult Nutrition Survey (MANS)	2004	Participant's home
Australasia			
Australia	National Nutrition Survey (NNS)	1995	Participant's home
New Zealand	New Zealand National Nutrition Survey (NNS97)	1996-1997	Participant's home
	New Zealand Adult Nutrition Survey (NZANS)	2008-2009	Participant's home

" : ditto
n/a: not available

Time-span fieldwork	Intermediate controls	Final data controls
Aug 2001-Oct 2001	n/a	n/a
Jan 2004-Jan 2005	Quality control at data entry, checking completeness and accuracy of collected data, regular meetings to review the progress of fieldwork and interviewers.	Identification of extreme values of nutrients and food groups
Jan 2001-Dec 2002	The CAPI software program has built-in data edit and consistency checks to reduce data entry errors. Interviewers were alerted the when unusual or potentially erroneous data values were recorded.	Interview records were reviewed by the NHANES field office staff for accuracy and completeness. A subset of the household interviews was verified by re-contacting the survey participants. Periodically, interviews were audio-taped and reviewed by NCHS and contractor staff.
Jan 2003-Dec 2004	"	"
Jan 2005-Dec 2006	"	"
Jan 2007-Dec2008	"	"
Jan 2009-Dec2010	"	"
Oct 1998-Mar1999	n/a	n/a
Oct 2005-May 2006	n/a	n/a
May 2008-May2009	Cross-check data, quality control during data entry, completeness and accuracy checks of collected data, regular meetings to review the progress of fieldwork and make adjustments as required	Calculation of EI:BMRest
n/a	Internal controls on quality measures have been based on collecting measures of selected factors from multiple perspectives and then using these data to refine measurements.	Individual's average daily dietary intake, calculated from the household survey, was compared with dietary intake based on 24-h recall data. In case of discrepancies, households were revisited.
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
n/a	Interview with participant to review food records and check for completeness	n/a
Nov 1998-Dec 1998	Cross-check of data, participants were recontacted to provide extra information when the data is incomplete or possibly wrong	Extreme values for some nutrients and food groups were calculated
Nov 2001-Dec 2001	"	"
Apr 2005-May2005	"	"
Jul 2007-Dec 2007	"	"
Jan 2008-Dec 2008	"	"
Jan 2009-Dec 2009	"	"
Oct 2002-Dec 2003	Data entry clerks trained to identify, describe foods and recipes and performed quality control checks, interviewers reviewed the recall with the respondent to check for completeness and accuracy	Calculation of EI:BMRest
Feb 1995-Mar 1996	Data was scrutinised during data entry, coding and output processing for accuracy and quality	Calculation of EI:BMRest, extreme values for some nutrients and foods were calculated
Dec 1996-Nov 1997	Interviewers sent diet recalls to project office within 24 hrs of collection so the project office could check each recall for accuracy and completeness which enabled interviewers to go back to participants, and/or clarify data with project office	Extreme values for nutrient intakes were scrutinised after conversion of food to nutrients
Oct 2008-Oct 2009	"	"

Table 6: Data/Nutrient analyses of national nutrition surveys per continent

Continent *Country*	**Survey name**	**Year(s)**	**Food classification system**
Africa			
Nigeria	Nigeria Food Consumption and Nutrition Survey (NFCNS)	2001-2003	USDA based, adapted to foods eaten by the Nigerian population
North-America			
Canada	Canadian Community Health Survey - Nutrition (CCHS)	2004	Bureau of Nutritional Sciences (BNS) food groups, based on British and American food group systems
United States	What we Eat in America (WWEIA), National Health and Nutrition Examination Survey (Continuous NHANES)	2001-2002	Food Surveys Research Group (FSRG) defined food groups
		2003-2004	"
		2005-2006	"
		2007-2008	"
		2009-2010	"
Mexico	National Nutrition Survey 1999 (NNS-1999)	1998-1999	n/a
	Encuesta Nacional de Salud y Nutrición 2006 (ENSANUT 2006), Mexican Health and Nutrition Survey 2006 (MHNS-06)	2005-2006	n/a
South-America			
Brazil	Brazilian Individual Dietary Survey (IDS 2008-2009)	2008-2009	National food classification system
Asia			
China	China Health and Nutrition Survey (CHNS)	1989	n/a
		1991	"
		1993	"
		1997	"
		2000	"
		2004	"
		2006	"
		2009	"
Japan	National Nutrition Survey in Japan (NNS-J)	2004-2007	n/a
Korea	Korean National Health and Nutrition Examination Survey (KNHANES)	1998	National food classification system
		2001	"
		2005	"
		2007	"
		2008	"
		2009	"
Malaysia	Malaysian Adult Nutrition Survey (MANS)	2004	n/a
Australasia			
Australia	National Nutrition Survey (NNS)	1995	National food classification system (ANSURS)
New Zealand	New Zealand National Nutrition Survey (NNS97)	1996-1997	National food classification system
	New Zealand Adult Nutrition Survey (NZANS)	2008-2009	"

" : ditto
n/a: not available

Food composition databases	Statistical procedures/ adjustment (software)	Methods for calculating under- or overreporters
Nutrient Composition of Commonly Eaten Foods in Nigeria – Raw, Processed and Prepared	n/a	n/a
Nutrition Survey System (NSS)	Nusser method using SIDE (Iowa State University)	Equations by Black and Cole
USDA Food and Nutrient Database (FNDDS), 1.0	SUDAAN was used to adjust for survey design effects resulting from NHANES' complex, multi-stage, probability sampling	EI:BMRest
USDA Food and Nutrient Database (FNDDS), 2.0	Nusser method using C-SIDE (Iowa State University)	“
USDA Food and Nutrient Database (FNDDS), 3.0	NCI method	“
USDA Food and Nutrient Database (FNDDS), 4.1	“	“
USDA Food and Nutrient Database (FNDDS), 5.0	“	“
USDA Nutrient database for standard reference, University of California Food composition database, Tabla de composición de alimentos para uso en América Latina (PAHO, INCAP), Tablas de composición de alimentos mexicanos del Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Tablas de valor nutritivo de los alimentos de mayor consumo en México, Food composition and nutrition tables (Souci, Fachmann & Kraut)	n/a	n/a
n/a	n/a	n/a
Nutrition Coordination Center Nutrient Databank (Nutrition Data System for Research - NDSR, Minneapolis), Brazilian Food Composition Table (TACO)	Nusser method using C-SIDE (Iowa State University)	Not applied
Food Composition Table for China (ed. 1991)	n/a	n/a
“	“	“
“	“	“
“	“	“
“	“	“
Food Composition Table for China (ed. 2002)	“	“
Food Composition Table for China (ed. 2004)	“	“
“	“	“
Standard Tables of Food Composition in Japan	n/a	n/a
Food composition table from the National Rural Living Science Institute	Nusser method using C-SIDE (Iowa State University)	Not applied
“	“	“
“	“	“
“	“	“
“	“	“
“	“	“
USDA Food Database, Canadian Food Database, Mexico Food Database, Malaysian Food Composition Tables (all available in Nutritionist Pro), Singapore Food Composition Guide, ASEAN Food Composition Tables, and The China Food Composition Tables	n/a	EI:BMRest
NNS nutrient composition database AUSNUT (1995) developed by the Australia New Zealand Food Authority (ANZFA)	Adjustment for within-person variability using the equation put forward by the US National Academy of Science (NAS) Subcommittee on Criteria for Dietary Evaluation (1986)	EI:BMRest
New Zealand Food Composition Database (NZFCD), FOODfiles electronic subset of data from the NZFCD, NUTTAB Food Composition Tables (Australia), McCance and Widdowson's Composition of Foods and other international data as required	Nusser method using C-SIDE (Iowa State University)	Not applied
“	“	“

Table 7: Recruitment and training of the interviewers in national nutrition surveys per continent

Continent *Country*	Survey name	Year(s)	Recruitment criteria interviewers
Africa			
Nigeria	Nigeria Food Consumption and Nutrition Survey (NFCNS)	2001-2003	n/a
North-America			
Canada	Canadian Community Health Survey - Nutrition (CCHS)	2004	Professional interviewers who work on a variety of surveys, full-time and part-time
United States	What we Eat in America (WWEIA), National Health and Nutrition Examination Survey (Continuous NHANES)	2001-2002	High School diploma required/BA preferred
		2003-2004	"
		2005-2006	"
		2007-2008	"
		2009-2010	"
Mexico	Mexican Health and Nutrition Survey 2006 (MHNS-06)	2005-2006	n/a
	Encuesta Nacional de Salud y Nutrición 2006 (ENSANUT 2006), Mexican Health and Nutrition Survey 2006 (MHNS-06)	2005-2006	n/a
South-America			
Brazil	Brazilian Individual Dietary Survey (IDS 2008-2009)	2008-2009	n/a
Asia			
China	China Health and Nutrition Survey (CHNS)	1989	Trained nutritionists
		1991	"
		1993	"
		1997	"
		2000	"
		2004	"
		2006	"
		2009	"
Japan	National Nutrition Survey in Japan (NNS-J)	2004-2007	Registered dietitians and dietitians for nutrition component of health survey
Korea	Korean National Health and Nutrition Examination Survey (KNHANES)	1998	Trained dietitians/nutritionists
		2001	"
		2005	"
		2007	"
		2008	"
		2009	"
Malaysia	Malaysian Adult Nutrition Survey (MANS)	2004	Nutritionists familiar with local food customs
Australasia			
Australia	National Nutrition Survey (NNS)	1995	Qualified nutritionists
New Zealand	New Zealand National Nutrition Survey (NNS97)	1996-1997	Trained interviewers familiar with local food customs passing an admission test
	New Zealand Adult Nutrition Survey (NZANS)	2008-2009	"

": ditto
n/a: not available

Number of interviewers (n)	Training material/Training topics	Training duration	Notes
4 teams of 2 interviewers per state (n total = 96)	n/a	n/a	
600	Software training, interview training	3,5 days	
n/a	Intensive training course and supervised practice interviews, periodic and annual retraining sessions	2 weeks	
“	“	“	
“	“	“	
“	“	“	
“	“	“	
n/a	n/a	n/a	
n/a	n/a	n/a	
n/a	Software training, training on contacting participants, interview training, datacollection skills	1 week	
160	Specific training in the collection of dietary data for field staff and office staff	3 days	
“	“	“	
“	“	“	
“	“	“	
“	“	“	
“	“	“	
“	“	“	
“	“	“	
n/a	n/a	n/a	
160	Training on contacting participants, interview training, datacollection skills	5 days	
100	“	3 days	
150	“	4 days	
10	“	11 days	A smaller number of well-trained dietitians were used after changing to the annual survey
12	“	10 days	
12	“	15 days	
n/a	Training on interviewing and probing skills, quantification of portion sizes of foods	n/a	
n/a	Intensive training and supervision of interviewers to reduce non-sampling errors	n/a	
n/a (every interviewer was assisted by one assistant)	Software training, training on contacting participants, interview training, datacollection skills and training on the use of the surveytools.	Interviewer: 2 weeks Assistant: 2 days	Additional training was provided at the regional level every two months. Pacific interviewers and assistants were trained to survey non-English speaking Pacific and Asian immigrant groups.
22	“	2 weeks	Additional training was provided at the regional level every three months. Pacific interviewers and assistants were trained to survey non-English speaking Pacific and Asian immigrant groups.

Discussion

In this chapter, an inventory of methodological aspects related to the performance of national food consumption surveys is presented. The inventory comprises a total of twenty nine food consumption surveys performed in eleven countries from five continents. In five countries (Canada, US, Mexico, China and Korea), the FCS was part of a larger health examination survey from which three (US, China and Korea) have been continuous programs. When surveys were not part of a larger health examination survey, the overview shows that questionnaires on health and physical activity were often still included.

The most common approach to assess dietary intake was the use of replicate 24-HDR in combination with an FFQ. In most countries, replicate 24-HDR interviews were administered to subsamples ranging from <10% to 30% of the total sample. For instance, in 2002, the Korean National Nutrition Survey by Season (KNNSS) was conducted in which an additional 24-HDR was administered to a subsample of KNHANES over three subsequent seasons to offset seasonal variation in food intake (Kim, Shim, Paik, Song, & Joung, 2011). Duplicate and triplicate 24-HDR were administered to all participants in the US and China respectively. A single 24-HDR without additional FFQ was used in Nigeria and Mexico (NNS-1999). In the most recent Mexican Health and Nutrition survey (MHNS-06), the 24-HDR was replaced by a semi-quantitative FFQ that was used to assess frequencies of consumption during the past seven days (Barquera, S. et al., 2008). This FFQ included the 95% most consumed foods reported in the 24-HDR collected in the previous survey (MNS-99) (Barquera, S. et al., 2010). Two countries used a dietary record to assess intakes (Brazil and Japan). However, a research group under the auspices of the Japanese Ministry of Health, Labour and Welfare suggested to transfer the method currently in use from a semi-weighed dietary record combined with an FFQ to the 24-HDR making international comparisons possible (Tokudome, Nishi, & Tanaka, 2012). Regardless of the DIA methods used, administration took place most often in the participant's home providing the major advantage for interviewers to verify food packages or household measures in their home if this could help them to obtain more detailed information. In a study performed by Huybrechts et al. (2011), participants of the EFCOVAL project were asked to indicate their preferred location for a future 24-HDR interview. Forty nine percent of the subjects would prefer the study centre (versus 22% at home and 10% at work) if the interview was face-to-face and 63% would prefer to be at home for a telephone interview (compared with 11% at work). The high number of subjects that preferred the study centre for face-to-face interview might be explained because the EFCOVAL protocol required a visit to the study centre to collect blood samples and to provide participants with material for 24-h urine collections.

A large variety of portion size estimation tools was used in the different surveys ranging from three-dimensional aids like food models, cups, spoons and thickness sticks to two-dimensional albums or booklets depicting either photographs of foods, plates and glasses, or drawings of glasses, mugs and bowls (USDA food model booklet). The USDA Food Model Booklet was also adapted to create the USDA Food Models for Estimating Portions available for nutrition educators, consumers, and researchers to use outside the context of the fully computerized Automated Multiple-Pass Method (AMPM) (U.S. Department of Agriculture, 2007). The AMPM is a validated 5-step computerized dietary recall instrument developed by USDA and used in the "What We Eat in America" survey, the dietary intake interview component of the U.S. National Health and Nutrition Examination Survey (NHANES) (Blanton, Moshfegh, Baer, & Kretsch, 2006; Moshfegh et al., 2008). Computer Assisted Interview (CAI) software is frequently used in national nutrition surveys because it allows structured and standardized collection of dietary intake data. The present overview shows that several countries use USDA-based CAI software and food classification. The leading role of this department is not surprising given its long history that goes back to 1892 (Ahuja, Moshfegh, Holden, & Harris, 2013). Like North America, Europe has harmonized its CAI software for future standardized pan-European food consumption surveys (Ocke et al., 2011). The EPIC-Soft program, originally developed for the EPIC Study by the International Agency for research on Cancer (IARC), has been validated (Crispim, Sandra P., de Vries, et al., 2011; Crispim, S. P., Geelen, et al., 2011) and adapted to fit the purpose of pan-European food consumption surveys (Slimani et al., 2011).

The current overview is the first in its kind to present a wide range of methodological aspects associated with national food consumption surveys across multiple continents. Although substantial efforts have been made to make a comprehensive overview, it is inevitable that some information was not captured. For instance, on the African continent, several countries have performed nutrition and monitoring surveys in the past 25 years, nonetheless, they are not included in the present overview because reports were not available in English. This artefact, referred to as language bias (Higgins & Green, 2011), may also be the case for other countries. In South Africa, the first of a series of nutrition and health examination survey (SANHANES-1) was planned in 2012 (Labadarios, 2011; Human Sciences Research Council, 2012), and therefore, not included in the present overview. For developing countries the focus of nutrition or health monitoring surveys is mostly on estimating prevalences of malnutrition and aspects related to food security. Because individual quantitative dietary intake surveys are expensive and difficult to implement, the FAO Dietary Diversity questionnaire has been developed as a simple proxy to measure access to food at the household level

(Hoddinott & Yisehac, 2002) and micronutrient adequacy in women's and children's diets at the individual level (Working Group on Infant and Young Child Feeding Indicators, 2006; Arimond et al., 2010).

Recruitment criteria for interviewers in national nutrition surveys are different between Asia and North America. In all Asian countries presented in the overview, interviews were conducted by either qualified/registered dietitians or nutritionists. In Japan, no interview was performed since dietary records were used, however, dietitians were recruited for data entry. In Canada and US it was not mandatory that the interviewers be dietitians or nutritionists. Both surveys rely either on professional interviewers involved in a variety of surveys or survey staff with a given minimal educational qualification, complemented with specific software and interview training. The duration of the training provided to interviewers varied across all available surveys from 2 days to 15 days (median duration: 7.5 days).

This overview shows that the methods used for dietary intake assessment in national nutrition surveys is rather similar across continents. The most frequently used method is the 24-HDR, sometimes administered repeatedly to correct for within-person variability, and mostly using interview software. Nevertheless, caution is still warranted when comparing results from food surveys between countries because of differences in conversion factors used for calculating nutrients (e.g. energy, protein, etc.). A variety of errors are introduced because many national or regional food composition tables or databases contain incomplete, outdated and unreliable data, or, countries borrow data from publicly available databases and neighbouring countries when such tables or databases are unavailable or inadequate (FAO, 2013).

Notwithstanding the growing consensus about the use of the 24-HDR methodology in food consumption surveys, the assessment remains self-reported. The most accurate and precise method for measuring energy expenditure is the doubly labelled water (DLW) method (Schoeller, 2002). In weight stable conditions, one can expect that energy intake equals energy expenditure; hence, DLW is used in studies examining the validity of energy intake assessment. Such validation studies have indicated that the prevalence of energy underreporting in self-reported methods was about 30% (range: 12%-67%), and the magnitude of underestimation of energy intake was roughly 15% (range: 7-20%) (Hill & Davies, 2001; Trabulsi & Schoeller, 2001; Poslusna, Ruprich, de Vries, Jakubikova, & van't Veer, 2009). These reporting errors vary between men and women and are generally higher among overweight and obese subjects (Moshfegh et al., 2008).

Conclusions

Although the 24-HDR is the best method available to monitor dietary intakes of free-living subjects in large samples, it also has limitations and future research remains necessary to explore and develop methods that help us to measure dietary intake of populations and subgroups. For national FCS it is recommended to combine different DIA methods (replicate 24-HDR and FFQ). For purposes of comparability of surveys, standardized procedures for sampling and data collection are required and a detailed description of the methods used should be included when reporting results. The inventory used in this chapter can serve as a guide to check if all methodological aspects related to the performance of a FCS are stated in such reports.

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General discussion

The principal aims of this dissertation were to examine the validity of instruments used in the Belgian food consumption survey and to further the scientific knowledge in the domain of nutrition research methodology on an international level, considering also the importance of harmonization. More specifically, in the first part of this work, the relative validity of the EPIC-Soft guided 24-HDR, the associated picture book with photographs of foods used for portion size estimation, and, the short food frequency questionnaire were investigated in a Belgian sample. The second part focused on the use of specific biochemical markers in validation studies on a European level. The final part provided an overview of the dietary assessment methods used for nutritional surveillance on a global scale.

As a comprehensive discussion linked to the individual studies can be found in the respective chapters, this discussion section offers the reader a short summary of their main findings. Then, some methodological considerations are raised, and recommendations for policy and future research are given. Finally, a general conclusion is formulated.

Main findings

Validity of 24-hour recall using EPIC-Soft

The Belgian version of the EPIC-Soft guided 24-HDR was evaluated for energy misreporting using accelerometry data. Estimated nutrients from the 24-HDR were also compared with those obtained from a 5-day EDR and urinary recovery of nitrogen, potassium and sodium.

Energy

The degree of energy misreporting was assessed in a subsample (*n*=76) by comparison of energy intake using a 24-HDR against TEE calculated from accelerometer data. For duplicate 24-HDR, the overall percentage of energy under-reporters, acceptable reporters and over-reporters was 17.1%, 64.5% and 18.4%, respectively. Under-reporting of energy intake was significantly higher in women (26.3%) compared to men (7.9%; $\chi^2(2)= 6.361$, $P= 0.042$). For subjects classified as under-reporters (*n*= 13), median energy underreporting was 52% in men and 42% in women.

Protein

The mean (SE) daily protein intake (g) estimated from the EDR and 24-HDR was for men 92.3 (4.6) and 96.8 (5.1), and for women 72.9 (2.3) and 64.6 (3.7), respectively (*n* = 51, adults). The mean (SE) daily protein intake and excretion (g) estimated from

24-HDR and urinary nitrogen for men was 101.7 (3.3) and 110.8 (3.2); and 79.0 (2.5) and 87.5 (2.6) for women (BE, *n*= 123). When comparing the 24-HDR to urinary nitrogen, underestimation was 8.2% and 9.7% for protein in men and women, respectively.

Potassium

The mean (SE) daily potassium intake (mg) estimated from the EDR and 24-HDR was 3461 (172) and 3661 (200) for men, and 2858 (116) and 2550 (194) for women (*n* = 51, adults). The mean (SE) daily potassium intake and excretion (mg) estimated from 24-HDR and urinary potassium was 4024 (131) and 4301 (148) for men, and 3513 (148) and 3928 (138) for women (BE, *n*= 123). When comparing the 24-HDR to urinary potassium, underestimation was 6.4% and 10.5% for men and women, respectively.

Sodium

Considerable underestimation of dietary sodium intake both at population and group level was found when using the EPIC-Soft version that does not specifically ask for salt content of reported foods. Reporting accuracy (95% CI) of dietary sodium, assessed using a duplicate 24-HDR taking into account salt adjustment for discretionary salt use compared to excreted sodium (24-h urinary sodium/0.9), was 0.68 (0.63-0.73) for Belgium, 0.76 (0.71-0.82) for Norway, and 0.80 (0.74-0.85) for Czech Republic. The salt adjustment procedure increased reporting accuracy, however, not to satisfying levels.

Portion size estimation

The portion size estimation study in this work addressed several psychological constructs necessary for portion size estimation. Nonetheless, separating these constructs to identify their related errors was shown to remain difficult. Ultimately, the objective of the study was to imitate the actual context in which the food photographs are used and to describe the size of errors in portion size estimation, given that context. For the Belgian food consumption survey this context is recalling portion sizes after one or two days.

The results obtained showed tendency for underestimation for all foods investigated except for margarine, which was highly overestimated. Since consumption of bread was underestimated, the amount of margarine spread on bread was also underestimated. Correcting the estimated amount of margarine for propagated errors in bread consumption estimation increased overestimation of margarine from 94.7% to 111.9%.

The implications of the estimation errors presented are dependent on the context in which the portion size estimation aid is used, whether it will be in the context of nutritional surveillance or epidemiology. For nutritional surveillance, the absolute level of consumption for the population is relevant. Looking at the data for beverages presented in this work, this would mean a rather small underestimation of coffee and water of 1.7% and 3.4%, respectively. For bread and margarine on bread, estimation errors were found to be higher (-8.7% and 111.9% respectively). For epidemiological association studies, the ranking of participants rather than the absolute amount is important. If Spearman's rank correlations between consumed and estimated weights were examined, the opposite was found suggesting a higher validity of the food photographs for bread and margarine on bread compared to coffee and water.

Food frequency questionnaire

The purpose of the short FFQ is to be used in the context of nutritional surveillance (i.e. food consumption surveys), complementary to a repeated 24-HDR interview. It thus provides policy makers with a quick instrument to screen consumption behaviour of the population, and to detect zero consumers necessary for proper estimation of food intake distributions from more detailed dietary interviews. The qualitative FFQ showed a fair to moderate agreement in ranking participants towards their food intake compared to a 7-day EDR. Considerable differences were found across gender and age categories with respect to the FFQ's ability to correctly rank participants according to their usual intake. Acceptable ranking of participants by the FFQ was demonstrated for beverages, fruit, milk and soy products, cheese, alcoholic beverages, fried restgroup foods and fats.

Food groups for which relative validity turned out rather low were typical carbohydrate containing food groups like bread and cereals, and potatoes and grains. A possible explanation for bread and cereals might be that bread is likely to be consumed more than once a day with large differences in portion sizes between participants which is not reflected by the FFQ, and, especially in the older age category, breakfast cereals are consumed less frequently. For food groups with low validity more detailed questionnaires, containing more food items, may be needed to accurately assess actual food consumption. On the other hand, the trade-off between adding items for improvement of validity and longer questionnaires, which in turn can affect participation rate, should be kept in mind.

In the study presented in chapter 3, the ability of the FFQ to correctly rank participants according to their food intake was assessed using a 7-day EDR. Although reporting errors between both instruments are uncorrelated, the EDR covers only a short period of time. Although a 7-day EDR accounts for considerable day-to-day variation of dietary intake, seasonal variation is not reflected. Since the time frame that the FFQ covers was 12 months prior to completion, a collection of four 7-day EDR, one in every season, would have been more suitable in order to capture seasonal variation of intake.

24-h urine collections

Measures from duplicate 24-h urine collections were used to develop a prediction model for estimating UCE to serve as an indicator for detecting incomplete urine collections. PABA was used as a reference and is assumed to correctly identify incomplete urines. The UCE prediction model was able to explain up to 76% of the variance in urinary creatinine excretion using gender, age, weight and gender*weight as independent variables. Although 93.5% of the observed urinary creatinine values from a first urine collection fell within 95% CI of the model predictions from a second collection, the sensitivity of the ratio of observed to predicted creatinine was very low. The study showed that when exclusion of urine collections was based on urinary creatinine excretion, a large part of incomplete collections remains unidentified because of low sensitivity, resulting in an underestimation of urine-based analytes used during further analysis.

Comparison of food consumption surveys

The most common approach to assess dietary intake is the use of replicate 24-HDR in combination with an FFQ. Often, replicate 24-HDR interviews are administered either on the total sample or subsamples to correct for within-person variability. Administration of the dietary intake assessment most often takes place in the participant's home, providing interviewers with the major advantage to be able to verify actual food packages or household measures. CAI software is frequently used in national nutrition surveys as it allows structured and standardized collection of dietary intake data. Nevertheless, caution is warranted when comparing results from food surveys between countries because of differences in conversion factors used for calculating nutrients (e.g. energy, protein, etc.).

Methodological considerations

Relative validity

The 7-day and 5-day EDR were chosen as a relative reference method because of their acceptable level of accuracy in dietary intake assessment compared to other methods (Bingham et al., 1995). Moreover, the measurement errors of the EDR and the

24-HDR or FFQ are independent since, unlike the 24-HDR or FFQ, the EDR does not depend on memory and involves immediate estimation of portion sizes. This independency of errors will hold only when participants are in fact registering foods and drinks immediately when consumed. If a participant completes his dietary record at the end of the day, or worse, after a couple of days, the principal advantage of an EDR is lost. Therefore, instructions for participants on how to complete a food diary should stress the importance of immediate recording when consuming foods or drinks.

Prevalence of energy underreporting for both the 24-HDR and EDR in the present study was quite similar to that reported in the literature (Poslusna, Ruprich, de Vries, Jakubikova, & van't Veer, 2009). Also, underreporting prevalences were found to be higher in women in previous publications (Hirvonen, Mannisto, Roos, & Pietinen, 1997; Price, Paul, Cole, & Wadsworth, 1997; Asbeck et al., 2002). Possibly, the significantly lower underreporting rate in men versus women using the 24-HDR can be attributed to an interviewer guided recall in men providing more complete daily intakes than those based on self-reported food records.

As documented by the international comparison of food consumption surveys, there is consensus about the use of the 24-HDR methodology as principal dietary intake instrument, nevertheless, the assessment is based on self-reporting. The most accurate and precise method for measuring energy expenditure is the doubly labelled water (DLW) method (Schoeller, D. A., 2002). In healthy weight stable conditions, energy intake can be expected to equal energy expenditure; hence, DLW is used in studies examining the validity of energy intake assessment. However, DLW could not be used in the present studies due to restrictions in financial means and experience. Validity studies using DLW have found energy underreporting prevalences in self-reported methods to be 30% (range: 12%-67%), while underestimation of energy intakes was roughly calculated as 15% (range: 7-20%) (Hill & Davies, 2001; Trabulsi & Schoeller, 2001; Poslusna et al., 2009). These reporting errors vary between men and women and are generally higher among overweight and obese subjects (Moshfegh et al., 2008).

Energy misreporting was investigated in a subsample using the well-tested CSA accelerometry (Melanson & Freedson, 1995; Freedson, Melanson, & Sirard, 1998; Sirard, Melanson, Li, & Freedson, 2000) and has been shown to correlate significantly with DLW-derived energy expenditure estimations (Ainslie, Reilly, & Westerterp, 2003; Plasqui & Westerterp, 2007). Nevertheless, not all physical activity can be translated into acceleration or deceleration resulting in errors in predicted energy expenditure, especially in high intensity activity (Ainslie et al., 2003). In addition, CSA sensors have been suggested to not be sufficiently sensitive to quantify energy expenditure in free-living individuals (Bassett et al., 2000).

Generalization of energy, protein, potassium and sodium results to other nutrients of interest should be done with care. Although we might want to assume that the validation results of single nutrients can be used as a proxy to other nutrients, there is evidence nowadays that some foods, and consequently related nutrients, might be selectively misreported (Pryer, Vrijheid, Nichols, Kiggins, & Elliott, 1997; Rumpler, Kramer, Rhodes, Moshfegh, & Paul, 2008). Besides, only two days of 24-HDR were used while the inclusion of more than two days may be necessary to improve the use of this 24-HDR in the assessment of other nutrient intake distributions (Palaniappan, Cue, Payette, & Gray-Donald, 2003).

Study samples

Participating in a study with a large battery of methods tested is very demanding and needs motivation. Therefore, it is likely that characteristics of participants are different than those from non-participants. In total, three different samples were used: 1) validity study of the 24-HDR and short FFQ used during the first Belgian food consumption survey using estimated food records and accelerometry as relative reference (*n*= 175; men and women; 15 years and over; three age categories) (see chapter 1 and 3), 2) validity study of food photographs used for portion size estimation (*n*= 111; men and women; 45-65 years) (see chapter 2), and 3) European Food Consumption Validation - EFCOVAL study (*n*= 600; men and women, 45-65 years, 5 European countries) (see chapter 4 and 6; in chapter 5 a subsample of EFCOVAL was used, *n*= 365).

In terms of BMI-category, all samples except that of the Belgian food consumption validation study were well in line with the general population (figures were within 10% difference per BMI category for normal weight, overweight and obese). In the sample of the Belgian food consumption validation study, the prevalence of overweight persons was lower and the prevalence of normal weight participants was higher than that of the general population. The percentage of participants classified as obese were comparable to that in the general population (12 and 14%, respectively). Consequently, this observation may indicate that a sampling bias is present weakening the generalizability of the instrument's performance in a national nutrition survey context. Previous studies have documented differential underreporting of energy and protein intake by overweight and obese individuals (Heerstrass, Ocke, Bueno-de-Mesquita, Peeters, & Seidell, 1998; Lissner et al., 2007). Also, analysis from EFCOVAL data showed that BMI predicted most of the bias in protein and potassium intake and largely explained the variation of bias across centres (Crispim et al., 2012).

It is very hard to compare educational level of the samples to that of the general population because there is a large age dependency (with increasing age the prevalence of lowest educational level also increases in Belgium). Educational level of the sample from the Belgium food consumption validation study (35%, 40% and 25% for low, intermediate and high education, respectively) and that from the food photography study (40%, 20% and 40% for low, intermediate and high education, respectively) does not deviate much from that of the general population in Belgium (40%, 35% and 25% for low, intermediate and high education, respectively). The Belgian sample used in the EFCOVAL study deviates largely in terms of educational distribution from that of the general population, especially when age of the participants is considered. In the age category 50+, the percentages of the general Belgian population with low, intermediate and high education level is 65%, 20% and 15%, respectively. For the Belgian EFCOVAL sample, educational distribution was 16%, 25% and 60% for low, intermediate and high education, respectively. In a study among a North Swedish sample, energy intake from a 24-HDR was divided by estimated basal metabolic rate and a cut-off of 1.2 was used to identify underreporting. It was found that high BMI but not education biased food recording (Johansson, Wikman, Ahren, Hallmans, & Johansson, 2001). In a large US doubly labeled water study, higher BMI and higher education levels were associated with higher odds of underreporting using a 24-HDR in men (Tooze et al., 2004). Due to the convenience sampling approach, participants included in the different strata are a selected group of the population and not a population based random sample. Also, no upper age limit was set for inclusion into the study; therefore, some participants were older than 80 years (15% of the oldest age category). It was suggested by Rothenberg (2009) that elderly up to the age of 80 perform well in reporting their food habits retrospectively and that from the age of 80, elderly tend to report food habits earlier in life.

The sample used for portion size estimation had sufficient statistical power to demonstrate statistically significant differences between actual and estimated portion sizes. Also, factors like gender and BMI were taken into account and reflected the characteristics of the population included in dietary surveys in Belgium. It was decided to investigate a narrow age group (45-65 years) to match the age group used during the EFCOVAL study and to limit the heterogeneity of the sample in order to control variation in age-related estimation errors.

The five selected samples used in the EFCOVAL study may not be representative for their respective country populations because they can be expected to consist of health-conscious and motivated subjects who could have learned about the type of assessment because urine collections and therefore also 24-HDR over the same days had to be planned. However, almost no variation in protein and potassium biases of the 24-HDR using EPIC-Soft was observed across the centres. In addition, it was suggested that the group-level bias in protein intake for both genders and potassium intake for women did not vary across centres and to a certain extent varied for potassium intake in men (Crispim et al., 2012). Post hoc power analysis (with alpha 0.05 and power 80%) of foods with no significant differences between actual and estimated portion size showed that the degree of difference in portion size detectable given the sample size was 25ml for coffee and 75ml for water or 11% and 20% of actual consumed portions for coffee and water, respectively.

Food composition data

It has been recognized in the EU that important benefits could result from harmonizing food composition data across member states. These benefits include improved quality, availability and compatibility of nutrient data (Egan et al., 2007). Food composition databases have generally been compiled as independent national activities to meet local requirements for calculation nutrient intakes. This has made it difficult to use national databases internationally. An inventory on the comparability of a number of European food composition databases showed that national food composition tables and databases are not sufficiently standardized with nutrients differing in definition, analytical methods, units and mode of expression (Deharveng et al., 1999). Furthermore, this can result in significant artificial differences in calculating nutrient and energy supply and intakes (Charrondière et al., 2002).

The recognition of the need to improve the harmonization of analytical laboratory methods, definitions and mode of expression of nutrients and the compatibility and comparability of international FCDB has led to the development of a number of collaborations and networks over the past 30 years, including the International Network of Food Data Systems (INFOODS), COST Action 99, and the European Food Information Resource Network of Excellence (EuroFIR, http://www.eurofir.net). The EUROFIR project has recently led to an updated food composition database for nutrient intake (Roe et al., 2013). In the absence of an existing standardized European FCDB for nutritional epidemiology and as a pre-requisite for pooled diet-disease analyses at the EU level, the European Prospective Investigation into Cancer and Nutrition (EPIC) Nutrient DataBase (ENDB) was developed for use in the EPICstudy (Slimani et al., 2007).

Policy recommendations

In Belgium, national food consumption surveys are not regularly performed. The very first nationwide nutrition and health survey was the Belgian Interuniversity Research on Nutrition and Health (BIRNH study), a large longitudinal epidemiological study for which nutrition and health related data was gathered in the period between 1979 and 1984. Dietary intake was assessed using a one-day food record. A total of 11.302 Belgians participated in the study (Kornitzer & Dramaix, 1989). The first Belgian food consumption survey among a representative sample of 3200 participants was performed in 2004. Food intake was collected using repeated non-consecutive 24-HDR (face-to face) in combination with a food frequency questionnaire (De Vriese et al., 2005).

In 2000, the WHO Regional Committee for Europe endorsed the First Action Plan for Food and Nutrition Policy, WHO European Region 2000-2005 (WHO, 2001). All 51 member states of the WHO European Region were represented and agreed to implement the guidelines proposed in the action plan. By 2004, however, national nutrition action plans were operational in only 6 of the 15 EU Member States, while another 4 were in the pipeline. A study performed by Lachat et al. (2005) found that, in general, the available action plans were in agreement with the international recommendations. By the end of 2005, a National Food and Health Plan for Belgium 2005-2010 was launched (Federal Public Service on Health Food Chain Safety and Environment, 2005). Policy developments over the past few years indicated how to strategically adapt and renew the First Action Plan for Food and Nutrition Policy, resulting in the WHO European Action Plan for Food and Nutrition Policy 2007-2012 (WHO, 2008). During the WHO European Ministerial Conference, held in Vienna July 2013, the Vienna Declaration on Nutrition and Non-communicable Diseases in the Context of Health 2020 was signed. Among the priority areas on which political and strategic efforts were to be intensified was the support on "*surveillance, monitoring, evaluation and research of the population's nutritional status and behaviours by consolidating, fine-tuning and scaling up existing national and international monitoring and surveillance systems, and ensuring the transparency and accessibility of data to promote new research*" (WHO, 2013).

It is acknowledged by the National Food and Health Plan for Belgium that a national food consumption survey should be repeated on a regular basis in order to evaluate the effects of targeted interventions. The currently planned national food consumption survey should already have been performed. It was, however, postponed due to the major Belgian political crisis in 2011 (Europolitics, 2011, December 11th). The anticipated time of data collection for this national food consumption survey, which is to include children as well, is 2014. It is recommended to perform a national food consumption survey every 2 to 5 years comprising all age groups. Alternatively, a continuous food consumption survey with alternating targeted age groups, as performed in the Netherlands, could be considered also.

Finally, the Belgian food composition database Nubel needs further development. Although its number of nutrients has increased – in the last version omega 3 and 6 fatty acids, selenium and vitamin D were added – the inclusion of additional food compounds (e.g. bioactive compounds like vitamin K, phytosterols and flavonoids) is strongly advised in order to secure intake assessments of these compounds by the Belgian population (Patil, Jayaprakasha, Chidambara Murthy, & Vikram, 2009). Also, the source of the analytic values and the number of data points on which the figures are based should be made available. As the use of inadequate food composition data may lead to erroneous research results, wrong policy decisions, misleading food labels, false health claims and inadequate food choices, developing and maintaining food composition tables or databases is a challenging but indispensable future investment (FAO, 2013).

Recommendations for future research

Based on the findings from this dissertation, some directions for future research can be raised. First, procedures to estimate dietary sodium intake using EPIC-Soft could be developed. For the Belgian version of EPIC-Soft, inclusion of salt use in composite meals and recipes should be investigated. Also, facets and descriptors related to salt content of foods and discretionary salt use can be developed in EPIC-Soft. The addition of 24-h urine collections to the protocol of the national food consumption survey could serve as an opportunity to further validate adapted versions of the dietary intake assessment methods used.

Validity of portion size estimation using pictures and drawings from the EPIC-Soft picture book should be further investigated. Especially for margarine spread on bread, large overestimation was found for the current set of photographs. Hence, a study on the validity of photographs showing smaller amounts of margarine spread on bread is therefore recommended. The study presented in chapter 2 is complex and time consuming since recall and portion size estimation of consumed foods was evaluated. Perhaps, only perception testing of other photographs from the EPIC-Soft picture book than those studied here may already unveil problems in portion size estimation of specific photographs.

The validity of some food groups present in the short FFQ was limited and needs further investigation. The food groups bread and cereals, and, potatoes and grains had poor ranking agreement with the 7-day EDR. For bread and cereals it should be investigated if the addition of the amount of food corresponding to one serving improves its ranking agreement. Also, the standard amount of one serving of bread could be increased. For the moment, this amount corresponds with the weight of one slice of bread. It is however not clear for the participant whether the frequency of consumption of bread refers to one slice or a sandwich which usually consists of two slices. The intake of potatoes and grains is overestimated by the FFQ. This food group consists of boiled potatoes, rice and pasta which are asked as single foods. Although grouping of items has been shown to lead to an underestimation of intake (Serdula et al., 1992), it has also been shown that increasing the number of items can lead to an overestimation of intake (Krebssmith, Heimendinger, Subar, Patterson, & Pivonka, 1995). The FFQ could be improved by the inclusion of an instruction. For potatoes and grains, this could be done by declaring that, typically, the total number of consumed portions over one week should proximate seven.

As presented in chapter 7 and 8, there is international agreement about the use of the 24-HDR methodology in food consumption surveys. Nevertheless, with the introduction of new validated tools for estimating food intake like remote sensing devices (Sazonov et al., 2010; Dong, Hoover, Scisco, & Muth, 2012), remote food photography (Daugherty et al., 2012; Martin et al., 2012), or cameras worn around the neck to capture point-of-view images in response to movement, heat and light (Gemming, Doherty, Kelly, Utter, & Ni Mhurchu, 2013), future research should be targeted toward applying, improving, and extending these methods for measuring energy intake in free-living persons (Illner et al., 2012; Schoeller, Dale A et al., 2013).

Only a selection of biomarkers is available to evaluate actual intake from dietary intake assessments. Therefore, exploration and development of new biomarkers would be very welcome. Suitable biomarkers for evaluating the assessment of other nutrients, foods and chemical substances have to be searched (Hedrick et al., 2012). A possible option is the further development of the new class of predictive biomarkers, as has been recently proposed for assessing sugar intake (Tasevska, Runswick, McTaggart, & Bingham, 2005; Joosen, Kuhnle, Runswick, & Bingham, 2008; Schoeller, D. A., 2013). Also, flavonoids offer a wide range of compounds for which associations between intake and excretion/serum level need further research. Although some flavonoids like polyphenols have been studied (Perez-Jiminez, et al., 2010; Spencer, et al., 2008), both the complex relationship between dietary intakes and nutritional biomarkers and the very large number of compounds available make this field of research extremely challenging. For all new candidate biomarkers investigated there should be an explanation for the correlation between intake and biomarker; a clear dose–response relationship should be established using dietary intervention studies;

there should be detailed information about the limitations of the biomarker (like saturation effects or limitation to a subgroup of the population); and; there should be information about the analytical methods used to analyse the biomarker (Kuhnle, 2012). In addition, a possible useful field for developing biomarkers may be that of the nutritional metabonomics for evaluating dietary patterns (Jenab, Slimani, Bictash, Ferrari, & Bingham, 2009).

Last, it would be valuable to simulate the cumulative effect of the estimation errors associated with the 24-HDR methodology found in this work on estimated total nutrient intake of the Belgian population using data from the 2004 Belgian food consumption survey. Since post collection data manipulation is extensive for EPIC-Soft, this work would require substantial efforts and time and was therefore beyond the scope of this dissertation.

Practical recommendations

In this paragraph, some practical recommendations for future Belgian food consumption surveys are provided. Obviously, results from future research highlighted in the previous paragraph will also have their practical implications in upcoming food consumption surveys.

First, it is advised to collect biological samples like 24h-urine in future food consumption surveys enabling calibration of nutrient intakes to those obtained from dietary biomarkers like nitrogen, potassium and sodium. Because of the logistic complexity, respondent burden, and high cost of conducting 24-h urine collections in a national survey, collections in a subsample could be considered. Also, timed-spot urine samples have been evaluated as a low burden and low cost alternative to the 24-h collection for estimating intakes at the population level, however, their validity for some nutrients remains problematic (Wang et al., 2013).

Second, since EFSA has initiated the first pan-European food consumption survey to be carried out in the EU ("What's on the Menu in Europe?" - EU Menu), further national implementation of harmonized procedures associated with the EU MENU project is recommended. In fact, EFSA supports organizations of EU Member States carrying out dietary surveys at national level provided that a number of minimum methodological requirements are met. These include that the food classification system and related levels of detail of the food consumption data should be described and made compatible with the EFSA FoodEx2 food classification system (IARC, 2013). Also, national participation to the customization of the EPIC-Soft databases and training of interviewers, which is considered as an integrated component of the overall standardization process, will be essential. A full e-Standardized Methodological Platform (e-SMP) will be made available to support countries during these implementations. The e-SMP is a new research tool developed by IARC allowing the implementation, collection, handling and analyses of dietary information in a standardized, efficient and sustainable way within and between countries (IARC, 2013).

A third and final recommendation is related to the estimation of usual intake distributions. Because many consumers do not consume all foods every day, days of zero intakes are present if the 24-HDR happens to be on a non-consumption day. Even when replicate 24-HDR are available, usual intake estimation of such foods remains difficult (Kipnis et al., 2009). To overcome this problem, an additional food frequency questionnaire that queries the propensity to consume a food over the past year is helpful (Subar et al., 2006). In the previous Belgian FCS, the Nusser method was applied using the C-Side program to estimate distributions of usual intake of foods and nutrients. (Nusser, Carriquiry, Dodd, & Fuller, 1996; Iowa State University, 1997). In the frame of the EFCOVAL project, a web-based statistics package for estimating usual dietary intake was developed (Harttig, Haubrock, Knuppel, Boeing, & Consortium, 2011). The Multiple Source Method (MSM) is characterized by a two-part shrinkage technique applied to residuals of two regression models, one for the positive daily intake data and one for the event of consumption. The method can make use of covariate information such as consumption frequency information from an FFQ to improve the modelling of consumption probability and intake amount. The MSM website provides a program package allowing scientists to calculate usual dietary intakes by combining short-term and long-term measurements (multiple sources). The program is hosted on a website of the German Institute of Human nutrition (DIFE) and can be accessed at https://nugo.dife.de/msm (German Institute of Human Nutrition, 2009).

General conclusion

In this dissertation methodological aspects associated with dietary intake assessment during the Belgian food consumption survey were investigated and evaluated from an international perspective. Also, a review of methods involved in national or regional food consumption surveys performed worldwide was performed. Clearly, no method is free of measurement errors and the challenge is to find the most optimal method to reach proposed study aims, taking into account availability of time, budget, respondent burden and logistics. For the dietary intake component of a food consumption survey, this implies in many occasions the use of multiple instruments. The results and findings presented in this work can be used during interpretation of results obtained from the Belgian food consumption surveys and serve as a guide for the conceptualization, implementation and development of instruments during future validity studies.

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Executive summary

There is a major emphasis in the European Union, as in many other parts of the world, to encourage a healthier and safer living among its citizens. Diet and nutrition are important factors in the promotion and maintenance of good health throughout the entire life course and scientific evidence increasingly supports the view that alterations in diet have strong effects on health. However, currently no harmonized food consumption information is available at the EU level. Although many European countries have standardized methods to obtain information on food consumption, comparability is hampered due to methodological differences. Access to uniform food consumption data is fundamental for several functions of the European authorities and other stakeholders. This information supports dietary monitoring needed for planning, implementing and evaluating nutrition and public health policies. It also enables development and evaluation of prevention activities targeted at reducing health epidemics (e.g. overweight and obesity, type 2 diabetes) and is mandatory for research on associations of food intake and dietary and health behaviour patterns with acute and chronic disease risks.

At EU level there are currently no requirements with regard to the national collection of food consumption data on the individual level. Nevertheless, national or regional dietary surveys are already performed in many European countries and provide valuable information for use in national policy and are central in their nutritional surveillance programs.

In Belgium, the most recent food consumption survey dates from 2004. The methods used for dietary intake assessment were in line with those recommended by the European food consumption survey methods consortium (EFCOSUM). This implies the collection of two non-consecutive 24-hour dietary recalls (24-HDR) reflecting short-term dietary intake, complemented with a food frequency questionnaire (FFQ) for long-term assessment on consumption frequencies of selected foods.

The principal aim of this dissertation is to investigate the validity of instruments used in dietary intake assessment of food consumption surveys. From these findings, practical recommendations for the Belgian food consumption survey, policy recommendations and directions for future research are formulated. The general introduction provides the reader with a succinct background on dietary assessment methods and validation research. Next, the relative validity of the 24-HDR, the FFQ and a selection of food photographs used for portion size estimation was assessed in a sample representing the Belgian population. Then, urinary biomarkers across different EU countries were taken to assess the validity of the 24-HDR in estimating dietary protein, potassium and sodium intake, and, to assess the usefulness of urinary creatinine for detecting incomplete 24-hour urine collections. This work, performed at the European level, was performed in close collaboration with the European food consumption validation consortium (EFCOVAL[1]) . Finally, an extensive overview of methodological aspects associated with dietary intake assessment used during food consumption surveys in Europe and the rest of the world was compiled placing the European strategies and methods for harmonized collection of food consumption data in a global perspective.

More women than men (26% vs. 8%) were classified as energy under-reporter when intakes from two non-consecutive 24-HDR were compared to total energy expenditure measured by accelerometry. Compared to urinary biomarkers, two 24-HDR underestimated protein intake by 8% and 10% in Belgian men and women respectively. Potassium intake was underestimated by 6% and 11% in Belgian men and women respectively. Reporting accuracy (95% CI) of dietary sodium calculated as the ratio of sodium intake to excretion (24-h urinary sodium/0.9), taking into account salt adjustment for discretionary salt use, was 0.68 (0.63-0.73) (Belgian data).

Food level intake estimated from the FFQ was compared to 7-day estimated diet records. For fruit, fish, fried foods and fats, no systematic bias was present, hence, for these food groups, the FFQ appears to be reasonably valid for assessment of group level intakes in both genders and across different age categories. However, for the food groups bread and cereals, potatoes and grains, and sauces, poor ranking agreement between both methods was present indicating that the FFQ is not able to rank individuals properly for these food groups given the assumption that a 7-day EDR is an unbiased instrument for measurement of usual intake.

Errors in portion size estimation using food photographs were observed during both perception and conceptualization by participants. Underestimation of consumed portion size was present for bread (-9%), coffee (-2%) and water (-3%) (% difference of mean). Consumption of margarine spread on bread was highly overestimated (+95%). When participants were presented with photographs, actual weights of squared slices of bread were underestimated by 3-10% and oval slices were overestimated by 14%. All presented portions of margarine spread on bread were systematically overestimated. Errors were largest for smallest portions and declined with increasing portion size (+175% to +21%).

1. The need to standardise food consumption data has been addressed in several European projects. The EU-funded EFCOSUM project (1999-2002) and its successor, EFCOVAL (2006-2010), worked toward the development of a method for a European food consumption survey that delivers cross-country comparable individual food consumption data.

When biomarkers from 24-h urine collections are used in validation studies of dietary assessment methods, it is clearly inappropriate to use incomplete urine collections. Two markers are available to check for complete urine collections; urinary creatinine excretion (UCE) and para-Aminobenzoic acid (PABA). A multiple linear regression model using urinary analytes from a large European sample showed that UCE can be predicted from readily available subject information like gender, weight and age (adjusted r^2= 0.76). However, both the prediction-based as a traditional creatinine index were unable to detect incomplete urine collections when compared to PABA given their sensitivity of 0.08 (0.03-0.17) and 0.49 (0.34-0.63) respectively.

An inventory of experiences and methodological aspects related to dietary intake assessment in the context of food consumption surveys was made. In total, 33 food consumption surveys of 15 countries from Europe, Africa, Asia, North- and South-America and Australasia were included in the overview. On all continents, the most common approach to assess dietary intake was the use of replicate 24-HDR complemented with an FFQ. Generally, replicate 24-HDR interviews (face-to-face or telephone) were administered either on the total sample or subsamples to correct for within-person variability and to properly asses the number of non-consumers in order to estimate intake distributions of episodically consumed foods. Computer assisted interview software was frequently used in allowing structured and standardized collection of dietary intake data. Mostly, interviews took place in the participant's home providing interviewers with the major advantage to be able to verify actual food packages or household measures.

The dissertation is completed with a general discussion and recommendations for policy, directions for future research and practical implications for the Belgian food consumption survey are provided.

Samenvatting

Een belangrijke taak van de Europese Unie is het aanmoedigen van een gezonde en veilige levensstijl bij de bevolking. Voeding is een belangrijke factor bij de ontwikkeling en het behoud van een goede gezondheid gedurende de ganse levensloop en toenemend wetenschappelijk bewijs toont aan dat wijzigingen in voedingsgewoonten belangrijke effecten hebben op de gezondheid. Momenteel is er echter geen eenvormigheid in de manier waarop voedselconsumptiegegevens in de verschillende Europese landen verzameld wordt. Nochtans is toegang tot dergelijke uniforme gegevens van fundamenteel belang voor verschillende taken die de Europese overheden en andere belanghebbenden op zich dienen te nemen, zoals het plannen, uitvoeren en evalueren van een degelijk voedings- en gezondheidsbeleid. Bovendien vormen voedselconsumptiegegevens de basis voor het ontwerpen en evalueren van preventiecampagnes gericht op het terugdringen van ziekten, zoals overgewicht en obesitas, en diabetes type 2. Ze zijn tevens essentieel in het onderzoek naar de associaties tussen voedingsinname en eet- en leefgewoonten, en het risico op het ontwikkelen van acute of chronische ziekten.

Europa stelt momenteel geen eisen aan haar lidstaten met betrekking tot het verzamelen van nationale voedselconsumptiegegevens. Toch worden in een groot aantal Europese landen al nationale of regionale voedselconsumptiepeilingen uitgevoerd, die waardevolle informatie bieden voor en een centrale plaats innemen in de uitwerking van nationale voedings- en gezondheidsprogramma's.

In België dateert de meest recente voedselconsumptiepeiling uit 2004. De methode die daarbij gebruikt werd voor het schatten van de voedselinname was toen al in overeenstemming met de aanbevelingen van het European Food Consumption Survey Methods (EFCOSUM) consortium. Deze aanbevolen methode omvat het verzamelen van twee niet-opeenvolgende 24-uurs voedingsnavragen (24-hour dietary recall, 24-HDR) die peilen naar de voedselconsumptie gedurende de vorige dag, aangevuld met een voedselfrequentie vragenlijst (food frequency questionnaire, FFQ) dat de consumptiefrequenties van een selectie voedingsmiddelen gedurende het voorbije jaar in kaart brengt.

De voornaamste doelstelling van dit proefschrift is de validiteit te onderzoeken van methoden die gebruikt worden voor het meten van voedselinname bij voedselconsumptiepeilingen. Uit de bevindingen volgen beleidsaanbevelingen en praktische

1 De harmonisatie van voedselconsumptiepeilingen in Europa werd onderzocht in verschillende Europese projecten. De door de EU gefinancierde projecten EFCOSUM (1999-2002) en EFCOVAL (2006-2010) werkten aan de ontwikkeling van methoden om in Europese lidstaten voedselconsumptiegegevens te verzamelen die methodologisch vergelijkbaar zijn.

adviezen voor de Belgische voedselconsumptiepeiling, en suggesties voor verder onderzoek. De algemene inleiding geeft de lezer een beknopt overzicht van de verschillende methoden om voedselinname te meten en van de huidige kennis aangaande validatieonderzoek. Ze wordt gevolgd door de voorstelling van onderzoeksresultaten betreffende de relatieve validiteit van de 24-HDR, de FFQ, en van een selectie van afbeeldingen die gebruikt worden voor het schatten van portiegroottes. Vervolgens worden de resultaten weergegeven van een Europese studie waarin, aan de hand van biologische merkers uit urine, de validiteit van de 24-HDR werd onderzocht bij het schatten van de inname van eiwitten, kalium en natrium, en het nut van urinair creatinine in de detectie van onvolledige 24-uurs urine collecties. Dit werk werd uitgevoerd in het kader van een Europese studie in nauwe samenwerking met het European Food Consumption Validation (EFCOVAL) consortium[1]. Tot slot volgt een uitgebreide inventarisatie van methodologische aspecten bij de uitvoering van voedselconsumptiepeilingen wereldwijd om zo de Europese strategieën en methoden voor een geharmoniseerde verzameling van voedselconsumptiegegevens in een mondiaal perspectief te plaatsen.

Meer vrouwen dan mannen (26% versus 8%; n=76) rapporteerden een lagere energie-inname aan de hand van twee niet-opeenvolgende 24-HDRs dan wanneer hun totale energieverbruik gemeten werd door accelerometrie. Vergeleken met de urinaire biologische merkers, leverden twee 24-HDRs een onderschatting van de eiwitinname met 8% bij de Belgische mannen en 10% bij de vrouwen. Kaliuminname werd onderschat met 6% bij Belgische mannen en 11% bij de vrouwen. De verhouding (95% BI) geschatte natriuminname/urinaire natriumexcretie (24-h urinair natrium/0.9) bedroeg 0,68 (0,63-0,73) voor de Belgische steekproef binnen EFCOVAL.

De inname van voedingsmiddelengroepen op basis van een FFQ werd eveneens vergeleken met deze van een 7-daags geschat eetdagboek. Voor de voedingsmiddelengroepen fruit, vis, gefrituurde voedingsmiddelen en vetten werden geen systematische afwijkingen gedetecteerd. Voor deze groepen van voedingsmiddelen blijkt de FFQ in staat om op groepsniveau de inname accuraat te schatten, dit zowel voor beide geslachten als voor de verschillende bestudeerde leeftijdscategorieën. Echter, voor de voedingsmiddelengroepen brood en ontbijtgranen, aardappelen en granen, en sauzen was de overeenkomst tussen beide methoden laag en bleek de FFQ niet in staat is om personen correct te rangschikken volgens inname.

Bij het gebruik van afbeeldingen om portiegroottes te schatten werden fouten waargenomen bij zowel conceptualisatie als perceptie van de tweedimensionale beelden. De werkelijk geconsumeerde porties voedingsmiddelen (conceptualisatie) werden onderschat: -9% voor brood, -2% voor koffie en -3% voor water (gemiddeld procentueel verschil). De consumptie van margarine op brood werd overschat met 95%. Wanneer deelnemers gevraagd werd om afbeeldingen van portiegroottes naast gepresenteerde voedingsmiddelen te plaatsen (perceptie) werd het werkelijk gewicht van vierkante sneetjes brood onderschat met 3-10%, afhankelijk van de grootte, en werden ovale sneden overschat met 14%. Alle gepresenteerde hoeveelheden margarine op brood werden systematisch overschat. De fouten waren het grootst voor de kleinste porties en namen af met toenemende portiegrootte (+175% tot +21%).

Indien biologische merkers uit 24-uurs urine collecties worden gebruikt in validatiestudies is het belangrijk om over volledige urinecollecties te beschikken. Twee merkers zijn beschikbaar om de volledigheid van een urinecollectie te controleren, namelijk creatinine excretie in de urine (UCE) en toediening van para-aminobenzoezuur (PABA). Een meervoudig lineair regressiemodel met data van een grote Europese steekproef bleek in staat te zijn om UCE te voorspellen op basis van gemakkelijk beschikbare informatie zoals geslacht, lichaamsgewicht en leeftijd (adjusted R^2 = 0,76). Zowel de voorspelde UCE als een in de literatuur beschreven creatinine index bleken echter niet in staat om de onvolledige urinecollecties te detecteren in vergelijking met PABA, met een respectieve gevoeligheid van 0,08 (0,03-0,17) versus 0,49 (0,34-0,63).

In dit proefschrift wordt een inventarisatie geboden van methodologische aspecten bij de uitvoering van voedselconsumptiepeilingen. Het overzicht omvat 33 voedselconsumptiepeilingen van 15 landen uit Europa, Afrika, Azië, Noord- en Zuid-Amerika en Oceanië. Op alle continenten bleek de herhaalde 24-HDR de meest gebruikte methode om voedselinname te schatten, aangevuld met een FFQ. De 24-HDR werden doorgaans herhaald (face-to-face of telefonisch), hetzij bij de totale steekproef hetzij bij een selectie van de steekproef. Deze herhalingen hebben als doel te corrigeren voor de binnen-persoons variatie van inname om zo de gebruikelijke inname adequaat te schatten. Vaak werd software gebruikt om de interviews af te nemen, waardoor gegevens op een gestructureerde en gestandaardiseerde wijze verzameld worden. De interviews vonden meestal plaats in de woning van de deelnemers waardoor interviewers het aanzienlijk voordeel geboden werd om verpakkingen en gebruikte huishoudmaten te verifiëren.

Het proefschrift wordt afgesloten met een algemene discussie en aanbevelingen voor beleid, suggesties voor verder onderzoek en praktische adviezen voor de Belgische voedselconsumptiepeiling.

Addenda

List of Abbreviations

24-HDR, 24-hour dietary recall;

Adj., adjusted;

AMPM, Automated Multiple-Pass Method;

BE, Belgium;

BMI, body mass index;

CAI, computer assisted interview;

CAPI, computer assisted personal interview;

CI, confidence interval;

CV, coefficient of variation;

CZ, Czech Republic;

DFCS, Dutch food consumption survey;

DIA, dietary intake assessment;

DLW, doubly labelled water;

DRNA, dietary sodium intake;

EDR, estimated dietary record;

EFCOSUM, European Food Consumption Survey Methods;

EFCOVAL, European Food Consumption Validation;

EFSA, European Food Safety Authority;

EI, energy intake;

EPIC, European Prospective Investigation into Cancer and Nutrition;

EU Menu, "What's on the menu in Europe?";

FAO, food and agriculture organisation of the United Nations;

FCDB, food composition database;

FCS, food consumption survey;

FCT, food composition table;

FFQ, food frequency questionnaire;

FR, France;

IARC, International Agency for Research on Cancer;

LA, linoleic acid;

LR+, positive likelihood ratio;

MEC, mobile examination centre;

MET, metabolic equivalent;

MSM, multiple source method;

MUFA, mono-unsaturated fatty acids;

n/a, not available;

NHANES, National Health and Nutrition Examination Survey;

NL, the Netherlands;

NO, Norway;

ns, not significant;

PABA, *para*-Aminobenzoic acid;

PR, participation rate;

PSU, primary sampling unit;

PUFA, poly-unsaturated fatty acids;

RCT, randomized control trial;

SD, standard deviation;

SE, sensitivity <u>or</u> standard error;

SFA, saturated fatty acids;

Sign, significance;

SP, specificity;

TEE, total energy expenditure;

UCE, urinary creatinine excretion;

UN, United Nations;

URNA, urinary sodium excretion;

USDA, United States department of agriculture;

WHO, World Health Organization;

WWEIA, What We Eat in America.

Short food frequency questionnaire

Voedselfrequentie-vragenlijst

Gelieve onderstaande vooraf aandachtig te lezen.

Hoe deze vragenlijst in te vullen:

Duid in de tabellen op de volgende pagina's aan hoe vaak u de vermelde producten eet.
Denk hierbij aan uw gemiddelde over een volledig jaar.

Ter verduidelijking wordt een voorbeeld uitgewerkt:

Voorbeeld 1: U eet nooit andijvie

Voorbeeld 2: U eet in het seizoen (mei-juni) ongeveer 2 maal per week asperges
Als u dit over een gans jaar bekijkt, komt dit neer op een gemiddelde van 8 tot 10 maal per jaar.
U kruist het vakje "Minder dan 1 dag per maand" aan.

Voorbeeld 3: U eet gemiddeld om de twee dagen een appel.
U kruist het vakje "2-4 dagen per week" aan.

Duid <u>slechts één</u> keuze aan voor elke vraag.

EX.01. Hoe vaak eet u:

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
01 Andijvie	●	○	○	○	○	○	○	○	○
02 Asperges	○	●	○	○	○	○	○	○	○
03 Appels	○	○	○	○	●	○	○	○	○

41833

Het algemene voedingspatroon

FFQ.01. **In onderstaande tabel staat een hele reeks voedingsmiddelen(groepen). Probeer (zo exact mogelijk) weer te geven hoe vaak u de opgesomde producten eet of drinkt. Denk hierbij aan uw gemiddelde over een <u>volledig jaar</u>.**

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
01 Water (leidingwater, flessenwater,...)	○	○	○	○	○	○	○	○	○
02 Koffie, thee	○	○	○	○	○	○	○	○	○
03 Fruitsap, groentensap	○	○	○	○	○	○	○	○	○
04 Light-frisdranken	○	○	○	○	○	○	○	○	○
05 Frisdranken	○	○	○	○	○	○	○	○	○
06 Sportdranken (Isotar, Aquarius,...)	○	○	○	○	○	○	○	○	○
07 Pepdranken (Redbull,...)	○	○	○	○	○	○	○	○	○
08 Wijn (ook champagne en schuimwijn)	○	○	○	○	○	○	○	○	○
09 Bier (ook alcoholarm bier)	○	○	○	○	○	○	○	○	○
10 Sterke dranken (Whisky, Cognac,...)	○	○	○	○	○	○	○	○	○
11 Andere alcoholische dranken (porto, cider, aperitieven,...)	○	○	○	○	○	○	○	○	○
12 Sojadranken, sojadesserts	○	○	○	○	○	○	○	○	○

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
13 Melk in koffie of thee	○	○	○	○	○	○	○	○	○
14 Melk (ook karnemelk, chocolademelk,...)	○	○	○	○	○	○	○	○	○
15 Yoghurt, platte kaas	○	○	○	○	○	○	○	○	○
16 Snoep, chocolade (ook candybars bv. Mars,...)	○	○	○	○	○	○	○	○	○
17 Koeken	○	○	○	○	○	○	○	○	○
18 Patisserie, koffiekoeken (fruittaartje, éclair, slagroomtaart, croissant,...)	○	○	○	○	○	○	○	○	○
19 Zaden, zadenpasta (zonnebloempitten, sesamzaden,...)	○	○	○	○	○	○	○	○	○
20 Noten, notenpasta (amandelnoten, pistachenoten, pindakaas,...)	○	○	○	○	○	○	○	○	○
21 Gedroogd, gekonfijt fruit	○	○	○	○	○	○	○	○	○
22 Fruit	○	○	○	○	○	○	○	○	○
23 Ontbijtgranen	○	○	○	○	○	○	○	○	○
24 Wit brood, witte broodproducten	○	○	○	○	○	○	○	○	○
25 Bruin/volkoren brood, bruine/volkoren broodproducten	○	○	○	○	○	○	○	○	○

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
26 Zoete toespijs	○	○	○	○	○	○	○	○	○
27 Kaas (geen platte kaas)	○	○	○	○	○	○	○	○	○
28 Viswaren (gerookte vis, vissalades, visconserven,...)	○	○	○	○	○	○	○	○	○
29 Vleeswaren / charcuterie (gerookte vleeswaren, vleessalades, vleesconserven,...)	○	○	○	○	○	○	○	○	○
30 Eieren	○	○	○	○	○	○	○	○	○
31 Vegetarische producten (tofu, quorn, tempé,...)	○	○	○	○	○	○	○	○	○
32 Schaal-, schelpdieren	○	○	○	○	○	○	○	○	○
33 Vis	○	○	○	○	○	○	○	○	○
34 Orgaanvlees (lever, niertjes,...)	○	○	○	○	○	○	○	○	○
35 Konijn en wild	○	○	○	○	○	○	○	○	○
36 Gevogelte	○	○	○	○	○	○	○	○	○
37 Vlees (schaap, rund, paard, varken,...)	○	○	○	○	○	○	○	○	○
38 Rijst	○	○	○	○	○	○	○	○	○

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
39 Pasta, deegwaren	○	○	○	○	○	○	○	○	○
40 Gefrituurde aardappelproducten (frieten, kroketten,...)	○	○	○	○	○	○	○	○	○
41 Gebakken aardappelen	○	○	○	○	○	○	○	○	○
42 Gekookte en gestoomde aardappelen, aardappelpuree	○	○	○	○	○	○	○	○	○
43 Peulvruchten (bonen, linzen, erwten,...)	○	○	○	○	○	○	○	○	○
44 Rauwe groenten	○	○	○	○	○	○	○	○	○
45 Bereid groenten	○	○	○	○	○	○	○	○	○
46 Chips en gefrituurde snacks (chips, borrelhapjes, kippennugget,...)	○	○	○	○	○	○	○	○	○
47 Sauzen op basis van mayonaise (tartaar, béarnaise, ...)	○	○	○	○	○	○	○	○	○
48 Ketchup	○	○	○	○	○	○	○	○	○

FFQ.02. Hoe vaak gebruikt u volgende vetstoffen om te smeren? Denk hierbij aan uw gemiddelde over een volledig jaar.

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
01 Margarine / minarine	○	○	○	○	○	○	○	○	○
02 Boter, reuzel, smout	○	○	○	○	○	○	○	○	○

41833

Rauwe voedingsmiddelen

FFQ.03. Hoe vaak eet u volgende rauwe voedingsmiddelen? Denk hierbij aan uw gemiddelde over een <u>volledig jaar</u>.

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	1 maal per dag	2-3 maal per dag	Meer dan 3 maal per dag
01 Rauwe oesters	O	O	O	O	O	O	O	O	O
02 Rauwe mosselen	O	O	O	O	O	O	O	O	O
03 Sushi	O	O	O	O	O	O	O	O	O
04 Gerookte visproducten	O	O	O	O	O	O	O	O	O
05 Garnalen	O	O	O	O	O	O	O	O	O
06 Steak tartare	O	O	O	O	O	O	O	O	O
07 Gehakt	O	O	O	O	O	O	O	O	O
08 Rauwe ongekookte melk (van de boerderij)	O	O	O	O	O	O	O	O	O
09 Zelfgemaakte mayonaise	O	O	O	O	O	O	O	O	O
10 Zachte kaas op basis van rauwe melk (vb. Brie, Camembert,...)	O	O	O	O	O	O	O	O	O

41833

Het maaltijdenpatroon

FFQ.04. **Gelieve in onderstaande tabel aan te geven hoe vaak u de opgesomde maaltijden gebruikt.**
Opmerking:Een drankje alleen (bv.een kop melk, een kop koffie) kan niet als maaltijd beschouwd worden

	Nooit	Minder dan 1 dag per maand	1-3 dagen per maand	1 dag per week	2-4 dagen per week	5-6 dagen per week	elke dag
01 Een ontbijt	○	○	○	○	○	○	○
02 Een middagmaal	○	○	○	○	○	○	○
03 Een avondmaal	○	○	○	○	○	○	○

41833

Standard portions and food groups of FFQ

Standard portions of foods

Water: 200 ml

Koffie: 125 ml

Fruitsap: 200 ml

Light dranken: 200 ml

Frisdranken: 200 ml

Sportdranken: 250 ml

Pepdranken: 250 ml

Wijn: 125 ml

Bier: 250 ml

Sterke dranken: 42.5 ml

Andere dranken: 75 ml

Sojadranken: 250 ml

Koffiemelk: 7.5 ml

Melk: 200 ml

Yoghurt: 125 ml

Snoep: 55 g

Koek: 15 g

Taart: 110 g

Zaden: 20 g

Noten: 20 g

Gedroogd fruit: 20 g

Fruit: 125 g

Ontbijtgranen: 30 g

Brood, wit: 30 g

Brood, bruin: 30 g

Zoete toespijs: 30 g

Kaas: 20 g

Viswaren: 20 g

Vleeswaren: 20 g

Ei: 50g

Vegetarische producten: 75 g

Schaal- en schelpdieren: 150 g

Vis: 150 g

Orgaanvlees: 105 g

Vlees, wild: 150 g

Vlees, gevogelte: 130 g

Vlees: 105 g

Rijst: 175 g

Pasta: 210 g

Frieten: 225 g

Aardappelen, gebakken: 175 g

Aardappelen, gekookt: 175 g

Peulvruchten: 75 g

Groenten, rauw: 85 g

Groenten, bereid: 90 g

Chips: 30 g

Mayonnaise: 40 g

Ketchup: 40 g

Margarine: 10 g

Boter: 10 g

Grouping of individual foods to groups

Beverages= water + koffie + fruitsap + light dranken

Bread & cereals = ontbijtgranen + brood, wit + brood, bruin

Potatoes & grains = rijst + pasta + aardappelen, gekookt

Vegetables = peulvruchten + groenten, rauw + groenten, gekookt

Fruit = fruit

Milk & soy products = koffiemelk + melk + yoghurt + sojadranken

Cheese = kaas

Meat & eggs = vleeswaren + ei + vegetarische producten + orgaanvlees + vlees, wild + vlees, gevogelte + vlees

Fish = viswaren + schaal- en schelpdieren + vis

Alcoholic beverages = wijn + bier + sterke dranken + andere dranken

Restgroup food = snoep + koek + taart

Restgroup drinks = frisdrank + sportdrank + pepdrank

Fried restgroup foods = frieten + aardappelen, gebakken + chips

Sauces = mayonnaise + ketchup

Fats = margarine + boter

EFCOVAL salt questionnaire

EFCOVAL Questionnaire salt intake **Confidential**

Questionnaire for salt intake assessment

This questionnaire will be used by the EFCOVAL researchers to collect information about your salt usage.

1. Please state your name and first name

____

2. What is your date of birth?

DAY		MONTH		YEAR			

3. What is your gender?

- O Male
- O Female

PARTICIPANT N°				

4. For how many family members are the meals generally prepared?

___ (number)

5. Are you on a low-salt diet?

- ○ Yes
- ○ No

6. Do you usually use salt:

- ○ No, salt is not used, neither during preparation of meals nor by adding salt to the meals during consumption
- ○ Yes, I add salt to my meals during consumption, but salt is not used during preparation of meals
- ○ Yes, salt is used during preparation of meals, however I don't add salt to my meals during consumption
- ○ Yes, salt is used during preparation of meals and I add salt to my meals during consumption

7. How often do you (or a family member) buy salt?

- ○ Never
- ○ Once every 6 months or less
- ○ Once every 2 to 3 months
- ○ Less than once a month
- ○ Monthly
- ○ More than once every month
- ○ I don't know

8. How much salt do you (or a family member) buy in general when purchasing salt?

- ○ Less than 1 kg
- ○ 1 kg
- ○ Between 1 and 5 kg
- ○ More than 5 kg

- ○ I don't know
- ○ We don't buy salt

9. What type of salt do you (or a family member) generally use in the preparation of your meals?

- ○ Non iodised salt
- ○ Iodised salt
- ○ Other, namely:____________________
- ○ I don't know
- ○ Salt is not used during preparation of meals

Brand:___________________________
Quantity: __________ g

10. Is salt present on the dinner table (e.g. in a salt tube) during the consumption of meals?

- ○ Never
- ○ Occasionally
- ○ Often
- ○ Always
- ○ I don't know

11. What type of salt do you generally add to your meals during consumption

- ○ Non iodised salt
- ○ Iodised salt
- ○ Other, namely:____________________
- ○ I don't know
- ○ I don't add salt to my meals during consumption

Brand:___________________________
Quantity: __________ g

Outline Of The Epic-Soft Specifications Questionnaire

General information about respondent(s)

Specifications about the EPIC-Soft program

Specifications EPIC-Soft related tools and guidelines

Specifications about (visual) portion size estimation aids

Specifications about the reference guidelines/training courses

EPIC-Soft data handling and analyses

EPIC-Soft data analyses

Linking of food consumption data with:

Food composition tables

Raw agricultural crop databases

Databases including food contamination data

Other databases (like bio-active compounds)

EPIC-Soft use for diet optimization purposes

Logistics of studies using EPIC-Soft

EPIC-Soft logistics

Results from EPIC-Soft validation studies

EPIC-Soft validation study and/or inter-rater variability

Other aspects and literature

EPIC-Soft as data entry system

List of relevant publications

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Publications

Journal articles

A1 journals

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De Keyzer W., Huybrechts I., De Henauw S. Relative validity of repeated 24-hour recalls using EPIC-SOFT for estimating nutrient intakes among the Belgian population. (2009). 7th International Conference on Diet and Activity Methods (ICDAM 7), 5/06/09 → 7/06/09, Washington DC, United States.

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De Keyzer, W. (2009). Eindrapport PWO-project Ontwikkeling van een geïntegreerde tool ter ondersteuning van de diëtistenpraktijk. Hogeschool Gent, Gent.

de Looy, A. (editor), de Looy, A., Almeida de Souza, J., Bila, C., Boz Kegyes, R., Cuervo, M., De Keyzer, W., Favreau, A-M., Govers, E., Jager, M., Liddell, J., Nauman, E., & Van Ael, K. (2010). DIETS report 5: Quality Assurance, Dietetic Competence and Practice Placement Standards.

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Presentations

Oral presentations

De Keyzer, W. (2007). Opzoeken van wetenschappelijke informatie. Studiedag Hogeschool Gent, 25-mei-2007, Gent, Belgium.

De Keyzer W. (2008). Preparing students for practice placement learning. DIETS IInd conference, 25-sep-2008, Frankfurt, Germany.

De Keyzer W. (2009). Relative validity of repeated 24-hour recalls using EPIC-SOFT for estimating nutrient intakes among the Belgian population. 7th International Conference on Diet and Activity Methods (ICDAM 7), 6-jun-2009, Washington DC, United States.

De Keyzer W. (2010). Introductie in basisstatistiek. Medewerkersmeeting Hogeschool Gent Departement Gezondheidszorg Vesalius, 2-jul-2010, Gent, Belgium.

De Keyzer W. (2010). Op zoek naar wat waar is … . Evidence Based Practice, waar wetenschap en praktijk elkaar ontMOETen. Studiedag Vlaamse Beroepsvereniging van Voedingsdeskundigen en Diëtisten (VBVD), 25-maa-2010, Geel, Belgium.

De Keyzer W. (2011). Relative validity of a short qualitative food frequency questionnaire for national food consumption surveys (presentation given by Huybrechts I.). 11th European Nutrition Conference, 27-okt-2011, Madrid, Spain.

De Witte Nico, Labeau Sonia, De Keyzer Willem, D'haese Ivan. (2011). Beoordeling van de kwaliteit van stageplaatsen. Onderzoek naar de validiteit en betrouwbaarheid van CLES (Vlaamse versie), een instrument ter beoordeling van stageplaatsen in de verpleegkunde. LNO2-congres, Lerend Netwerk van Onderwijsondersteuners, Novotel, 19-mei-2011, Leuven, Belgium.

Poster presentations

De Keyzer Willem, Verschraegen Mia, Callewaert Nele, De Henauw Stefaan, Debourdeaudhuij I. (2005). Ontwikkeling van een geïntegreerde softwaretool ter ondersteuning van de diëtistenpraktijk. 8e Voedings- en Gezondheidscongres. 18/11/05 → 19/11/05 - Brussel, België.

Callewaert Nele, De Keyzer Willem, Verschraegen Mia. (2006). Heeft de huidige diëtistenpraktijk nood aan een geïntegreerde software tool? 9e Voedings- en Gezondheidscongres. 17/11/06 → 18/11/06 - Brussel, België.

Dohogne Sofie , Callewaert Nele, Vereecken Carine, De Keyzer Willem. (2008). Inschatten van portiegroottes met behulp van foto's: perceptie en conceptualisatie. 11e Voedings- en gezondheidscongres. 14/11/08 → 15/11/08 - Brussel, België.

De Keyzer, W., & De Witte, N. (2009). How well do caregivers detect malnutrition in elderly residents. 3rd DIETS (Dietitians Improving Education and Training Standards) Conference. 23/9/09 → 24/9/09 - Lisbon, Portugal.

De Keyzer, W., Bral, V., & De Witte, N. (2009). Caregivers' capability of detecting malnutrition in elderly residents. Wageningen Nutritional Sciences Forum: Too much, too little. 4/3/09 → 6/3/09 - Utrecht, The Netherlands.

De Keyzer Willem, Huybrechts Inge, De Maeyer Mieke, Ocké Marga, Slimani Nadia, van 't Veer Pieter, De Henauw Stefaan. (2010). Food photographs in nutritional surveillance: errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption. DIETS IVth Conference. 3/12/10 → 4/12/10 - Amsterdam, Nederland.

Van Caneghem Sven, Huybrechts Inge, De Keyzer Willem, Verschraegen Mia. (2010). Belgian city goes vegetarian on Thursday. DIETS IVth Conference. 3/12/10 → 4/12/10 - Amsterdam, Nederland.

De Wandel David, Labeau Sonia, De Keyzer Willem, Vogelaers Dirk, Blot, Stijn. (2011). Student nurses perceptions on hand hygiene: analysis of behavioral and environmental determinants. International Conference on Infection Prevention & Control. 29/06/11 → 2/07/11 - Genève, Zwitserland.

De Wandel David, Labeau Sonia, De Keyzer Willem, Vogelaers Dirk, Blot Stijn. (2011). Student nurses perceptions on hand hygiene: analysis of behavioral and environmental determinants. Eleventh Congress of the International Federation of Infection Control. 12/10/11 → 15/10/11 - Venetië, Italië.

Deriemaeker Peter; Clarys Peter, Deliens T, Huybrechts Inge, Vanaelst Barbara, De Keyzer Willem, Hebbelinck M, Mullie P. (2013). Diet quality of vegans, vegetarians, semi-vegetarians, pesco-vegetarians and omnivores. 16de Voedings- en gezondheidscongres. 22/11/13 → 23/11/13 - Brussel, België.

Participation in councils, boards, committees and networks

Councils

Research council – University College Ghent: 2014-
Faculty council of Education, Health and Social Work – University College Ghent: 2011-2012
Faculty council of Health Care – University College Ghent: 2007-2011

Boards

Program board professional bachelor in Nutrition and dietetics – University College Ghent: 2003-

Committees

Work group member Gezond bezig! – University College Ghent: 2012-

Networks

DIETS I Thematic Network (2006-2009): Dietitians Improving the Education and Training Standards work package member, key contact

DIETS II Thematic Network (2010-2013): Dietitians ensuring education, teaching and professional quality work package member, key contact
Nutrition society UK: 2007-
Belgian Nutrition Society: 2008-
Vlaamse Vereniging voor Klinische Voeding en Metabolisme (VVKVM): 2014-
The European Society for Clinical Nutrition and Metabolism (ESPEN): 2014-

Editorial work

Associate editor of Archives of Public Health - BioMedCentral

Activities as a referee

Reviewer for journals

Archives of Public Health
Biological Trace Element Research
British Journal of Nutrition
International Journal of Pediatric Obesity
Journal of Nutrition and Metabolism
Journal of the American College of Nutrition
Maternal & Child Nutrition
Obesity

Reviewer of research projects

Research project (PWO) Erasmus University College Brussels
Research projects (PWO) University College Ghent

Jury activities

Masters' thesis evaluation for Master of Science in Health Care Management and Policy – Ghent University
Masters' thesis evaluation for Master of Science in Physical Education and Sport Science – Vrije Universiteit Brussel

Educational activities

Promotor of dissertations

Bachelor level

Promotor of numerous dissertations of university college students in nutrition and dietetics

Master level

Copromotor of Master students in Biomedical sciences, Health Care Management and Policy, and Medicine

Overview of teached courses at bachelor level

Applied dietetics
Applied informatics
Applied statistics (exercise sessions)
Culinary techniques (theory, exercise sessions)
Dietary prescription products
Dietetics
Evidence-based research
Food additives
Food analysis methods (theory, laboratory sessions)
Food packages
Microbiology (theory, laboratory sessions)
Food microbiology (theory, laboratory sessions)
Nutritional science (theory, exercise sessions)
Research methods (theory, exercise sessions)

Additional professional information

Guest teacher in Erasmus teacher exchange program with Mikkeli Polytechnic, Mikkeli, Finland, 2011
International coordinator of the course program in nutrition and dietetics, 2006