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The Assessment of Individual Usual Food Intake in Large-Scale Prospective Studies

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Key Words

Dietary assessment • Dietary questionnaires • Dietary recalls • Epidemiologic studies • Food frequency questionnaire • Food intake • Large-scale studies on food intake • Statistical modelling

Abstract

Recent research has called into question the current practice to estimate individual usual food intake in large-scale studies. In such studies, usual food intake has been defined as diet over the past year. The aim of this review is to summarise the concepts of dietary assessment methods providing food intake data over this time period. A conceptualised framework is given to help researchers to understand the more recent developments to improve dietary assessment in large-scale prospective studies, and also to help to spot the gaps that need to be addressed in future methodological research. The conceptual framework illustrates the current options for the assessment of an individual's food consumption over 1 year. Ideally, a person's food intake on each day of this year should be assessed. Due to participants' burden, and organisational and financial constraints, however, the options are limited to directly requesting the long-term average (e.g. food frequency questionnaires), or selecting a few days with detailed food consumption measurements

(e.g. 24-hour dietary recalls) or using snapshot techniques (e.g. barcode scanning of purchases). It seems necessary and important to further evaluate the performance of statistical modelling of the individual usual food intake from all available sources. Future dietary assessment might profit from the growing prominence of internet and telecommunication technologies to further enhance the available data on food consumption for each study participant. Research is crucial to investigate the performance of innovative assessment tools. However, the self-reported nature of the data itself will always lead to bias. Copyright © 2010 S. Karger AG, Basel

Introduction

During the past decade, interest in the relationship between diet and the risk of chronic diseases has resulted in a substantial number of prospective epidemiological studies with emphasis on nutrition. Recently, limitations of commonly used dietary assessment methods – foremost the food frequency questionnaires (FFQs) – have been identified, calling into question their ability to explore the role of diet in chronic disease aetiology [1]. These recent developments have encouraged nutritional epidemiologists to critically evaluate and improve exist-

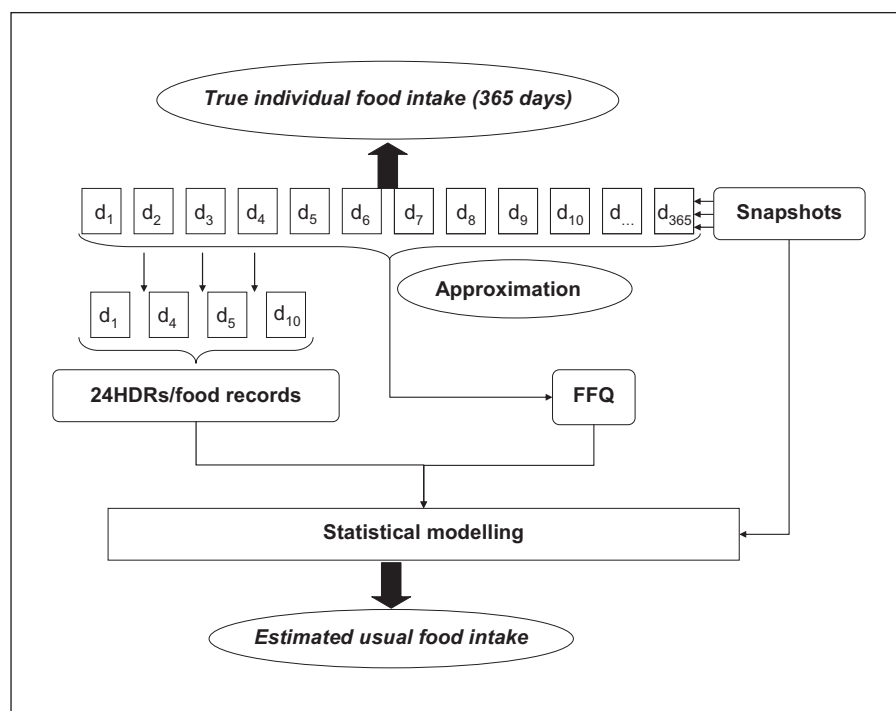


Fig. 1. Conceptual framework on dietary assessment for large-scale prospective studies (d: day; 24 HDRs: 24-hour dietary recalls; FFQ: Food frequency questionnaire).

ing dietary assessment methodology [2–5] and to explore new approaches [6].

We would like to contribute to the current discussion by conceptualising the recent advances in optimal estimation of individual usual food intake, and help to identify gaps that need to be addressed in methodological research. It is not intended to be a comprehensive review of the literature on dietary assessment instruments, as this has been done previously [7, 8]. Instead, we have focused on the qualifications of self-reported dietary assessment methods for the collection of valid data on individual food intake over 1 year, which is the time period often used as a proxy measure for long-term usual diets in large-scale prospective studies. Therefore, individual *usual food intake* is defined for our purposes as average food intake over 1 year.

Current Options for the Assessment of Food Intake

Ideally, complete assessment of a person’s usual food intake would consist of data collected each day of the year under study (fig. 1). However, this seems rather infeasible due to participants’ burden, and organisational and financial constraints. Alternatively, a part of the information of food intake is assessed, and subsequently extrapo-

lated or modelled to estimate individual usual food intake.

The most recent advances in estimating usual dietary intake originate from research into population distributions of food or nutrient intake within surveys which have largely been based on multiple 24-hour dietary recalls (24HDRs) [9, 10]. The assumption that simple averaging of multiple 24HDRs would adequately reflect average food intake during 1 year has been challenged. Further, several statistical methods have been introduced to estimate population distributions of intake [11, 12]. The latest innovation from the National Cancer Institute introduced an enhanced statistical method combining information from 24HDRs with additional covariate information, e.g. frequency information from a FFQ [9, 10]. The authors demonstrated how well dietary data of different sources, specifically quantitative data of multiple 24HDRs and data on ranking of study participants from a FFQ, can provide high-quality dietary information, particularly for the proper assessment of usual intake of foods that are not consumed every day [13].

Earlier approaches to combine information from several dietary assessment methods in prospective studies made use of calibration substudies. For example, linear regression calibration approaches regress the FFQ-derived data on 24HDRs data of a subgroup of the study

population and apply this regression equation to the total study population, thus shifting the mean of FFQ-data to the mean of the 24HDR-data and adjusting for random measurement errors [14]. An extension of this approach is the non-linear calibration accounting for the whole distribution of the reference instrument. It adopts the FFQ distribution not to a linear but to a non-linear distribution given by at least two 24HDRs per individual [15].

The intention to better estimate individual usual dietary intake by calibration, however, has to be differentiated from the intention to correct relative risk estimates using a calibration study [16–18], which is what the original theory for calibration in nutritional epidemiology aimed at.

At this point, we would like to take one step back and review the different sources of self-reported dietary information and their qualities and limitations in measuring individual usual food intake.

Well-known methods of recording dietary intake include the assessment of single days of the year (24HDRs or food records) or querying the habitual intake of a year (FFQs and diet histories; fig. 1). However, new methods have been developed that incorporate technological developments, such as photographs of meals or bar code scanning of food purchases.

Long-Term Approaches

The FFQ has long been considered the appropriate dietary assessment instrument in large-scale epidemiological studies due to its ability to rank participants at reasonable costs [19]. In 1980, it was introduced with the first large-scale cohort study on cancer incidence [20] as counterpart of approaches in the 1950s and 1960s applying preferably food records in small-scale prospective studies [21, 22].

Briefly, the FFQ queries participants to report the frequency of consumption and optionally portion size of a finite list of food items over a specified period of time in the recent past, generally the previous year. Efforts have been made to optimise the food list and the portion size information. Diet histories are similar instruments, which inquire food intake following a meal pattern throughout usual days, or simply more details about usual dietary habits in addition to the frequency and portion size information [23]. Both techniques assume that the study participant has some regularity in his diet and is able to report and quantify this regularity.

The FFQ design differs widely, conditioned by study population, number of items, response categories, inclusion of portion size questions, length, gender and age specificities or delivery format (web-based, face-to-face, telephone, or mail investigations) [24–29]. However, their assessment characteristics are similar.

High day-to-day variability in foods and micronutrient intake is still favouring the FFQ approach [8], although current research has demonstrated limitations regarding the presentation, construction and predictive validity of the FFQ leading some scientists to suggest that inconsistent findings of epidemiologic studies on diet and cancer are due to assessment errors by this instrument [2–5, 30, 31]. Since the limitations are associated with the instrument, the criticism is not restricted to cancer research but to all endpoints, including coronary heart disease and diabetes mellitus. However, particularly the failure of FFQs to detect risk associations to cancer is controversially discussed. Besides true but modest relationships that might be concealed by FFQs [32], a further possible explanation might be the long latency period assumed for this disease [33]. Still, FFQs have the ability to assess usual dietary intake via a single application, with low costs and easy administration. Additionally, web-based applications have the potential to alleviate some of the assessment errors inherent in FFQs, e.g. more cognitive support through interactivity or less missing data through facilitated data processing. Especially for younger study populations with often rapid changes in dietary behaviour [34], the potential beneficial effect of web-based FFQs might be apparent [28]. However, extensive validation research has not yet been conducted to evaluate these potential improvements.

Short-Term Approaches

The 24HDR is an interview that collects detailed information on all food and beverage consumed by a participant during the previous day [35]. The most sophisticated instruments prompt individuals to provide information on portion sizes, food preparation methods, recipe ingredients, brand names of commercial products and use of dietary supplements. Interviews were originally conducted face to face by pen and pencil [36], followed by both telephone or face-to-face interviews using computer programs [37, 38]. The Automated Multiple-Pass Method of the US Department of Agriculture is an example of a commonly used approach for 24HDR in US surveys [39] whereas the multi-language program EPIC-

SOFT is most commonly used within Europe [40]. Self-administered computer- and web-based versions are currently being developed [41] to overcome the potentially restrictive costs of highly trained interviewers and elaborate administration required to obtain high-quality data. However, whether the advantages of automated systems for probing, coding and analysis will outweigh potential disadvantages, such as a less representative sample because of the exclusion of non-literate subjects or subjects with less computer skills, is yet to be determined.

The food record is a detailed protocol of all foods and beverages consumed over a specific period of time, usually 3–7 days. Ideally, the recording is conducted at the time of food or beverage consumption to minimise dependence on memory and includes details on portion sizes (weighed or estimated), brand names, recipe ingredients, cooking methods and condiments. It is well established that participants react to recording their diet by changing their usual eating habits [7]. The performance of handwritten food records has been compared to their new counterparts, the electronic food records or personal digital assistants with camera, dictaphone or mobile phone, in children and adults [42–45]. Mobile phones as voice-recording devices for spoken diet records [46] or portable food records [45] are further innovative ideas suitable to reach low-literacy groups, adolescents and elderly, but like all new techniques of food records, application in large-scale studies is hampered in terms of costs and burden in training. There is evidence to indicate that traditional food records can be used within prospective cohort studies with less efforts and only small loss of information [47], diminishing both careful in-person training of subjects in methods of keeping accurate records and the time required to review the data by trained nutritionists. However, participant response remains a concern for all these methods.

Snapshot Techniques

For our purposes, a *snapshot* is defined as detailed information on dietary practise at a certain point in time, such as single meals or purchases [48] rather than complete dietary sequences like the diet throughout a day. The idea of using snapshots to characterise an individual's diet is mostly connected to new technologies such as mobile phones with camera or portable barcode readers with personal digital assistants. The use of these techniques goes far beyond paper-and-pencil techniques

and requires complex computer programs before data use. However, the use of such technologies gains considerable acceptance and might be easy to apply for the study participant [49]. Smart card technology methods showed effectiveness in measuring single meals and their components [50], whereas product code scanners provided useful information either on foods available for consumption [51] or on specific food groups indeed consumed, such as low-fat spreads and cooking fats [52]. However, research is needed on how snapshot techniques provide useful data for statistical modelling of food intake data.

Conclusions

None of the traditional dietary assessment instruments appears to be on its own suitable to assess individual usual food intake during 1 year in large-scale studies. 24HDRs and food records provide accurate data of single days in terms of dietary quantification, which has also been shown by close correspondence to objective biomarker data, but are expensive in use in large settings, and difficult to extrapolate to average usual food intake, mostly due to episodically consumed foods. FFQs are qualified tools to cover seasonal variations and might be superior to monitor rarely consumed foods, but are limited in the food lists and the provision of quantitative data as opposed to information on ranking. An advantage of traditional assessment methods, however, is that strengths and weaknesses have been characterised through past validation studies.

In general, the advent of modern technologies might foster the application of web-based tools instead of paper questionnaires and in-person interviews in future studies. Kristal et al. [5] calculated potential costs of using 24HDRs on a large-scale basis in traditional manner and illustrated that new technologies for data collection are needed.

However, despite the use of web-based tools, their methodology follows essentially the traditional dietary assessment methodology. In this context *snapshots* are different, but evidently not appropriate to solely assess individual usual food intake. It remains questionable, if the use of a new technology on its own improves dietary data assessment in prospective studies by substituting a traditional dietary assessment instrument.

Therefore, advances in statistical modelling ought to be pursued alongside new technologies, as the combination of data from different methods may optimise the

strengths of each approach whilst balancing their weaknesses [9, 13]. In particular, the inclusion of snapshot information in the estimation of individual usual food intake warrants further investigation [53]. As a further development of the above-mentioned method of the National Cancer Institute, a multiple-source method is currently being tested in our department which enables the estimation of individual usual food intake combining 24HDRs and FFQ-data, even for foods with a sizable percentage of non-consumers [54].

The limitations inherent in all self-reported dietary assessment methods have to be taken into consideration, as even innovative applications of traditional instruments and new statistical modelling can only partly adjust for random errors and probably not for measurement errors [55–58]. Under-/overreporting, particularly by overweight and obese subjects, has limited possibilities for correction [55, 59–62]. In addition, calibration studies using biomarkers warrant further investigation [63]. Their extended integration in future dietary assessment, including the use of statistical methods for combining data in large-scale prospective studies, seems to be promising

[64], but is still costly and challenging in terms of sample collection, incorporation in statistical analysis and data interpretation [65].

We are approaching a historically new period of research and practice in the dietary assessment methodology for large-scale prospective studies [31], similar as has been seen in the 1980s when the FFQ was introduced. The need for proper dietary assessment in large-scale epidemiological studies exists concurrently with the growing insight that such studies require substantial investments and long-term commitments of research and development institutions. Deriving individual usual food intake data from a combination of methods seems to be a promising approach, and its methodological value has to be further explored.

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