Chapter 1

Dietary Assessment Methodology

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I INTRODUCTION

This chapter is a revision of the similarly named chapter in the earlier editions [1–3] of this book, which itself was based on the "Dietary Assessment Resource Manual" [4] by Frances E. Thompson and Tim Byers, adapted with permission from the *Journal of Nutrition*. Dietary assessment encompasses food supply and production at the national level, food purchases at the household level, and food consumption at the individual level. This review focuses only on individual-level food intake. It is intended to serve as a resource for those who wish to assess diet in a research study, for example, to describe the intakes of a population, using individual measurements for group-level analysis. This chapter does not address clinical assessment of individuals for individual counseling. The first section reviews major dietary assessment methods, their advantages and disadvantages, and validity. The next sections describe which dietary assessment methods are most appropriate for different types of studies and for various types of populations. Finally, specific issues that relate to all methods are discussed.

II DIETARY ASSESSMENT METHODS

A Dietary Records

In the dietary record approach, the respondent records the foods and beverages and the amounts of each consumed over one or more days. Ideally, the recording is done at the time of the eating occasion in order to avoid reliance on memory. The amounts consumed may be measured, using a scale or household measures (e.g., cups or tablespoons), or estimated using models, pictures, or no aid. If multiple days are recorded, they are usually consecutive, and no more than 7 days are included. Recording periods of more than 4 consecutive days are usually unsatisfactory, as reported intakes decrease [5] due to respondent fatigue, and individuals who do comply may differ systematically from those who do not. Because the foods and amounts consumed on consecutive days of reporting may be related (e.g., leftovers and eating more one day and less the next day), it may be advantageous to collect nonconsecutive single-day records in order to increase representativeness of the individual's diet.

To complete a dietary record, each respondent must be trained in the level of detail required to adequately describe the foods and amounts consumed, including the name of the food (brand name, if possible), preparation methods, recipes for food mixtures, and portion sizes. In some studies, this is enhanced if the investigator contacts the respondent and reviews the report after 1 day of recording. At the end of the recording period, a trained interviewer should review the records with the respondent to clarify entries and to probe for forgotten foods [6]. Dietary records also can be recorded by someone other than the subject, such as parents reporting for their children.

The dietary record method has the potential for providing quantitatively accurate information on food consumed during the recording period [7]. By recording foods as they are consumed, the problem of omission may be lessened and the foods more fully described. Furthermore, reporting amounts of food as they are consumed should provide more accurate portion size information than if the respondents were recalling portion sizes of foods previously eaten.

Although intake data using dietary records are typically collected in an open-ended form, close-ended forms have also been developed [8–10]. These forms consist of listings of food groups; the respondent indicates whether that food group has been consumed. In format, these "checklist" forms resemble food frequency questionnaires

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(FFQs) (see Section II.C). Unlike FFQs, which generally query about intake over a specified time period such as the past year or month, checklists are intended to be filled out concurrently with actual intake or at the end of a day for that day's intake. A checklist can be developed to assess particular "core foods" that contribute substantially to intakes of some nutrients [11], and it also has been used to track food contaminants [12]. Portion size can also be asked, either in an open-ended manner or in categories.

A potential disadvantage of the dietary record method is that it is subject to bias both in the selection of the sample and in the sample's completion of the number of days recorded. Dietary record keeping requires that respondents or respondent proxies be both motivated and literate (except for photograph-based methods), which can potentially limit the method's use in some population groups (e.g., low literacy, recent immigrants, children, and some elderly). The requirements for cooperation in keeping records can limit who will respond, compromising the generalizability of the findings from the dietary records to the broader population from which the study sample was drawn. Research indicates that incomplete records increase significantly as more days of records are kept, and the validity of the collected information decreases in the later days of a 7-day recording period, in contrast to information collected in the earlier days [5]. Part of this decrease may occur because many respondents develop the practice of filling out the record retrospectively rather than concurrently. When respondents record only once per day, the record method becomes similar to the 24-hour dietary recall in terms of relying on memory rather than concurrent recording.

An important disadvantage of this method is that recording foods as they are being eaten can affect both the types of food chosen and the quantities consumed [13–15]. The knowledge that foods and amounts must be recorded and the demanding task of doing it may alter the dietary behaviors the tool is intended to measure [16], creating "reactivity bias." This effect is a weakness when the aim is to measure typical dietary behaviors. However, when the aim is to enhance awareness of dietary behaviors and change them, as in some intervention studies, this effect can be seen as an advantage [17]. Recording, by itself, is an effective weight loss technique [18,19]. Recent interest in "real-time" assessment has led to the development of numerous mobile "apps" for self-monitoring that enable concurrent recording and immediate, automated feedback. This approach generally has been found to improve self-monitoring and adherence to dietary goals compared with traditional paper-and-pencil dietary records [20,21].

A third disadvantage is that unless dietary records are collected electronically, the data can be burdensome to code and can lead to high personnel costs. Dietary assessment software that allows for easier data entry using common spellings of foods can save considerable time in data coding. Even with high-quality data entry, maintaining overall quality control for dietary records can be difficult because information often is not recorded consistently among different respondents, nor is the information coded consistently among different coders. This highlights the need for training of both the respondents and the coders.

Several approaches using a variety of technological advances have been used to allow easier data capture and less respondent burden; some may be particularly beneficial among low-literacy groups. For example, a computer-administered instrument allows the respondent to select the food consumed and the appropriate portion size from photographs on a screen [22,23]; this can be done using touch-screen technology [24]. The proliferation of mobile devices with cameras allows simultaneous photographic records of the foods selected [25]. However, for this approach to be quantifiable, before and after pictures of a consumption event and training of the participant in how to consistently take pictures using a standard reference object are required. Wearable cameras which can continuously take pictures or videos have been developed [26,27], lessening the burden on the respondent and potentially allaying some reactivity (i.e., changes in the respondent's behavior that are caused by the instrument). These methods have great potential to improve portion size accuracy.

Automated processing of the image information for these methods is not yet fully developed. The images that illustrate the beginning of the consumption event and its completion must be selected, the food has to be identified [28], and the mathematical properties of the food image need to be quantified [29] in order to develop an accurate estimate of the food's volume. However, if these problems can be solved, the foods can be linked to appropriate databases (see Section V.E), dramatically reducing the burden of coding [30]. In the meantime, the images could be identified manually by staff or the respondent in an accompanying application, and later coded.

Respondent burden and reactivity bias may be less pronounced for the "checklist" [31], because checking off a food item is easier than recording a complete description of the food [32], and the costs of data processing can be minimal, for example, paper forms that are machine scannable, or electronic forms on a computer or mobile device. Checklists are often developed to assess particular foods that contribute substantially to intakes of some nutrients. As the comprehensiveness of the nutrients to be assessed increases, the length of the form also increases, and it becomes more burdensome to complete at each eating occasion and may increase reactivity. Nonetheless, precoded food diaries to assess diet have been developed, evaluated, and used: the precoded food diary used in the 2005–08 Danish National Survey of Diet and Physical Activity contained about 400 items and portion size choices [33]; a precoded food diary used in Norway contained 277 items [34]. However, checklists are limited in their ability to assess the diet, because of lack of details on the particular food consumed, food preparation, portion sizes, and other relevant information.

Food records have been evaluated most frequently through comparison to another instrument, often 24-hour recalls. However, no self-report instrument is without reporting error, and thus relative validation is not necessarily useful. Instead, when possible, validation studies should consider using "recovery" biomarkers that are unbiased reference instruments. Only a few are currently available. These are total energy expenditure from doubly labeled water for energy [35], and protein (nitrogen) [36], potassium [37], and sodium based on 24-hour urine collections [38]. Many studies in selected small samples of adults indicate that reported energy and protein intakes on dietary records are underestimated in the range of 4–37% compared to energy expenditure as measured by doubly labeled water and protein intake as measured by urinary nitrogen [18,39–53]. In the largest doubly labeled water study using food records, with about 450 postmenopausal women in the Women's Health Initiative, energy and protein intakes reported on food records were underestimated by about 20% and 4%, respectively, and protein density (kcal of protein as a percentage of total kcal) was overestimated by about 17% [54]. Underreporting on dietary records is probably a result of the combined effects of incomplete and inaccurate recording and the impact of the recording process on dietary choices leading to undereating, and thus not typical of usual intake [18,48,55,56]. The highest levels of underreporting on dietary records have been found among individuals with greater body mass index (BMI) [41,43,44,54,57,58], particularly women [41,43,44,52,59–61]. This effect, however, may be due, in part, to the fact that overweight individuals are more likely to be dieting on any given individual day [62]. These relationships between underreporting and BMI and sex have also been found among elderly individuals [63]. Other research shows that demographic or psychological indices such as education, employment, social desirability, body image, or dietary restraint also may be important factors related to underreporting on diet records [41,48,60,61,64–67]. A few studies suggest that energy underreporters compared to others have reported intakes that are lower in absolute intake of most nutrients [58], higher in percentage of energy from protein [58,61], and lower in percentage of energy as carbohydrate [58,61,68,69] and in percentage of energy from fat [69]. Correspondingly, energy underreporters may report lower intakes of desserts, sweet baked goods, butter, and alcoholic beverages [58,69], but more grains, meats, salads, and vegetables [58]. Some research has examined the performance of food checklists relative to accelerometry [70] or, more commonly, complete dietary records [8,9,32], 24-hour dietary recalls [11], dietary history [71], and biological markers [71]. An evaluation study of the 7-day precoded food diary used in the Danish National Survey of Dietary Habits and Physical Activity 2000–02 reported that energy intake was underestimated by 12% compared to accelerometer [70].

Some approaches have been suggested to overcome underreporting in the dietary record. These include enhanced training of respondents and incorporating psychosocial questions known to be related to underreporting in order to control for the effect of underreporting [56]. Another approach is to calibrate dietary records to doubly labeled water or urinary nitrogen, biological indicators of energy expenditure and protein intake, respectively, including covariates of sex, weight, and height, to more accurately predict individuals' energy and protein intake [72]. This approach was applied to a subcohort of the Women's Health Initiative. Calibration equations that included BMI, age, and ethnicity explained much more of the variation in the energy and protein biomarkers than did calibration without the covariates, for example, 45% versus 8% for energy [54]. Further research is needed to test this approach in other populations and to develop and test other modeling approaches.

B 24-Hour Dietary Recall

In the 24-hour dietary recall, the respondent is asked to remember and report all the foods and beverages consumed in the preceding 24 hours or on the preceding day. The recall typically is conducted by interview, in person or by telephone [73,74], either computer-assisted [75] or using a paper-and-pencil form, although self-administered computer administration is becoming more prevalent [76–80]. When interviewer-administered, well-trained interviewers are crucial because much of the dietary information is collected by asking probing questions. Interviewers should be knowledgeable about foods available in the marketplace and about preparation practices, including prevalent regional or ethnic foods.

The interview is often structured, usually with specific probes, to help the respondent remember all foods consumed throughout the day. An early study found that respondents with interviewer probing reported 25% higher dietary intakes than did respondents without interviewer probing [81]. Probing is especially useful in collecting necessary details, such as how foods were prepared. It is also useful in recovering many items not originally reported, such as common additions to foods (e.g., butter on toast) and eating occasions not originally reported (e.g., snacks and beverage breaks). However, interviewers should be provided with standardized neutral probing questions so as to avoid leading the respondent to specific answers when the respondent really does not know or remember.

The current state-of-the-art 24-hour dietary recall protocol in the United States is the U.S. Department of Agriculture's (USDA) Automated Multiple-Pass Method (AMPM) [82,83], which is used in the U.S. National Health and Nutrition Examination Survey (NHANES). The AMPM five-pass method consists of (1) an initial "quick list," in which the respondent reports all the foods and beverages consumed, without interruption from the interviewer; (2) a forgotten foods list of nine food categories commonly omitted in 24-hour recall reporting; (3) time and occasion, in which the time each eating occasion began and what the respondent would call it are reported; (4) a detail pass, in which probing questions ask for more detailed information about the food and the portion size, in addition to review of the eating occasions and times between the eating occasions; and (5) final review, in which any other item not already reported is asked [82,83]. In addition, a two-dimensional Food Model Booklet [84], developed from USDA research, is used in the NHANES in order to facilitate more accurate portion size estimation. A 24-hour recall interview using the multiple-pass approach typically requires between 30 and 45 minutes.

Data processing software systems are currently available in most developed countries, allowing direct coding of most foods reported during the interview. This is highly efficient with respect to processing dietary data, minimizing missing data, and standardizing interviews [85,86]. If direct coding of the interview is done, methods for the interviewer to easily enter those foods not found in the existing database should be available, and appropriate use of these methods should be reinforced by interviewer training and quality control procedures.

A huge technological advance in 24-hour dietary recall methodology is the development of automated self-administered data collection instruments [76,78−80, 87−91]. These systems vary in their design, inclusion of probes regarding details of foods consumed and possible additions and omissions, the approach to asking about portion size, and the number of foods in their databases. The Automated Self-Administered 24-hour dietary recall (ASA24) developed at the National Cancer Institute (NCI) [76,90,91] incorporates many elements of the AMPM 24-hour interview developed by USDA [82]. Prompts used in the AMPM are asked in the program. Portion sizes are reported using digital photographs depicting up to eight sizes as portion size aids [91]. The system uses the most current USDA survey database [92] to allow automated coding and processing and ultimately estimation of nutrient and food group intakes. The ASA24 system is freely available for web or mobile phone administration [76]. Such automated tools make feasible the collection of high-quality dietary data in large-scale population research. Automated self-administered recalls have been compared to interviewer-administered recalls. One study in adolescents found that differences between interviewer- and self-administered recalls were minimal [80]. A feeding study of 86 adults found that the AMPM and the ASA24 were comparable in their agreement with observed intake [93]. Additionally, a large field study in 1083 adults found that nutrient and food group intakes estimated from AMPM and ASA24 recalls were comparable, and that the ASA24 was preferred over the AMPM by 70% of the participants [94].

There are many advantages to the 24-hour recall. When an interviewer administers the tool and records the responses, literacy of the respondent is not required. For self-administered versions, literacy can be a constraint. Because of the immediacy of the recall period, respondents are generally able to recall most of their dietary intake. Because there is relatively little burden on the respondents, those who agree to do 24-hour dietary recalls are more likely to be representative of the population than are those who agree to keep food records. Thus, the 24-hour recall method is useful across a wide range of populations. In addition, interviewers can be trained to capture the detail necessary so that new foods reported can be researched later by the coding staff and coded appropriately. Finally, in contrast to record methods, dietary recalls occur after the food has been consumed, and if unscheduled, reactivity is not a problem.

The main weakness of the 24-hour recall approach is that individuals may not report their food consumption accurately for various reasons related to knowledge, memory, and the interview situation. These cognitive influences are discussed in more detail in Section V.A. A potential limitation, as is true for food records, is that multiple days of recalls may be needed for the study objective. Whereas a single 24-hour recall can be used to describe the average dietary intake of a population, multiple days of recalls are needed to model estimates of the population's usual intake distributions. Multiple administrations of 24-hour recalls also allow more precise estimation of relationships with other factors (see Section V.G).

As with other self-report instruments, relative validation, for example, comparing 24-hour recalls with food records, is not particularly useful. The validity of the 24-hour dietary recall has been studied by comparing respondents' reports of intake either with intakes unobtrusively recorded/weighed by trained observers or with recovery biomarkers. Numerous observational studies of the performance of the 24-hour recall have been conducted with children (see Section IV.C). In studies of adults, group mean nutrient estimates from 24-hour recalls have been found to be similar to observed intakes [5,95], although respondents with lower observed intakes have tended to overreport energy and those with higher observed intakes have tended to underreport energy [95]. One observational study found energy underreporting during a self-selected eating period in both men and women, similar underreporting during a controlled diet period in men, and accurate reporting during a controlled diet period in women; underestimates of portion sizes accounted for much of the underreporting [96]. A study of adults comparing AMPM and ASA24 to observed intake found that both protocols captured about 80% of the foods and drinks actually consumed; there were few differences in nutrient and food group intakes between observed and reported for both protocols [93]. Studies with the recovery biomarkers of doubly labeled water and urinary nitrogen generally have found underreporting using 24-hour dietary recalls for energy in the range of 3–34% [22,42,79,83,97–103], with the largest two studies in adults using a multiple-pass method showing average underreporting to be between 12% and 23% [83,100]. For protein, underreporting tends to be in the range of 11–28% [97,100,101,103–107]. An analysis of data pooled from five of the larger recovery biomarker studies found an average rate of underreporting of 15% for energy and 5% for protein [108]. However, underreporting is not always found. Some studies found overreporting of energy from 24-hour dietary recalls compared to doubly labeled water in proxy reports for young children and adolescents [109,110]. In addition, it is likely that the commonly reported phenomenon of underreporting in Western countries may not occur in all cultures; for example, Harrison et al. [111] reported that 24-hour recalls collected from Egyptian women were well within expected amounts. Finally, in many studies, energy adjustment has been found to reduce error. For example, for protein density (i.e., percentage energy from protein), 24-hour dietary recalls conducted in the large biomarker studies were in close agreement or somewhat higher compared to a biomarker-based measure [54,100,101].

In past national dietary surveys using multiple-pass methods, findings suggest that energy underreporting may affect up to 15% of all 24-hour recalls [112,113]. Underreporters compared to nonunderreporters tended to report fewer numbers of foods, fewer mentions of foods consumed, and smaller portion sizes across a wide range of food groups and tended to report more frequent intakes of low-fat/diet foods and less frequent intakes of fat added to foods [112]. As was found for records, factors such as BMI, sex, social desirability, restrained eating, education, literacy, perceived health status, and race/ethnicity have been shown in various studies to be related to underreporting in recalls [48,54,62,64,83,98,106,108,112–116]. The 24-hour dietary recall is considered the least biased self-report instrument, and thus is useful for most research purposes. The NCI Dietary Assessment Primer gives extensive guidance as to its use in research studies [117].

C Food Frequency

The food frequency approach asks respondents to report their usual frequency of consumption of each food from a list of foods for a specific period. Information is collected on frequency, but little detail is collected on other characteristics of the foods as eaten, such as the methods of cooking, or the combinations of foods in meals. Many FFQs also incorporate usual portion size questions or specify portion sizes as part of each question. Overall nutrient intake estimates are derived by summing, over all foods, the products of the reported frequency of each food by the amount of nutrient in a specified (or assumed) serving of that food to produce an estimated daily intake of nutrients, dietary constituents, and food groups. In most cases, the purpose of an FFQ is to obtain a crude estimate of usual total daily intakes over a designated time period.

There are many FFQ instruments, and many continue to be adapted and developed for different populations and purposes. Among those evaluated and commonly used are the Block Questionnaires [118], the Harvard University Food Frequency Questionnaires or Willett Questionnaires [119], the Fred Hutchinson Cancer Research Center Food Frequency Questionnaire [120,121], and the NCI's Diet History Questionnaire [122], which was designed with an emphasis on cognitive ease for respondents [123,124]. FFQs have been developed for use with specific populations in the United States (e.g., African Americans, Hispanics) and throughout the world. Because of the number of FFQs available, investigators planning to use an FFQ need to carefully consider which best suits their research needs. "Brief" FFQs that assess a limited number of dietary exposures are discussed in the next section.

The appropriateness of the food list is crucial in the food frequency method. The entire breadth of an individual's diet, which includes many different foods, brands, and preparation practices, cannot be fully captured with a finite food list. Obtaining accurate reports for foods eaten both as single items and in mixtures is particularly problematic. FFQs can ask the respondent either to report a combined frequency for a particular food eaten both alone and in mixtures or to report separate frequencies for each food use. (For example, one could ask about beans eaten alone and in mixtures, or one could ask separate questions about refried beans, bean soups, beans in burritos, etc.) The first approach is cognitively complex for the respondent, but the second approach may lead to double counting (e.g., burritos with beans may be reported as both beans and as a Mexican mixture). Often, FFQs will include similar foods in a single question (e.g., beef, pork, or lamb). However, such grouping can create a cognitively complex question (e.g., for someone who often eats beef and occasionally eats pork and lamb). Differences in definitions of the food items asked may also be problematic; for example, rice is judged to be a vegetable by many nonacculturated Hispanics living in the United States, a judgment not shared in other race/ethnic groups [125]. Finally, when a group of foods is asked as a single question, assumptions about the relative frequencies of intake of the foods constituting the group are made in the assignment of values in the nutrient database. These assumptions are generally based on information from an external study population (such as from a national survey sample) even though true eating patterns may differ considerably across population subgroups and over time.

Each quantitative FFQ must be associated with a database to allow estimation of nutrient intakes for an assumed or reported portion size of each food queried [126]. For example, the FFQ item of macaroni and cheese encompasses a wide variety of different recipes with different nutrient composition, yet the FFQ database must have a single nutrient composition profile. There are several approaches to constructing such a database. One approach uses quantitative dietary intake information from the target population to define the typical nutrient density of a particular food group category. For example, for the food group macaroni and cheese, all reports of the individual food codes reported in a population survey can be collected, and a mean or median nutrient composition (by portion size if necessary) can be estimated. Values can also be calculated by sex and age. Dietary analysis software, specific to each FFQ, is then used to compute nutrient intakes for individual respondents. These analyses are available commercially for the Block, Willett, and Fred Hutchinson FFQs, and are publicly available for the NCI Diet History Questionnaire.

In pursuit of improving the validity of the FFQ, investigators have addressed a variety of frequency questionnaire design issues, such as length, closed- versus open-ended response categories, portion size, seasonality, and time frame. Frequency instruments designed to assess total diet generally list more than 100 individual line items, many with additional portion size questions, requiring 30−60 minutes to complete. In fact, some research suggests that FFQs with even longer food lists (e.g., 200 items) may perform better than those with shorter food lists (e.g., 100 items) [127]. This raises concern about the length and its effect on response rates. Although respondent burden is a factor in obtaining reasonable response rates for studies in general, a few studies have shown that respondent burden does not seem to be a decisive factor for FFQs [124,128,129]. This tension between length and specificity highlights the difficult issue of how to define a closed-ended list of foods for a food frequency instrument. Using food record intake information, a recently described mathematical approach considers the length, coverage, and explained variance to derive an optimized food list [130]. It is suggested that this tool be used in conjunction with expert judgment from a research nutritionist.

Although the amounts consumed by individuals are considered an important component in estimating dietary intakes, it is controversial as to whether or not portion size questions should be included on FFQs [127]. Frequency has been found to be a greater contributor than serving size to the variance in intake of most foods [131,132], suggesting that the additional respondent burden of reporting serving sizes is not worthwhile. Others cite small improvements in the performance of FFQs that ask the respondents to report a usual serving size for each food [133,134]. Some incorporate portion size and frequency into one question, asking how often a particular portion of the food is consumed [135]. Although some research has been conducted to determine the best ways to ask about portion size on FFQs [123], the marginal benefit of such information in a particular study may depend on the study objective and population characteristics [136]. The ramifications of using self-reported versus standard portion sizes were illustrated in a case−control study that found different odds ratios depending on which metric was used [137].

Another design issue is the time frame about which intake is queried. Most instruments inquire about usual intakes during the past year, but others ask about the past week or month [138], depending on specific research situations. Even when intake during the past year is asked, some studies have indicated that the season in which the questionnaire is administered has an influence on reporting for the entire year [139−141].

Finally, analytical decisions are required in how food frequency data are processed. In research applications in which there are no automated quality checks to ensure that all questions are asked, decisions about how to handle missing data are needed. In particular, in self-administered situations, there are usually many initial frequency questions that are not answered. One approach is to assign null values because some research indicates that respondents selectively omit answering questions about foods they seldom or never eat [142,143]. Another approach is the imputation of frequency values for those not providing valid answers. Only a few studies have addressed this issue [144,145], and it is currently unclear whether imputation is an advance in FFQ analyses. Recently, however, paper and pencil administration has declined and has been replaced by electronic administration which, because of programmable skip patterns, greatly reduces missing data.

Strengths of the FFQ approach are that it is inexpensive to administer and process and it asks about the respondent's usual intake of foods over an extended period of time. Unlike other methods, the FFQ can be used to circumvent recent changes in diet (e.g., changes due to disease) by obtaining information about individuals' diets as recalled about a prior time period. Retrospective reports about diet nearly always use a food frequency approach. Food frequency responses are used to rank individuals according to their usual consumption of nutrients, foods, or groups of foods. Nearly all food frequency instruments are designed to be self-administered, and most are either optically scanned paper versions or administered electronically [118,120, 122,146–148]. Because the costs of data collection and processing and the respondent burden have traditionally been much lower for FFQs than for multiple diet records or recalls, FFQs have been a common way to estimate usual dietary intake in large epidemiological studies.

The major limitation of the food frequency method is that it contains a substantial amount of measurement error [54,100–103,149]. Many details of dietary intake are not measured, and the quantification of intake is not as accurate as with recalls or records. Inaccuracies result from an incomplete listing of all possible foods and from errors in frequency and usual serving size estimations. The estimation tasks required for an FFQ are complex and difficult [150]. As a result, the scale for nutrient intake estimates from an FFQ may be shifted considerably, yielding inaccurate estimates of the average intake for the group. Research suggests that longer food frequency lists may overestimate whereas shorter lists may underestimate intake of fruits and vegetables [151], but it is unclear whether or how this applies to nutrients and other food groups.

Portion size of foods consumed is difficult for respondents to evaluate and is thus problematic for all assessment instruments (see Section V.D). However, the inaccuracies involved in respondents attempting to estimate usual portion size in FFQs may be even greater because a respondent is asked to estimate an average for foods that may have highly variable portion sizes across eating occasions and time periods [152].

Because of the error inherent in the food frequency approach, it is generally considered inappropriate to use FFQ data to estimate quantitative parameters, such as the mean and variance, of a population's usual dietary intake [153–158]. Although some FFQs seem to produce estimates of population average intakes that are reasonable [153,159,160], different FFQs will perform in often unpredictable ways in different populations, so the levels of nutrient intakes estimated by FFQs should best be regarded as only approximations [154]. FFQ data are usually energy adjusted and then used for ranking subjects according to food or nutrient intake rather than for estimating absolute levels of intake, and they are used widely in case–control or cohort studies to assess the association between dietary intake and disease risk [161–163]. For estimating relative risks, the degree of misclassification of subjects is more important than is the quantitative scale on which the ranking is made [164].

The definitive validity study for a food frequency–based estimate of long-term usual diet would require nonintrusive observation of the respondent's total diet over a long time. Such studies are not possible in free-living populations. One early feeding study, with three defined 6-week feeding cycles (in which all intakes were known), showed some significant differences in known absolute nutrient intakes compared to the Willett FFQ for several fat components, mostly in the direction of underestimation by the FFQ [165]. Many studies have compared food frequency estimates with those from multiple food recalls or records over a period of time (see [166] for a register of such studies). However, recalls and records cannot be considered as accurate reference instruments because they themselves have error. Validation studies of various FFQs using recovery biomarkers have found that FFQs underestimate energy intake by 11%–35% [42,48,51,54,79,97,99–103] and protein intake by up to 30% [46,47,54,97,100,101,103,167–171]. In a pooled analysis of five larger U.S. biomarker studies, FFQs underestimated energy by 28% and protein by 10% [108]. A few studies show that correlations between a biomarker for protein density constructed from both urinary nitrogen and doubly labeled water and self-reported protein density on an FFQ (kcal of protein as a percentage of total kcal) are higher than correlations between urinary nitrogen and FFQ-reported absolute protein intake [101,103,149], indicating that energy adjustment may alleviate some of the error inherent in food frequency instruments. Various statistical methods employing measurement error models and energy adjustment are used not only to assess the validity of FFQs but also to adjust estimates of relative risks for disease outcomes [54,172–182]. However, analyses indicate that correlations between an FFQ and a reference instrument, such as the 24-hour recall, may be overestimated because of correlated errors [54,101,149]. Furthermore, a few analyses comparing relative risk estimation from FFQs to dietary records [183,184] in prospective cohort studies indicate that observed relationships are attenuated with FFQs, thereby obscuring associations that might exist; however, not all analyses have found this result [185]. Some epidemiologists have suggested that the error in FFQs is a serious enough problem that more accurate methods (e.g., food records or 24-hour recalls) of assessing dietary intake in large-scale prospective studies should be considered [186–188].

Because of relatively large measurement error and bias found with FFQs, the NCI Dietary Assessment Primer suggests they be used sparingly, especially when other instruments such as 24-hour dietary recalls could be used. When FFQs are used as the main instrument, a concurrent calibration study on a subsample of the population using more accurate instruments should be included in the design [117]. See Section V.C for more discussion of calibration. Because FFQ data might be combined with recall or record data to improve estimates of intake and relative risks [188−190], the use of both instruments may be optimal [117].

D Brief Dietary Assessment Instruments

Many brief dietary assessment instruments, also known as "screeners," have been developed. These instruments can be useful in situations that do not require either assessment of the total diet or quantitative accuracy in dietary estimates. For example, a brief diet assessment of some specific dietary components may be used to triage large numbers of individuals into groups to allow more focused attention on those at greatest need for intervention or education. Measurement of dietary intake, even if imprecise, can also serve to activate interest in the respondent, which in turn can facilitate nutrition education. Brief instruments may therefore have utility in clinical settings or in situations in which health promotion and health education is the goal. In the intervention setting, brief instruments focused on specific aspects of a dietary intervention have been used to track changes in diet. However, because of concern that responses to questions of intake that directly evolve from intervention messages may be biased [191] and that these instruments lack sensitivity to detect dietary change [192], this use is not recommended. Brief instruments of specific dietary components such as fruits and vegetables have been used for population surveillance at the state or local level, for example, in the Centers for Disease Control and Prevention's (CDC) Behavioral Risk Factor Surveillance System (BRFSS) [193,194] and the California Health Interview Survey (CHIS) [195] (see Section III.A). Brief instruments have also been used to examine relationships between some specific aspects of diet and other exposures, such as in the National Health Interview Survey (NHIS) [196]. Finally, some suggest the use of brief instruments to evaluate the effectiveness of policy initiatives [195,197,198], although others question the ability of short measures to adequately evaluate dietary changes [199].

Brief instruments can be simplified or targeted FFQs, questionnaires that focus on specific eating behaviors other than the frequency of intake of specific foods, or daily checklists. Complete FFQs typically contain 100 or more food items to capture the range of foods contributing to the many different nutrients in the diet. If an investigator is interested only in estimating the intake of a single nutrient or food group, however, then far fewer foods need to be assessed. Often, only 15−30 foods might be required to account for most of the intake of a particular food component [200,201].

Numerous short questionnaires using a food frequency approach have been developed and compared with multiple days of dietary records, 24-hour recalls, complete FFQs, and/or biological indicators of diet. The NCI has developed a Register of Validated Short Dietary Assessment Instruments [202], which contains descriptive information about short instruments and their validation studies and publications, as well as copies of the instruments when available. To be included, publications are required to be in English language peer-reviewed journals and published since January 1998. Currently, the register includes nearly 140 instruments assessing more than 30 dietary factors from 31 different countries. Instruments in the register may be searched by dietary factors, questionnaire format, and number of questions. Descriptive information about the validation study includes the reference tool, the study population (age, sex, and race/ethnicity), and the geographical location.

Much of the focus in brief instrument development has been on fruits and vegetables and on fats. Some work has addressed other food components that are found in relatively few foods, such as calcium, added sugars, soy, phytoestrogens, and heterocyclic amines [202].

1 Brief Instruments Assessing Fruit and Vegetable Intake

Food frequency-type instruments to measure fruit and vegetable consumption range from a single overall question to 45 or more individual questions [203−207]. An early 7-item tool developed by the NCI and private grantees for NCI's 5 A Day for Better Health Program effort was used widely in the United States [208−210]. This tool was similar to one used in CDC's BRFSS [193,211,212]. Validation studies of the BRFSS and 5 A Day brief instruments to assess fruit and vegetable intake suggested that without portion size adjustments, they often underestimated actual intake [203,208,212−214]. Using cognitive interviewing findings (see Section V.A), NCI revised the tool, including adding portion size questions; some studies indicate improved performance [215] and utility in surveillance studies. However, its performance in community interventions was mixed. In six of eight site/sex comparisons, fruit and vegetable consumption was significantly overestimated in relation to results from multiple 24-hour recalls [216]. More important, the screener indicated change in consumption in both men and women when none was seen with the 24-hour recalls [217]. The BRFSS fruit and vegetable screener used in 2011–15 in odd years [193] assessed intake of solid fruit and 100% fruit juice and subgroups of vegetables that were particularly relevant to 2010 Dietary Guidelines for Americans [218]. Intake estimates from the 2011 and 2013 assessments with the new tool have been reported [194,219]. The instrument is being redesigned, using questions developed at NCI.

2 Brief Instruments Assessing Fat Intake

The MEDFICTS (meats, eggs, dairy, fried foods, fat in baked goods, convenience foods, fats added at the table, and snacks) questionnaire, initially developed to assess adherence to low total fat (<30% energy from fat) and saturated fat diets [219], asks about frequency of intake and portion size of 20 individual foods that are major food sources of fat and saturated fat in the U.S. diet. Its initial evaluation showed high correlations with dietary records [219]. In addition to the cross-sectional studies, the MEDFICTS underestimated percentage calories from fat; it was effective in identifying very high-fat intakes but was not effective in identifying moderately high-fat diets [220] or correctly identifying low-fat diets [221]. The number of mixtures reported on an FFQ (e.g., pizza and macaroni and cheese), which were not specifically included in the MEDFICTS tool, was negatively related to its predictive ability [221]. In a longitudinal setting, positive changes in the MEDFICTS score have been correlated with improvements in serum lipids and waist circumference among cardiac rehabilitation patients [222]. The instrument has been adapted for other populations with varying success [221,223]. Other fat screeners have been developed to preserve the between-person variability of intake [224–226]—that is, to focus on the fat sources that most distinguish differences in fat intake among individuals or groups. A 20-item screener was developed and tested at the German site of European Prospective Investigation into Cancer and Nutrition correlated with 7-day dietary records ($r = 0.84$) and a complete FFQ ($r = 0.82$) [224,225]. A 16-item percentage energy from fat screener had a correlation of 0.6 with 24-hour recalls in an older U.S. population [226]. However, its performance in overweight African-American women was poorer (mean of 33.0% vs 35.5% energy from fat for screener vs 24-hour recall) [227]. Its performance in an intervention study of adults varied by site [228].

Often, dietary fat reduction interventions are designed to target specific food preparation or consumption behaviors rather than frequency of consuming specific foods. Such behaviors might include trimming the fat from red meats, removing the skin from chicken, or choosing low-fat dairy products. Many questionnaires have been developed in various populations to measure these types of dietary behaviors [229–238], and many have been found to correlate with fat intake estimated from other more detailed dietary instruments [239,240] or with blood lipids [233,241,242]. In addition, some studies have found that changes in dietary behavior scores have correlated with changes in blood lipids [234,241,243]. The instrument has been updated and modified for use in different settings and populations [242,244,245]. A modification tested in African-American adolescent girls had a relatively low correlation ($r = 0.31$) with multiple 24-hour recalls [246]. In another modification developed for African-American women [247], a subset of 30 items from the SisterTalk Food Habits Questionnaire correlated with change in BMI ($r = -0.35$) as strongly as did the original 91 items ($r = -0.36$) [248].

3 Brief Multifactor Instruments

Recognizing the utility of assessing a few dimensions of diet simultaneously, several multifactor short instruments have been developed and evaluated. For example, Prime-Screen is composed of 18 FFQ items asking about consumption of fruits and vegetables, whole and low-fat dairy products, whole grains, fish and red meat, and sources of saturated and trans-fatty acids. The average correlation with estimates from a full FFQ over 18 food groups was 0.6 and over 13 nutrients was also 0.6 [249]. The NCI developed a dietary screener administered in the 2009–10 NHANES that included 28 items addressing consumption of fruits and vegetables, whole grains, added sugars, dairy, fiber, calcium, red meats, and processed meats [250]. This screener was also used in the 2010 and 2015 NHIS Cancer Control Supplement.

Some multicomponent behavioral questionnaires have also been developed. For example, Schlundt et al. [251] developed a 51-item Eating Behavior Patterns Questionnaire targeted at assessing fat and fiber consumption among African-American women. Newly incorporated in this questionnaire were questions to reflect emotional eating and impulsive snacking.

Some instruments combine aspects of food frequency and behavioral questions to assess multiple dietary patterns. For example, the Rapid Eating and Activity Assessment for Patients is composed of 27 items assessing consumption of whole grains, calcium-rich foods, fruits and vegetables, fats, sugary beverages and foods, sodium, and alcohol. When compared to dietary records, correlations were 0.49 with the original Healthy Eating Index (HEI) [252], a measure of overall diet quality, and moderately high (range of $r = 0.33–0.55$) for HEI subscores of fat, saturated fat, cholesterol, fruit, and meat. Correlations for other HEI subscores for sodium, grains, vegetables, and dairy were low (range of $r = 0.03–0.27$) [253].

Because the cognitive processes for answering food frequency-type questions can be complex, some attempts have been made to reduce respondent burden by creating brief instruments with questions that require only "yes—no" answers. This approach has been applied as a modification of the 24-hour recall [254]. These "targeted" 24-hour recall instruments aim to assess particular foods, not the whole diet [71,255—257]. They present a precoded close-ended food list and ask whether the respondent ate each food on the previous day; portion size questions may also be asked. For example, a web-administered checklist has been developed to measure the Dietary Approaches to Stop Hypertension diet. It includes a listing of foods grouped into 11 categories, and it includes serving size information [258].

4 Limitations of Brief Instruments

The brevity of these instruments and their correspondence with dietary intake as estimated by more extensive methods create a seductive option for investigators who would like to measure dietary intake at a low cost. Although brief instruments have many applications, they have several limitations. First, they do not capture information about the entire diet. Most measures are not quantitatively meaningful and, therefore, estimates of dietary intake for the population usually cannot be made. Even when measures aim to provide estimates of total intake, the estimates are approximations and have large measurement error. Finally, the specific dietary behaviors found to correlate with dietary intake in a particular population may not correlate similarly in another population or even in the same population at another time period. For example, a brief instrument developed to assess fast-food and beverage consumption in a primarily white, adolescent population [259] was not useful in an overweight Latina adolescent population [260]. Investigators should carefully consider the needs of their study and their own population's dietary patterns before choosing an "off-the-shelf" instrument designed to briefly measure either food frequency or specific dietary behaviors. Because of these limitations, the NCI Dietary Assessment Primer recommends that short instruments be used sparingly and when used, to be calibrated to a more accurate instrument such as 24-hour dietary recalls [117]. See Section V.C for more discussion on calibration.

E Diet History

The term *diet history* is used in many ways. In the most general sense, a dietary history is any dietary assessment that asks the respondent to report about past diet. Originally, as coined by Burke, the term *dietary history* referred to the collection of information not only about the frequency of intake of various foods but also about the typical makeup of meals [261,262]. Many now imprecisely use the term dietary history to refer to the food frequency method of dietary assessment. However, several investigators have developed diet history instruments that provide information about usual food intake patterns beyond simply food frequency data [263—266]. Some of these instruments characterize foods in much more detail than is allowed in food frequency lists (e.g., preparation methods and foods eaten in combination), and some of these instruments ask about foods consumed at every meal [265,267]. The term diet history is therefore probably best reserved for dietary assessment methods that are designed to ascertain a person's usual food intake in which many details about characteristics of foods as usually consumed are assessed in addition to the frequency and amount of food intake.

The Burke diet history included three elements: a detailed interview about usual pattern of eating, a food list asking for amount and frequency usually eaten, and a 3-day dietary record [261,262]. The detailed interview (which sometimes includes a 24-hour recall) is the central feature of the Burke dietary history, with the food frequency checklist and the 3-day diet record used as cross-checks of the history. The original Burke diet history, which requires administration by an interviewer, has not often been exactly reproduced because of the effort and expertise involved in capturing and coding the information. However, many variations of the Burke method have been developed and used in a variety of settings [263—266,268—272]. These variations attempt to ascertain the usual eating patterns for an extended period of time, including type, frequency, and amount of foods consumed; many include a cross-check feature [273,274].

Some diet history instruments have been automated and adapted for self-administration, sometimes with audio, thus eliminating the need for an interviewer to ask the questions [24,265,275]. Other diet histories have been automated but still continue to be administered by an interviewer [276,277]. Short-term recalls or records are often used for validation or calibration rather than as a part of the tool.

The major strength of the diet history method is its assessment of meal patterns and details of food intake rather than intakes for a short period of time (as in records or recalls) or only frequency of food consumption. Details of the means of preparation of foods can be helpful in better characterizing nutrient intake (e.g., frying vs baking), as well as exposure to other factors in foods (e.g., charcoal broiling). When the information is collected separately for each meal, analyses of the joint effects of foods eaten together are possible (e.g., effects on iron absorption of concurrent intake of tea or foods containing vitamin C). Although a meal-based approach often requires more time from the respondent than does a food-based approach, it may provide more cognitive support for the recall process. For example, the respondent may be better able to report total bread consumption by reporting bread as consumed at each meal.

A weakness of the approach is that respondents are asked to make many judgments about both the usual foods consumed and the amounts of those foods eaten. These subjective tasks may be difficult for many respondents. Burke cautioned that nutrient intakes estimated from these data should be interpreted as relative rather than absolute. All of these limitations are also shared with the food frequency method. The meal-based approach is not useful for individuals who have no particular eating pattern and may be of limited use for individuals who "graze" (i.e., eat throughout the day rather than at defined mealtimes). The approach, when conducted by interviewers, requires trained nutrition professionals and is thus costly. Finally, the diet history as a method is not well standardized, and thus methods differ from each other and are difficult to reproduce, making comparisons across studies difficult.

Relative to other assessment approaches, few validation studies of diet history questionnaires using biological markers as a basis of comparison have been conducted. The studies found that reported mean energy intakes using the diet history approach in selected small samples of adults were underestimated in the range of 2−23% compared to energy expenditure as measured by doubly labeled water [278−281]. Generally, underreporting of protein, compared to urinary nitrogen, was less than that for energy and only sometimes significantly different [279,281−283]. These results have also been seen in children [284], adolescents [285,286], and the elderly [264]. Because of small sample sizes in these studies, few were able to examine characteristics related to underreporting, and their results were mixed, with some finding more underreporting with higher BMI [283,284] and others finding no relationship [264,280,287]. Although the diet history approach was extensively used as the main study instrument in European cohorts initiated in the 1990s, the approach is seldom used now in new cohort studies as other approaches have evolved. The approach is sometimes used as a reference instrument [288−290].

F Blended Instruments/Combined Instruments

Better understanding of various instruments' strengths and weaknesses has led to creative blending of instruments with the goal of maximizing the strengths of each instrument. For example, a record-assisted 24-hour recall has been used in several studies with children [291,292]. The child keeps notes of what he or she has eaten and then uses these notes as memory prompts in a later 24-hour recall. A mobile phone food record app that includes before and after meal photographs with text entry has been tested in adolescents [293].

Analytical methods for using information from two different instruments are available. For example, Thompson et al. [294] combined information from a series of daily checklists (i.e., precoded record) with frequency reports from an FFQ to form checklist-adjusted estimates of intake. In an evaluation of this approach, agreement with 24-hour recalls improved for energy and protein but was unchanged for protein density [294]. A two-part statistical model developed by NCI uses information from two or more 24-hour recalls, allowing for the inclusion of daily frequency estimates derived from a food propensity questionnaire (a frequency questionnaire that does not ask about portion size), as well as other potentially contributing characteristics (e.g., age and race/ethnicity), as covariates [295]. Frequency information contributes to the model by providing additional information about an individual's propensity to consume a food, and is particularly useful for episodically consumed foods and nutrients [296]. The recalls, however, provide information about the nature and amount of the food consumed. Such methods are used to better measure usual intakes (see Section V.G). Several approaches consisting of multiple dietary assessment instruments are available to estimate associations between diet and disease. A prominent use is to calibrate a frequency questionnaire completed by all study subjects with information from a more accurate instrument, such as a 24-hour recall, completed by a subset. See Section V.C for more discussion of calibration. Carroll et al. [188] explored the number of days of 24-hour recall required to estimate associations between diet and disease in a cohort study and whether an FFQ, in addition, is beneficial. They concluded that for most nutrients and foods, 4−6 nonconsecutive days of 24-hour recall and an FFQ are optimal. The combination of FFQ and multiple 24-hour recalls was superior in estimating some nutrients and foods, especially for episodically consumed foods. Finally, the addition of biomarker information to self-reported dietary information has been shown to increase accuracy and statistical power to estimate associations between diet and disease [297,298].

Table 1.1 summarizes the important characteristics of the main self-report dietary assessment methods.

III DIETARY ASSESSMENT IN DIFFERENT STUDY DESIGNS

The choice of the most appropriate dietary assessment method for a specific research question requires careful

TABLE 1.1 Comparison of Self-Report Dietary Assessment Methods by Important Characteristics

	Dietary Record	24-Hour Recall	FFQ	Diet History	Screener
Type of Information Attainable					
Detailed information about foods consumed	X	X		X	
General information about food groups consumed			X		X
Meal-specific details	X	X		X	
Scope of Information Sought					
Total diet	X	X	X	X	
Specific components					X
Time Frame Asked					
Short term (e.g., yesterday, today)	X	X		X	
Long term (e.g., last month, last year)			X	X	X
Adaptable for Diet in Distant Past					
Yes			X	X	X
No	X	X			
Cognitive Requirements					
Measurement or estimated recording of foods and drinks as they are consumed	X				
Memory of recent consumption		X		X	
Ability to make judgments of long-term diet			X	X	X
Potential for Reactivity					
High	X				
Low		X	X	X	X
Time Required to Complete					
<15 minutes					X
>20 minutes	X	X	X	X	
Suitable for Cross-Cultural Comparisons Without Instrument Adaptation					
Yes	X	X		X	
No			X	X	X

consideration. The primary research question must be clearly formed, and questions of secondary interest should be recognized as such. Projects can fail to achieve their primary goal because of too much attention to secondary goals. The choice of the most appropriate dietary assessment tool depends on many factors. Questions that must be answered in evaluating which dietary assessment tool is most appropriate for a particular research need include the following [162]: (1) Is information needed about foods, nutrients, other food components, or specific dietary behaviors? (2) Is the focus of the research question on describing intakes using estimates of average intake, and does it also require distributional information? (3) Is the focus of the research question on describing relationships between diet and health outcomes? (4) What level of accuracy and precision is needed? (5) What time period is of interest? (6) What are the research constraints in terms of money, interview time, staff, and respondent characteristics?

The NCI Dietary Assessment Primer conceptualizes research questions into four categories: to describe a population's dietary intake; to examine associations between diet as an independent variable and another variable; to examine associations between an independent variable and diet as a dependent variable; and to evaluate the effect of an intervention on dietary intake. The role of measurement error in tool selection for each research objective is discussed in depth [117].

A Cross-Sectional Surveys

One of the most common types of population studies is the cross-sectional survey, a set of measurements of a population at a particular point in time. Such data can be collected solely to describe a particular population's intake. Alternatively, data can be used for surveillance at the national, state, and local levels as the basis for assessing risk of deficiency, toxicity, and overconsumption; to evaluate adherence to dietary guidelines and public health programs; and to develop food and nutrition policy. Cross-sectional data also may be used for examining associations between current diet and other factors including health. However, caution must be applied in examining many chronic diseases believed to be associated with past diet because the currently measured diet is not necessarily related to past diet. If the study objective requires quantitative estimates of intake, the 24-hour recall and possibly the food record instruments are recommended [117]. Less detailed instruments, such as FFQs or behavioral indicators, may be appropriate when qualitative estimates on limited exposures are sufficient—for example, frequency of consuming sugar-sweetened beverages and frequency of eating from fast-food restaurants.

1 Surveillance/Monitoring

When measurements are collected on a sample at two or more times, the data can be used for purposes of monitoring dietary trends. To assess trends in intakes over time, it would be ideal for the dietary surveillance data collection methods, sampling procedures, and food composition databases to be similar from survey to survey. As a practical matter, however, this is difficult, and the benefits of trend analysis may not outweigh the benefits of improving the methods over time. The dietary assessment method used consistently throughout the years in U.S. national dietary surveillance is the interviewer-administered 24-hour recall. However, recall methodology has improved over time based on cognitive research, the addition of multiple interviewing passes, standardization of probes, automation of the interview, and automation of the coding. The availability of automated self-administered 24-hour recall instruments may lead to further changes in methodology.

Another issue that affects the assessment of trends over time is changes in the nutrient or food grouping databases and specification of default foods. Changes in the food supply are reflected in additions or subtractions to food composition databases, whereas changes in consumption trends may lead to subsequent reassignment of default codes for foods not fully specified in 24-hour recalls or records (e.g., when type of milk is not specified, the default code is now 2% milk as opposed to whole milk in the past). Food composition databases, too, are modified over time because of true changes in food composition, improved analytic methods for particular nutrients, or inclusion of information for new dietary components. Since 1999, the major cross-sectional surveillance survey in the United States has been the NHANES [299]. This survey is conducted by the National Center for Health Statistics. The dietary component of the survey, called "What We Eat in America" [75], consists of 24-hour recalls collected using the USDA's AMPM (see Section II.B). The USDA also processes and analyzes the data. The 24-hour recalls in NHANES query the intake of dietary supplements as well as foods and beverages. Since 2003−04, NHANES has conducted two 24-hour dietary recalls on each respondent, allowing for estimation not only of average usual intake but also of the distributions of usual intake of the dietary components (see Section V.G).

NHANES provides high-quality dietary intake data at the national level, but these data are of limited use for state and local researchers planning and evaluating their programs and policies [300]. Collection of state and local data is often constrained by lack of resources or interview time, leading to the frequent use of less expensive brief instruments. For example, the CDC has used telephone-administered brief instruments to periodically assess fruit and vegetable intake within the BRFSS [193]. The California Department of Public Health, in its California Dietary Practices Survey, has assessed dietary practices among adults biennially since 1989 [301]. The CHIS used telephone-administered brief instruments to assess fruit and vegetable intake in 2001, 2005, and 2009 [195].

B Case−Control (Retrospective) Studies

A case−control study design classifies individuals with regard to current disease status (as cases or controls) and relates this to past (retrospective) exposures. In etiologic research, information about diet before onset of disease is needed. Dietary assessment methods that focus on current behavior, such as the 24-hour recall, are obviously not useful in retrospective studies of long past diet. The food frequency and diet history methods are the only viable choices for case−control (retrospective) studies.

In any food frequency or diet history interview, the respondent is not asked to recall specific memories of each eating occasion but, rather, to respond on the basis of general perceptions of how frequently he or she ate a food. In case−control studies, the relevant period is often the year before diagnosis of disease or onset of symptoms or at particular life stages, such as adolescence and childhood. Thus, in assessing past diet, an additional requirement is to orient the respondent to the appropriate time period.

The validity of recalled diet from the distant past is difficult to assess because definitive recovery biomarker information (e.g., doubly labeled water, urinary nitrogen) is not available for large samples from long ago. Instead, relative validity and long-term reproducibility of various FFQs have been assessed in various populations by asking participants from past dietary studies to recall their diet from that earlier time [302−304]. These studies have found that correlations between past and current reports about the past vary by nutrient and by food group [135,305], with higher correspondence for very frequently consumed and rarely consumed foods compared to that for foods consumed moderately often [305,306]. Evidence suggests that correspondence between past and recalled past decreases with the length of time between reports [302,307]. In particular, retrospective reports of diet in adolescence after long recall periods (i.e., >30 years) have shown little correspondence with the original reports [308−310]. Maternal reports about diets of their children in early childhood or adolescence and siblings reports of each other's diets in adolescence have also shown low correspondence with the original reports [310,311].

Correspondence of retrospective diet reports with the diet as measured in the original study usually has been greater than the correspondence of current diet with past diet. This observation implies that if diet from years in the past is of interest, it is usually preferable to ask respondents to recall it than to consider current diet as a proxy for past diet. Nonetheless, the current diets of respondents may affect their retrospective reports about past diets. In particular, retrospective diet reports from seriously ill individuals may be biased by recent dietary changes [302,312]. Some studies of groups in whom diet was previously measured indicate no consistent differences in the accuracy of retrospective reporting between those who recently became ill and others [313,314]. However, in two of three studies that have compared baseline prospective dietary information to later retrospective recall of the earlier diet, the correspondence of the information differed between those who later became cases and controls, introducing attenuation into risk estimates [310,315,316].

C Cohort (Prospective) Studies

In a cohort study design, exposures of interest are assessed at baseline and possibly at later times in a group (cohort) of people and disease outcomes occurring over time (prospectively) are then related to the baseline exposure levels. For many chronic diseases, large numbers of individuals need to be followed for years before enough new cases with that disease accrue to have adequate power for statistical analyses. A broad assessment of diet is usually desirable in prospective studies because many dietary exposures and many disease end points will ultimately be investigated, and areas of interest may not even be recognized at the beginning of a cohort study.

In order to relate diet at baseline prior to disease to the eventual occurrence of disease, a measure of the usual intake of foods (see Section V.G) by study subjects is needed. Multiple dietary recalls, multiple records, diet histories, and food frequency methods have all been used effectively in prospective studies. Cost and logistic issues have favored food frequency methods because many prospective studies require thousands of respondents. However, because of concern about significant measurement error and attenuation attributed to the FFQ [183,186,187,317−320], other approaches are being considered. One approach is the use of multiple automated self-administered 24-hour recall instruments (see Section II.B). Another approach is collecting multiple days of dietary records at baseline, with later coding and analysis of records for those respondents selected for analysis, using a nested case−control design [321,322]. The incorporation of emerging technological advances, such as mobile phones, in obtaining dietary records increases the feasibility of such approaches in prospective studies.

If using an FFQ as the main instrument in the cohort, it is desirable to include multiple recalls or records in representative subsamples of the population (preferably before beginning the study) to construct or modify the food frequency instrument and to calibrate it (see Section V.C). Information on the foods consumed could be used to ensure that the FFQ includes the major food sources of key nutrients, with appropriate portion size categories. Because the diets of individuals change over time, it is desirable to measure diet throughout the follow-up period rather than just at baseline. If diet is measured repeatedly over years, repeated calibration is also desirable. Information from calibration studies can be used for three purposes: to assist in study design, such as the sample size needed [164]; to calibrate values from the food frequency tool to values from the recalls/records [180]; and to determine the degree of attenuation/measurement error in the estimates of association observed in the study (e.g., between diet and disease) [175,178,180,182,323−327] (see Section V.C). Some research indicates that an optimal approach to dietary assessment in prospective studies may be the use of both multiple recalls or records and FFQs [188]. The FFQ can be particularly useful in contributing information about episodically consumed foods.

D Intervention Studies

Dietary intervention study designs usually consist of measures of interest for at least two time periods (typically, before and after intervention), and for at least two groups of participants, those receiving the intervention and those not (i.e., controls). Intervention studies range from relatively small, highly controlled, clinical studies of targeted participants to large trials of population groups.

The need for careful planning and formative research in designing useful community dietary intervention trials has been described [328]. A critical element is the existence of evidence that a particular intervention would create a measurable change in a particular group and setting. Intentional behavior change is a complex and sequential phenomenon, as has been shown for tobacco cessation [329], and this is also true for dietary change [330].

Interventions that aim to change the existing diet may use dietary assessment for two purposes: (1) initial screening for inclusion (or exclusion) into the study and (2) baseline measurement against which dietary changes resulting from the intervention are assessed. Not all intervention trials require initial screening. For those that do, screening can be performed using very detailed instruments or less burdensome instruments. For example, food frequency instruments were used in the Women's Health Trial [331] and in the Women's Health Initiative Dietary Modification Trial [332] to identify groups with high fat intake and thus determine eligibility.

Measurement of the effects of a dietary intervention requires a valid measure of change from baseline to the conclusion of the intervention period, and often, postintervention to assess the durability of any change. Dietary interventions that are expected to change an objective marker, for example, weight or blood lipids, are relatively straightforward to measure and analyze. However, if evaluation of the intervention requires measurement of change in self-reported diets, the task is complex, due to many possible biases.

Although not intending to be deceptive, some respondents may tend to report what they think investigators want to hear, leading to social desirability [333] and social approval [334] biases. Because of their greater subjectivity, behavioral questions, short instruments, and the food frequency method may be more susceptible to social desirability biases than the 24-hour recall method [73,191]. On the other hand, repeated measurement may lead to greater awareness of diet and enhanced reporting skills and thus may enhance accuracy [335]. Dietary records and scheduled 24-hour recalls are vulnerable to reactivity bias. If assessment is by 24-hour recalls, unannounced administration would avoid reactivity but possibly at the expense of participation as successful contact may be more difficult (and expensive). Most importantly, the potential for differential misreporting of diet between study groups (whether the misreporting in each group is similar or different) can affect the integrity of the results. Repeated measures of diet among study subjects can reflect reporting bias in the direction of the change being promoted [336].

Some work has been done to evaluate the use of self-report dietary assessment methods to measure dietary changes [245,336]. Researchers have found that dietary records and scheduled 24-hour recalls are associated with changed eating behavior during the record days and less correspondence with biological measures [337] and expected weight change [338], and increased underreporting [339]. One study using dietary screeners and a reference measure of multiple nonconsecutive unannounced 24-hour recalls found that change in fruit and vegetable intake in the intervention group was overestimated relative to the control group [217]. However, in the same study, a fat screener and the 24-hour recalls were consistent in finding no change in percentage energy from fat in the two groups [340]. Because of resource constraints and respondent burden, large intervention studies have often relied on less precise measures of diet, including FFQs and brief instruments. However, resource constraints may be less relevant with the availability of automated self-administered 24-hour dietary recall instruments and less burdensome dietary records.

Because self-reports of diet are subject to differential response bias in the context of an intervention study [335,336], an independent objective assessment of dietary change should be considered. For example, food availability and/or sales in worksite cafeterias, school cafeterias, or vending machines could be monitored. One such method useful in community-wide interventions is monitoring food sales [341]. Often, cooperation can be obtained from food retailers [342]. However, because the number of food items may be large, it may be possible to monitor only a small number, and the large effects on sales of day-to-day pricing fluctuations should be carefully considered. Another method to consider is measuring changes in biomarkers of diet, such as serum carotenoids [335,343] or serum cholesterol [344]. Consistency of changes in self-reported diet and appropriate biomarkers provides further evidence for real changes in the diet. Finally, social desirability biases could be measured and the resulting scales incorporated into intervention analyses. See Chapter 10, Nutritional Intervention: Lessons from Clinical Trials, and Chapter 11, Biomarkers and Their Use in Nutrition Intervention, for more in-depth discussions of the evaluation of diet in nutrition interventions and use of biomarkers in intervention studies, respectively.

IV DIETARY ASSESSMENT IN SPECIAL POPULATIONS

A Respondents Unable to Self-Report

In many situations, respondents are unavailable or unable to report about their diets. Dietary assessment in young children relies on surrogate reports. In case–control studies, surrogate reports may be obtained for cases who have died or who are too ill to interview. Although the accuracy of surrogate reports has not been examined using the recovery biomarkers of doubly labeled water or urinary nitrogen, comparability of reports by surrogates and subjects has been studied with the goal that surrogate information might be used interchangeably with information provided by subjects [345]. Common sense indicates that individuals who know most about a subject's lifestyle would make the best surrogate reporters [346]. Adult siblings provide the best information about a subject's early life, and spouses or children provide the best information about a subject's adult life. When food frequency instruments are used, the level of agreement between subject and surrogate reports of diet varies with the food and possibly with other variables, such as number of shared meals, interview situation, case status, and sex of the surrogate reporter. Mean frequencies of use computed for individual foods and food groups between surrogate reporters and subject reporters tend to be similar [347−349], but agreement is much lower when detailed categories of frequency are compared. Several studies have shown that agreement is better for alcoholic beverages, coffee, and tea than for foods.

When subjects themselves report intakes in the extremes of a distribution, their surrogates seldom report intakes in the opposite extreme, although the surrogates tend to report intakes in the middle of the distribution [350]. This may limit the usefulness of surrogate information for analyses that rely on accurate ranking. Furthermore, the quality of surrogate reports between spouses of deceased subjects and spouses of surviving subjects may differ substantially [351]. Thus far, however, little evidence suggests that dietary intakes are systematically overreported or underreported depending on the case status of the subject [352−354]. Nonetheless, use of surrogate respondents should be minimized for obtaining dietary information in analytical studies. When used, analyses excluding the surrogate reports should be done to examine the sensitivity of the reported associations to possible errors or biases in the surrogate reports. If planning a study using surrogate reports, sample size should be inflated to account for higher incidence of missing data, inability to recruit surrogates for some number of cases, and reduced precision of dietary estimates.

B Minority Populations

The widespread use of many "ethnic" foods in the United States throughout the population and the increasing diversity of the population have broadened the food composition databases and food lists used for the general population. Nonetheless, special modifications may be needed in dietary assessment methods when the study population is composed of individuals whose cuisine or cooking practices are not adequately represented in the instrument and/or database [355]. If the method requires an interview, interviewers of the same ethnic or cultural background are preferable so that dietary information can be more effectively communicated. If dietary information is to be quantified into nutrient estimates, examination of the nutrient composition database is necessary to ascertain whether ethnic foods are included and whether those foods and their various preparation methods represent those consumed by the target population [356]. It is also necessary to examine the recipes and assumptions underlying the nutrient composition of certain ethnic foods. Some very different foods may be called the same name, or identical foods may be called by different names [357,358]. For these reasons, it may be necessary to obtain detailed recipe information for all ethnic mixtures reported.

To examine the suitability of the initial database, preliminary information about typical diets should be collected from individuals in the minority groups. This information could come from recalls or records with accompanying interviews or from focus group interviews. These interviews should focus on the foods eaten and the ways in which foods are prepared in that culture. Recipes and alternative names of the same food should be collected, and field interviewers should be familiarized with the results of these focus groups. Recipes and food names that are relatively uniform should be included in the nutrient composition database. Even with these modifications, it may be preferable for the field interviewers to collect detailed descriptions of ethnic foods reported rather than to directly code these foods using preselected lists most common in computer-assisted methods. This would prevent the detail of food choice and preparation from being lost by a priori coding.

USDA continues to incorporate new foods into the National Nutrient Database for Standard Reference (SR) as does the University of Minnesota Nutrient Database System (see Section V.F). If a newly reported food is not available in the food composition database being used, a default code that is thought to closely mirror the nutrient composition of the new food can be used.

Use of FFQs developed for the majority population may be suboptimal for many individuals with different eating patterns. Many individuals consume both foods common in the mainstream culture and foods that are specific to their own culture. Modification of the existing food list can be accomplished through expert judgment, qualitative interviews with the target population [359], and/or examination of the frequency of reported foods in the population from a set of dietary records or recalls. For example, FFQs for Alaska Natives [360], Hispanics [361,362], and African Americans in the southern United States [363] have been developed using these approaches.

In addition to the food list, however, there are other important issues to consider when adapting existing FFQs for use in other populations. The relative intake of different foods within a food group line item may differ, thus requiring a change in the nutrient database associated with each line item. For example, Latino populations may consume more tropical fruit nectars and less apple and grape juice than the general U.S. population and therefore would require a different nutrient composition standard for juices. In addition, the portion sizes generally used may differ [364]. For example, rice may be consumed in larger quantities in Latino and Asian populations; the amount attributed to a large portion for the general population may be substantially lower than the amount typically consumed by Latino and Asian populations. Adaptation of an existing FFQ considering all of these factors has been done for an elderly Puerto Rican population [365], for white and African-American adults in the Lower Mississippi Delta [366], and for the Hawaii−Los Angeles Multiethnic Cohort Study [367]. The Southern Community Cohort Study incorporated both race/ethnicity and geographic region into its FFQ database [368].

With some populations, it may be preferable to administer an FFQ using an interviewer rather than self-administration because literacy and language barriers may limit participation in the study as well as quality of response. In addition, portion size models, which interviewers can bring to a home interview, may be preferable to portion size pictures available in a self-administered instrument [360].

The NCI Dietary Calibration/Validation Studies Register [166] can be used to search for studies using FFQs in specific race/ethnicity groups. Questionnaires aimed at allowing comparison of intakes across multiple cultures have been developed. Although some studies have found no appreciable performance differences across various race/ethnicity groups [369], most have found differences [365,367,370−374]. Understanding these differences is crucial to the appropriate interpretation of study results.

C Children

Assessing the diets of children is considered to be even more challenging than assessing the diets of adults. Children tend to have diets that are highly variable from day to day, and their food habits can change rapidly over time. Younger children are less able to recall, estimate, and cooperate in usual dietary assessment procedures than older children [375], so much information by necessity has to be obtained by surrogate reporters. Although they are more able to report, adolescents may be less motivated to give accurate reports. Baranowski and Domel [376] have posited a cognitive model of how children report dietary information.

Dietary assessment in children and adolescents has been discussed and reviewed [375,377−382]. The 24-hour recall, dietary records (including precoded checklists [8]), dietary histories, FFQs, brief instruments [383−385], and blended instruments such as a dietary record-assisted 24-hour recall [291] have all been used to assess children's intakes. The use of direct observation of children's diets has also been used extensively, most often as a reference method to compare with self-reported instruments [386,387]. As predicted from Baranowski and Domel's model, it has been found that children's estimates of portion size have large error [388], and they are less able than adults to estimate portion sizes [389] (see Section V.D). Overall, the consensus seems to be that the characteristics of different age groups call for the use of different assessment approaches [380].

For preschool-aged children, information is obtained from surrogates, usually the primary caretaker(s), typically a parent or external caregiver. If information is obtained only from one surrogate reporter, the reports are likely to be less complete. Even for periods when the caregiver and child are together, foods tend to be underestimated [390]. A "consensus" recall method, in which the child and parents report as a group on a 24-hour recall, has been shown to give more accurate information than a recall from either parent or child alone [391]. Sobo and Rock [392] describe such interviews and suggest tips for interviewers to maximize data accuracy. Food records have been used in many European population studies [393]. This approach may be acceptable, but is likely to be inappropriate for some populations. The U.S. NHANES administers 24-hour recalls to proxy reporters for children under 6 [394].

For older children, extensive research has been conducted on the self-reported 24-hour recall [395]. Baxter et al. [396] found that among fourth graders, accuracy of the 24-hour recall improves as the time between reporting and eating decreases, and meal-specific intrusions (i.e., reports of foods not consumed) are fewer in an open format interview than in a time-forward format interview (i.e., beginning at the earliest meal in the time period and working forward to the next meal). These intrusions are often associated with additional intrusions at the same meal [396]. Because accuracy of recall is greater when the time between eating and reporting is shorter, there will be differential error by meal; meals further away (e.g., at the beginning of the 24-hour recall period) will have substantially more error [397,398].

To make 24-hour recalls more feasible, self-administered automated 24-hour recall tools have been developed and tested for children [88]. An interviewer-administered 24-hour recall and a self-administered 24-hour recall using the Food Intake Recording Software System (FIRSSt) were compared to unobtrusive observations in fourth graders. Compared to observed intake, the interviewer-administered 24-hour recall was associated with a 59% match, 17% intrusion, and 24% omission rates, whereas the automated recall was associated with a 46% match, 24% intrusion, and 30% omission rates [88]. The most recent version, FIRSSt4, is an adaptation of the ASA24, simplified for children [399,400] and is available as ASA24-Kids [76]. Particular challenges of self-administered 24-hour recalls in this age group include instigating and maintaining motivation to complete the task, and, because of difficulty in estimating portion size incorporating training for portion size estimation within the application [401]. Other web-based 24-hour recall systems have been developed especially for children and adolescents, for example, SCRAN24 in Great Britain [402], Web DASC in Denmark [403], and CANAA-W in Belgium [404]. The Synchronized Nutrition and Activity Program (SNAP), a partial recall, directs children to report the previous day's food intake by ticking the number of times they consumed each of 40 foods and 9 drinks [405]. Another approach that has been taken with school-age children is a blended instrument, the record-assisted 24-hour recall, in which the children record only the names of foods and beverages consumed throughout a 24-hour period. This information serves as a cue for the later 24-hour recall interview. The European Food Consumption Validation Project, a consortium of 13 institutes from 11 European countries, provisionally recommended a similar approach—a food recording booklet for foods eaten away from home—for school children 7−14 years old. Studies examining the validity of this approach have had mixed results [291,292,406]. For children ages 6−11, the U.S. NHANES administers 24-hour recalls to the child assisted by an adult household member. Children 12 years old and older report for themselves and may have a proxy reporter if necessary [394].

Food frequency approaches are even more challenging for children and adolescents as they are for adults. Children's diets change more quickly over time, and may also be more variable from day to day than adults. In addition, children are less able to conceptualize intake over a long period of time. The instrument itself requires adaptation of the food list, question wording and format, and portion size categories, and consequently the database for converting responses to nutrient intakes. Food frequency instruments, some web administered, have been developed and tested for use in child and adolescent populations [146,407−410]. A web-based food behavioral questionnaire underestimated the intake of middle-school children compared to a multiple-pass 24-hour recall [411]. Generally, correlations between food frequency type instruments and more precise reference instruments have been lower in child and adolescent populations than in adult populations. For these reasons, the food frequency approach is not recommended for children and adolescents.

New technology has been incorporated into some dietary assessment approaches. Williamson et al. [412] developed and tested an observational method using digital photography in school cafeterias. The method consists of standardized photography of the food selected before the meal and the plate waste following the meal. Using reference portions of measured quantities of the foods, expert judgment is used to estimate the amount of each food consumed [413]. Technology-based methods, such as disposable cameras, mobile phones with cameras [414], and smart phones, are being developed for collecting records and may be particularly useful among adolescents, who prefer these methods to traditional methods [415]. Examples of these new methods are the Remote Food Photography Method [416] and Technology Assisted Dietary Assessment [417]. Generally, these methods require more development, and eventual large-scale evaluation.

In addition to performance considerations, the choice of which dietary assessment approach instrument to use in a given study may depend on the study objectives and study design factors, all of which will influence the appropriateness and feasibility of different approaches [418].

D Elderly

Measuring diets among the elderly can, but does not necessarily, present special challenges [419−422]. Both recall and food frequency techniques are inappropriate if memory or cognitive functioning is impaired. Similarly, self-administered tools may be inappropriate if physical disabilities such as poor vision are present. Interviewer administration is difficult when hearing problems are present [421]. Direct observation in institutional care facilities [419] or shelf inventories for elders who live at home can be useful. Even when cognitive integrity is not impaired, several factors can affect the assessment of diet among the elderly. Because of the frequency of chronic illness in this age group, it is more probable that special diets (e.g., low sodium, low fat) would have been recommended. Such recommendations could not only affect actual dietary intake but also bias reporting because individuals may report what they should eat rather than what they do eat. Alternatively, respondents on special diets may be more aware of their diets and may more accurately report them. When dentition is poor, the interviewer should probe regarding foods that are prepared or consumed in different ways. Relative to other age groups, the elderly are more apt to take multiple types of nutritional supplements [423−425], which present special problems

TABLE 1.2 Optimal Strategies for Special Populations

Special Population	Optimal Strategies
Respondents unable to self-report	Use best-informed surrogate
	Analyze effect of potential bias on study results
Ethnic populations	Use interviewers of same ethnic background
	Use nutrient composition database reflective of foods consumed
	For FFQs, use appropriate food list and nutrient composition database
Children	For young children, use caretakers in conjunction with child
	For older children and adolescents, blended instrument and other creative ways of engagement and motivation may work best
	For FFQs, use appropriate food list and portion size categories
Elderly	Assess any special considerations, including memory, special diets, dentition, use of supplements, etc., and adapt methods accordingly

in dietary assessment (see Chapter 2: Assessment of Dietary Supplement Use). Because of the concern of malnutrition among the elderly, specific instruments to detect risk of malnutrition [426], such as the Mini Nutritional Assessment [427] and the Mini Nutritional Assessment Short Form [428,429], the Geriatric Nutritional Risk Index [430−432], the Subjective Global Assessment [426,428], and the Scored Patient-Generated Subjective Global Assessment [433] have been developed. While all of these tools focus on the elderly, they vary by setting, purpose, and administration mode.

Some researchers have suggested that the short-term memory required for the 24-hour recall may be more difficult for the elderly, who are more adept at long-term memory [419]. However, interviewers conducting an FFQ among elderly respondents noted difficulty in maintaining interest and concentration, whereas these issues were not found during the more engaging 24-hour recall interview [420].

Validation studies using doubly labeled water and/or urinary biomarkers among the elderly are limited [42,434−436]. Generally, energy underreporting has been found to be positively related to elevated BMI and lower education, similar to younger populations. However, in the NIH-funded Health, Aging, and Body Composition Study cohort, Shahar et al. [436] found that a substantial portion of elderly reporters were undereaters, losing more than 2% of their weight over a year. The distinction between undereating and underreporting is particularly relevant in the elderly.

Adaptations of standard dietary assessment methods have been suggested and evaluated, including using memory strategies, notifying the respondent prior to the dietary interview [437], combining methods [438], conducting multiple interviews for long protocols [419], and adapting existing instruments [439]. Specific adaptations that have been made in elderly populations include use of household measures rather than pictures to portray portion size for sight-impaired respondents [420] and tailoring the food list and portion sizes to be characteristic of the elderly rather than all adults in FFQs and their related databases [440,441].

Some have suggested including measures of cognitive function within a study to aid interpretation of results, but one such study found no relationship between cognitive functioning score and the validity of an FFQ [442]. In another study those showing cognitive dysfunction were excluded, but this creates selection bias [443]. Another approach is to solicit surrogate information for those considered cognitively unfit [444]. Mobile and web-based methods may prove useful, but currently the acceptance, feasibility, and validity of such methods in the elderly are unknown [422].

The variability in functional status among the elderly suggests the need for a flexible approach in assessing dietary intake. Mixed mode design in survey research [445] has certain advantages with regard to enhancing coverage and decreasing nonresponse, but it may cause other biases [446].

Table 1.2 summarizes special considerations for specific populations.

V SELECTED ISSUES IN DIETARY ASSESSMENT METHODS

A Cognitive Testing Research Related to Dietary Assessment

Nearly all studies using dietary information about subjects rely on the subjects' own reports of their diets. Because such reports are based on complex cognitive processes, it is important to understand and take advantage of what is known about how respondents remember dietary information and how that information is retrieved and reported to the investigator. The need for and importance of such considerations in the assessment of diet has been discussed by several investigators [302,376,447−449], and research using cognitive testing methods [10,90,123,197, 215,253,267,448,450−454] and other qualitative research techniques [400,402,404,455−458] has been reported. A thorough description of cognitive interviewing methods is found in Willis [459,460].

Specific and generic memories of diet are distinctly different. Specific memory relies on particular memories about episodes of eating and drinking, whereas generic memory relies on general knowledge about typical diet. A 24-hour recall relies primarily on specific memory of all actual events in the very recent past, whereas an FFQ that directs a respondent to report the usual frequency of eating a food during the previous year relies primarily on generic memory. As the time between the behavior and the report increases, respondents may rely more on generic memory and less on specific memory [448].

Investigators can do several things to enhance retrieval and improve reporting of diet. Research indicates that the amount of dietary information retrieved from memory can be enhanced by the context in which the instrument is administered and by use of specific memory cues and probes. For example, for a 24-hour recall, foods that were not initially reported by the respondent can be recovered by interviewer probes. The effectiveness of these probes is well-established and is therefore part of the interviewing protocols for all standardized high-quality 24-hour recalls, including those administered in the NHANES. Probes can be useful in improving generic memory, too, when subjects are asked to report their usual diets from periods in the past [302,449]. Such probes can feature questions about past living situations and related eating habits.

The way in which questions are asked can affect responses. Certain characteristics of the interviewing situation may affect particular responses for foods viewed as “good” or “bad.” For example, the presence of other family members during the dietary interview may increase bias due to social approval or social desirability traits [333,334], especially for certain items such as alcoholic beverages. An interview in a health setting, such as a clinic, may also increase social approval bias in reporting about foods that were previously proscribed or recommended in that setting. In all instances, interviewers should be trained to refrain from either positive or negative feedback and should repeatedly encourage subjects to accurately report all foods.

B Validation Studies

Validation studies yield information about how well the primary or main method used to collect dietary data is measuring what it is intended to measure. It is important and desirable that the main dietary assessment method be evaluated against a less-biased reference method [179,180,182,461]. Furthermore, even if an instrument has been evaluated and shows satisfactory results, its proposed use in a different population may warrant additional validation research in that population. The purposes of such studies are to better understand how the method works in the particular research setting, to improve it if possible, and to use that information to better interpret results from the overall study.

There are two types of validation studies. The first assesses the validity of reported intakes for a specific number of days or meals in comparison to reference measures that approximate truth such as direct observation, feeding studies, or recovery biomarkers for a time period exactly consistent with each self-reported intake day. The results of this type of study provide estimates of differences in true versus reported intakes of nutrients and food groups, proportion of foods and drinks accurately reported and omitted, and correlation coefficients. This type of study can only be used for short-term instruments such as 24-hour recalls or food records. For example, if the 24-hour recall or food record is the main instrument in a study, available reference instruments include observational techniques, feeding studies, or recovery biomarkers [115,390,462,463]. In observation or feeding studies, accuracy can be assessed by determining the matches, intrusions and exclusions in the foods reported compared to true intakes, and for matches differences between actual and reported nutrient and food group intakes and portion sizes [93,464,465]. Recovery biomarkers are unbiased reference instruments and include 24-hour urine collections to measure protein, sodium, and potassium intakes and doubly labeled water which measures energy expenditure and is used as a measure of energy intake when individuals are in energy balance [41−47,98,167,168,170,171,466,467]. In studies using recovery biomarkers as the reference instruments, intakes estimated from the biomarkers can be compared to reported intakes from recalls or food records to assess reporting error. However, the high cost and increased respondent burden can make the collection of recovery biomarkers impractical for many studies. Additionally, known recovery biomarkers are limited in number.

The second type of validation study assesses how well reported intakes match true usual intakes and collects reference measures such as recovery biomarkers or less-biased self-report dietary assessment instruments for a time period not exactly consistent with each self-reported intake day. This type of validation study can be used across all self-report dietary assessment instruments when interest is in obtaining validation measures of usual intake. For example, when an FFQ is used as the main study instrument, it can be evaluated in a study that compares it to another less-biased dietary assessment method, such as 24-hour recalls or dietary records and, preferably, to recovery biomarkers. The results are summarized by statistics such as correlation coefficients, bias, and attenuation factors. Correlation coefficients are related to the loss of power to detect relationships between diet and health outcomes. They are also useful for estimating the sample size required in a study because the less precise the diet measure, the more individuals will be needed to attain the desired statistical power [468]. Bias provides information about the difference between average reported intake and average true intake, at the group level. Attenuation factors represent bias in the estimated effect of self-reported dietary components on a health outcome. Some of this "attenuation bias," can be addressed through the use of measurement error models that allow for within-person error in the reference instrument, resulting in estimates that more nearly reflect the correlation between the diet measure and true diet [325,468]. It is important to note that when an FFQ is being evaluated using other biased and imperfect self-report reference instruments such as dietary records or 24-hour recalls, reporting errors between an FFQ and records/recalls are correlated, therefore, the statistical measures that result, such as correlation, bias, and attenuation, will be overly optimistic compared to those determined from unbiased reference instruments such as recovery biomarkers.

Validation and calibration studies (see below) are challenging because of the difficulty and expense in collecting reference dietary information. Because of this, such studies are done frequently on subsamples of the total study sample. If possible, the subsample should be chosen randomly. In addition, it should be sufficiently large to estimate the relationship between the study instrument and a reference method with reasonable precision. Increasing the numbers of individuals sampled and decreasing the number of repeat measures per individual (e.g., for an FFQ validation, collecting two nonconsecutive 24-hour recalls on 100 people rather than four recalls on 50 people) often can help to increase precision without extra cost [469]. The subsequent analyses quantify the relationship between the primary or main dietary intake tool and the reference method, and the resulting statistics can be used for a variety of purposes.

Too often, the term "validated" is used indiscriminately in research publications, to imply that the instrument is "valid," rather than that the instrument has been evaluated [470]. Thus the existence of a validation study is used by some to imply that the instrument is valid, regardless of the validation study's results. Often, validation coefficients in the range of 0.4−0.6 are presented as evidence that an instrument is valid. In reality, however, such findings should not be used to answer a "yes" or "no" question with respect to whether or not an instrument is "valid." Instead, readers should consider how the instrument performed for the purpose of study planning or instrument improvement. One should also consider whether the validation study design used unbiased or imperfect reference measures to evaluate the main instrument. The identification of additional unbiased references is needed to allow more extensive evaluation of self-report dietary assessment instruments.

The NCI maintains a register of validation/calibration studies and publications on the web [166].

C Calibration and Regression Calibration

The term "calibration" is used to refer to the rescaling of dietary data obtained from a more biased, less accurate instrument using information obtained from a less-biased, more accurate instrument. A calibrated instrument can be used to estimate population means and compare subpopulation means more accurately than an instrument that has not been calibrated. Calibration is distinct from "regression calibration," a term used to describe a method that uses calibration as part of a statistical procedure to better estimate associations (e.g., relative risks) between diet and other factors, such as health outcomes.

Calibration can be used to relate reported intakes on an FFQ or screener to a more accurate reference instrument administered in the same population. For example, a study may administer an FFQ to all respondents and the reference instrument (such as 24-hour dietary recalls) to a subsample. Alternatively, external calibration using data from a reference population different from the study population can be performed. In this case, the external population should be similar to the study population. In both situations, scoring algorithms are estimated and used to rescale the dietary data from the screener. The use of such scoring algorithms for screeners has been shown to lead to estimates of mean intakes that are closer to means estimated with 24-hour recall than those derived solely from screeners.

Regression calibration is a method used to adjust estimates of associations between diet and health outcomes for measurement error. This requires a main dietary assessment instrument collected among all study subjects and a reference instrument collected in at least a subsample. This data to accomplish regression calibration often come from a validation study (described above). In cohort studies, the main instrument has most often been an FFQ, although the use of multiple recalls or multiple-day food records is now more feasible than in the past. The estimated regression relationship between an FFQ and the reference method is used to adjust the relationships between diet and outcome (e.g., relative risk of disease for subjects with high nutrient intake compared to those with low intake) as assessed in the larger study [164,175,176,325,471,472]. Many of these adjustments require the assumption that the reference method is unbiased [175,323]. However, as discussed above, at least for most nutrients and food groups, the reported intakes from reference instruments such as recalls and records are biased in a manner correlated with FFQ [149], violating this assumption, which leads to overestimates of validity. For these reasons, researchers use recovery biomarkers such as urinary nitrogen and doubly labeled water when possible because they are unbiased measures of intake. However, because these are available for only a few nutrients, data from imperfect reference instruments such as 24-hour dietary recalls or food records are used. Such data are assumed to be unbiased for true usual intake, even though they fall short of this ideal. Although using these imperfect reference instruments does not completely adjust estimated diet-outcome associations for the bias caused by dietary measurement error, on average, it may produce less-biased results than an unadjusted standard analysis based solely on FFQ data. Another area in need of further study is the effect of measurement error in a multivariate context because most research thus far has been limited to the effect on univariate relationships [178,182,473,474].

D Mode of Administration

Instruments may be interviewer-administered or self-administered. Interviewer-administered questionnaires may be in person or by telephone. A self-administered instrument may be completed on paper or electronically. All of these modes are currently used for dietary assessment.

For interviewer-administered instruments, telephone administration is less costly than in-person administration. However, concern is increasing about response rates in telephone surveys, given the public's distaste for prevalent telemarketing, technology that allows for screening of calls, the increase in the proportion of the population (especially young adults [475]) who use only wireless telephones, and the general resistance of the public to engage in telephone interviews. For these reasons, response rates obtained using random digit dialing techniques have been dropping.

Despite these difficulties, many surveys and studies do collect dietary data over the telephone. For example, BRFSS [193] and the CHIS [195], both, include dietary screeners. NHANES [299] administers an initial 24-hour recall at the examination site and a second 24-hour recall later by telephone. For 24-hour recalls collected by telephone, the difficulty of reporting serving sizes can be eased by mailing picture booklets or other portion size estimation aids to participants before the interview. Many studies have evaluated the comparability of data from telephone versus in-person 24-hour recall interviews. Several have found substantial but imperfect agreement between dietary data collected by telephone and that estimated by other methods, including face-to-face interviews [74,476–478] or observed intakes [479]. Godwin et al. [480] and Yanek et al. [481] examined the accuracy of portion size estimates for known quantities of foods consumed that were assessed by telephone and by in-person interviews. Both estimates were found to be similarly accurate.

Self-administration is less costly than interviewer-administration. In addition, self-administered surveys tend to minimize social desirability bias [482]. However, self-administration may not be feasible for segments of the population who have low literacy levels or limited motivation. Thus, selection bias is a potential problem.

Web-administered questionnaires have cost advantages and have become popular as the penetrance of the Internet increases. In 2013, 79% of households in the United States had Internet access [483]. Various FFQs [122], dietary history questionnaires [484], screeners [250,485], and 24-hour recall instruments [76,88,486] have been developed for web administration. In general, it has been found that initial response rates for web questionnaires are substantially lower than those for mailed or telephone interviewer questionnaires [487]. One study conducted in Sweden found a lower initial response rate to a web questionnaire compared to a mailed printed questionnaire but greater compliance in answering follow-up questions over the web [488]. Web-administered questionnaires may be more effective than telephone interviewer-administered questionnaires for presentation of complex questions that are better processed visually than aurally by respondents and that can be answered at a pace set by the respondent rather than by the interviewer [489]. Beasley et al. [490] found that the responses to questions about diet on a web-administered FFQ were not significantly different from responses on a paper version of the same questionnaire. One large-scale survey found that self-administered 24-hour recalls using the Internet yielded nutrient intake estimates similar to interviewer telephone-administered 24-hour recalls [94]. The Internet version was preferred over the telephone-administered version by 70% to 30% [94].

Dietary assessment with mobile phones or tablets is an active area of development and research. Several self-administered 24-hour recalls instruments are available on mobile devices [76]. Use of mobile phones to record and photograph foods is also possible [491,492]. Sharp et al. recently reviewed evaluative studies of mobile phones to assess diet [493] and found that validity was comparable but not superior to other conventional methods. Further studies in larger and more diverse populations comparing these mobile devices to other modes of data collection are needed to examine comparability as well as the potential for self-selection biases.

E Estimation of Portion Size

Research has shown that untrained individuals have difficulty in estimating portion sizes of foods, both when examining displayed foods and when reporting about foods previously consumed [91,389,399,480,494–510]. One study indicates that literacy, but not numeracy, is an important factor in an individual's ability to accurately estimate portion size [511]. Furthermore, respondents appear to be relatively insensitive to changes made in portion size amounts shown in reference categories asked on FFQs [512]. Portion sizes of foods that are commonly bought and/or consumed in defined units (e.g., bread by the slice, pieces of fruit, and beverages in cans or bottles) may be more easily reported than amorphous foods (e.g., steak, lettuce, and pasta) or poured liquids [91,509]. Other studies indicate that small portion sizes tend to be overestimated and large portion sizes underestimated [496,508,513].

Aids are commonly used to help respondents estimate portion size. Research showing that different types of aids are more or less effective for different types of foods [417,510,514] indicates that having multiple types of aids available may be optimal. The NHANES What We Eat in America uses an extensive set of three-dimensional models for an initial in-person 24-hour dietary recall [515]. Respondents then are given a Food Model Booklet developed by the USDA [516] along with a limited number of three-dimensional models and household measures (e.g., measuring cups and spoons) for recalls collected by telephone. Food pictures and models have been developed for other eating patterns, for example, Asian foods [517] and foods consumed in Mexico [518]. The accuracy of reporting using either models or household measures can be improved with training [412,519–521], but the effects may deteriorate with time [522]. Studies comparing the use of either household measures or pictures among children and adolescents indicate that pictures outperform household measures [514,518]. Studies that have compared three-dimensional food models to two-dimensional photographs in adults have shown that there is little difference in the reporting accuracy between methods [388,480,523,524]. One study in children, however, showed that using food models resulted in somewhat larger error than using digital images [506]. Portion size pictures, however presented, should be tailored to the particular populations and ages.

With the increased use of technology in dietary assessment, digital food images in multiple portion sizes are being tested. Studies have investigated the effects of number of portion pictures, size of picture, and concurrent versus sequential display on accuracy of report [91,399,505]. Such studies indicate preferences by respondents but generally little difference in accuracy. However, in two studies, one with adults [91] and the other with children [400], accuracy was higher when more portion size choices were offered. An emerging use of digital technology removes respondent judgments of portion size, instead relying on digital images of foods taken before and after consumption, either actively by the respondent [525,526] or passively by a wearable camera [527,528]. Computer software is then used to both identify foods and estimate the amount consumed.

F Choice of Nutrient and Food Database

It is necessary to use a nutrient composition database when dietary data are to be converted to nutrient intake data. Typically, such a database includes the description of the food, a food code, and the nutrient composition per 100 g of the food. The number of foods and nutrients included varies with the database. Research on nutrients, other dietary components, and foods is ongoing, and there is constant interest in updating current values and providing new values for a variety of dietary components of interest.

Some values in nutrient databases are obtained from laboratory analysis; however, because of the high cost of laboratory analyses, many values are estimated based on conversion factors or other knowledge about the food [529]. In addition, accepted analytical methods are not yet available for some nutrients of interest [530], analytical quality of the information varies with nutrient [530,531], and the variances or ranges of nutrient composition of individual foods are in most cases unknown but are known to be large for some nutrients [532]. Rapid growth in the food processing sector and the global nature of the food supply add further challenges to estimating the mean and variability in the nutrient composition of foods eaten in a specific locale.

One of the USDA's primary missions is to provide nutrient composition data for foods in the U.S. food supply, accounting for various types of preparation [533]. Information about the USDA's nutrient composition databases is available at the USDA's Nutrient Data Laboratory home page [534]. The USDA produces and maintains the Nutrient Database for SR. New releases are issued yearly; these include information on new foods and revised information on already included foods, and they identify foods deleted from the previous version of the database. The most recent release, SR28, includes information on up to 150 food components for 8789 foods [535], and is available online.

Interest in nutrients and food components potentially associated with diseases has led the USDA to develop specialized databases for a smaller number of food components, such as flavonoids [534]. A separate database developed by the USDA Food Surveys Research Group—the Food and Nutrient Database for Dietary Studies (FNDDS)—is used by many investigators in analyses of foods reported in NHANES' What We Eat in America dietary recalls and is based on nutrient values in the USDA SR database [92]. The FNDDS provides information for 65 nutrients and food components, and has no missing data for nutrient fields.

Nutrient composition data are also compiled by a number of other countries, and the International Network of Food Data Systems maintains an international directory of nutrient composition tables [536]. Combining different food composition databases across countries poses comparability challenges, however. The European Food Information Resource [537] was formed to support the harmonization of food composition data among the European nations [538]. The International Nutrient Databank Directory, an online compendium developed by the National Nutrient Databank Conference, provides information about the data included in a variety of databases, national reference databases, and specialized databases developed for software applications, such as the date the database was most recently updated, the number of nutrients provided for each food, and the completeness of the nutrient data for all foods listed [539].

In addition to nutrient databases, databases that relate dietary intake to dietary guidance have been developed in the United States [540,541]. The USDA Food Patterns Equivalents Database (FPED) provides quantities of specific food groups consistent with dietary guidance recommendations in order to allow for evaluation of whether diets meet dietary guidelines at a variety of calorie levels [542]. Just as FNDDS provides nutrient composition data, the FPED provides food group data per 100 g of each food code in FNDDS. Importantly, mixed dishes, such as pizza, are disaggregated to their food group components. The FPED contains data for 37 food group components (e.g., dairy, fruits, vegetables) [543].

Other databases are available in the United States for use in analyzing dietary records and 24-hour recalls, but most are based fundamentally on the USDA SR database, often with added foods and specific brand names. One prominent such database is the University of Minnesota's Nutrition Coordinating Center's (NCC) Food and Nutrient Database [544]. This database includes information on 165 nutrients, nutrient ratios, and other food components for more than 18,000 foods, including 8000 brand-name products. The NCC is constantly updating its database to reflect values in the latest release of the USDA SR database.

One limitation in all nutrient databases is the variability in the nutrient content of foods within a food category and the volatility of nutrient composition in manufactured foods. Recent changes in the sodium and fatty acid composition of manufactured foods, for example, illustrate the difficulty in maintaining accurate nutrient composition databases [545,546]. Obviously, a key consideration is how the database is maintained and supported.

Estimates of nutrient intake from 24-hour recalls and dietary records are often affected by the nutrient composition database that is used to process the data [547–549]. Inherent differences in the database used for analysis include factors such as the number of food items included in the database, how recently nutrient data were updated, and the number of missing or imputed nutrient composition values. Therefore, before choosing a nutrient composition database, a prime factor to consider is the completeness and accuracy of the data for the nutrients of interest. For some purposes, it may be useful to choose a database in which each nutrient value for each food also contains a code for the quality of the data (e.g., analytical value, calculated value, imputed value, or missing). Investigators need to be aware that a value of zero is assigned to missing values in some databases, whereas for other databases, the number of nutrients provided for each food may fluctuate depending on whether or not a value is missing, and for others all unknown values may be imputed.

The nutrient database should also include weight/volume equivalency information for each food item. Many foods are reported in volumetric measures (e.g., 1 cup) and must be converted to weight in grams in order to apply nutrient values. The number of common mixtures (e.g., spaghetti with sauce) available in the database is another important factor. If the study requires precision of nutrient estimates, then procedures for calculating the nutrients in various mixtures must be developed and incorporated into nutrient composition calculations.

Developing a nutrient database for an FFQ presents additional challenges [550] because each item on the FFQ represents a food grouping rather than an individual food item. Various approaches that rely on 24-hour recall data, either from a national population sample or from a sample similar to the target population, have been used [551–553]. Generally, individual foods reported on 24-hour recalls are grouped into FFQ food groupings, and a composite nutrient profile for each food grouping is estimated based on the individual foods' relative consumption in the population. For this approach to be effective, the 24-hour recall data must be representative of the population for whom the FFQ is designed and connected to a trustworthy nutrient database.

G Choice of Dietary Analysis Software

Data processing of 24-hour recalls and dietary record requires creating data that include a food code and an amount consumed for each food reported. Computer software then links the nutrient composition of each food on the separate nutrient composition database file, converts the amount reported to multiples of 100 g, multiplies by that factor, stores that information, and sums across all foods for each nutrient for each individual for each day of intake. Many software packages have been developed that include both a nutrient composition database and software to convert individual responses to specific foods and, ultimately, to nutrients. A listing of many commercial dietary analysis software products has been compiled [539].

Software should be chosen on the basis of the research needs, the level of detail necessary, the quality of the nutrient composition database, and the hardware and software requirements [554]. If precise nutrient information is required, it is important that the system be able to expand to incorporate information about newer foods in the marketplace and to integrate detailed information about food preparation by processing recipe information (e.g., the ingredients and cooking steps for homemade stew). Sometimes the study purpose requires analysis of dietary data to derive intake estimates not only for nutrients but also for food groups (e.g., fruits and vegetables), food components other than standard nutrients (e.g., nitrites), or food characteristics (e.g., fried foods). These additional requirements limit the choice of appropriate software.

The semiautomated food coding system used for NHANES is USDA's Dietary Intake System, consisting of the AMPM for collecting food intakes; the Post-Interview Processing System, which translates the AMPM data and provides initial food coding; and the Survey Net food coding system for the final coding of the intake data [86]. Survey Net is a network dietary coding system that provides online coding, recipe modification and development, data editing and management, and nutrient analysis of dietary data; multiple users can use the software to manage the survey activities. It is available to government agencies and the general public only through special arrangement with the USDA. NCI's ASA24 instrument performs automated coding of all reported foods. Foods which are not completely described are assigned default values.

Many diet history and food frequency instruments have also been automated. Users of these software packages should be aware of the source of information in the nutrient database and the assumptions about the nutrient content of each food item listed in the questionnaire.

H Estimating Usual Intakes of Nutrients and Foods

Usual intake is conceptualized as the long-term average intake of a food or nutrient. The concept of long-term average daily intake, or "usual intake," is important because dietary recommendations are intended to be met over time and diet–health hypotheses are based on dietary intakes over the long term. Consequently, it is the usual intake that is often of most interest to policymakers (e.g., the proportion of the population at or below a certain level of intake) or to researchers (e.g., relationships between diet and health).

Data from FFQs, 24-hour recalls, and dietary records have all been used to estimate usual intake at the group level. Obtaining accurate estimates of usual intake at the individual level is generally not possible with the dietary assessment tools available even for FFQs which attempt to estimate usual intake generally over a longer period such as the past year. FFQs are known to contain a substantial amount of measurement error (see Section II.C) [54,79,100–103,117,149]. Dietary recalls or records generally provide more accurate short-term intake estimates than frequency-type instruments.

For estimates of mean usual intake in the population, data from just a single day of recall or record can be used. Multiple days of recalls and records are needed to estimate the distribution of intakes. However, the distribution of simple within-person averages of intakes across a few days does not adequately represent the population's usual intake distribution [555], because of the large day-to-day variability of individuals' diets. Distributions generated from averaging only a few days of data are generally substantially wider than those of true usual intakes, and thus lead to overestimating the proportion of the population above or below a certain cut point, as illustrated in Fig. 1.1.

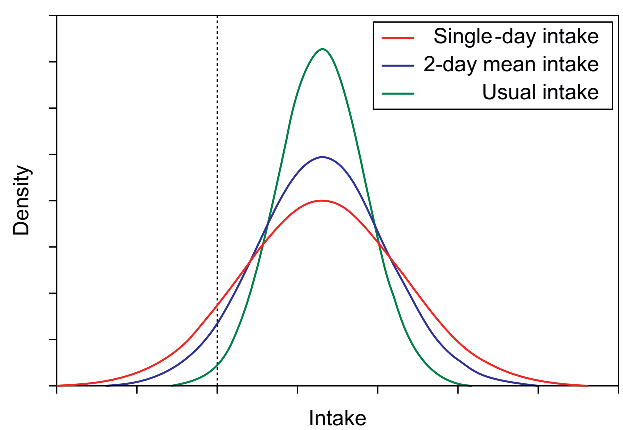

FIGURE 1.1 Effect of day-to-day variability on distributions. *Adapted from NCI Dietary Assessment Primer, Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from https://dietassessmentprimer.cancer.gov/.*

Statistical modeling can be used to more accurately portray the population's distribution by analytically estimating and removing the effects of day-to-day variation in dietary intake [555]. These methods rely on a minimum of two administrations of 24-hour recalls or dietary records to capture day-to-day variation. The earliest efforts at statistical modeling of usual intake were made by the Institute of Medicine [556] for nutrients, most of which are consumed nearly every day by most everyone, and then extended and updated for nutrients or foods that are more episodically consumed (e.g., dark green vegetables) by researchers at Iowa State University [557−559]. Others have developed usual intake statistical approaches as well [189,560−563]. The NCI method uses a minimum of two 24-hour recalls to estimate intake of both nutrients and episodically consumed foods [296]. This model as well as others [189] allows for covariates such as sex, age, race/ethnicity, or information from an FFQ to supplement the model [562]. One study using the NCI method showed that including FFQ data as covariates in modeling usual intakes from 24-hour recalls increased precision for assessing the relationship of a highly episodically consumed food, fish, with blood mercury levels [190]. Modeling usual intakes to assess relationships to health outcomes by combining data from a few 24-hour recalls with an FFQ has been shown to provide better estimates compared to a single FFQ or a few 24-hour recalls alone [188,189,295].

The NCI Measurement Error Webinar Series [564] provides a thorough discussion of dietary measurement error, including usual intake estimation.

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REFERENCES

[1] F.E. Thompson, A.F. Subar, Dietary assessment methodology, in: A.M. Coulston, C.L. Rock, E.R. Monsen (Eds.), Nutrition in the Prevention and Treatment of Disease, Academic Press, San Diego, CA, 2001, pp. 3−30.

[2] A.M. Coulston, C.J. Boushey (Eds.), Nutrition in the Prevention and Treatment of Disease, 2nd ed, Academic Press, San Diego, CA, 2008.

[3] F.E. Thompson, A.F. Subar, Dietary assessment methodology, in: A.M. Coulston, C.J. Boushey, M.G. Ferruzzi (Eds.), Nutrition in the Prevention and Treatment of Disease, Academic Press, San Diego, CA, 2013, pp. 5−46.

[4] F.E. Thompson, T. Byers, Dietary assessment resource manual, J. Nutr. 124 (1994) 2245S−2317S.

[5] M. Gersovitz, J.P. Madden, H. Smiciklas-Wright, Validity of the 24-hr. dietary recall and seven-day record for group comparisons, J. Am. Diet. Assoc. 73 (1978) 48−55.

[6] M.M. Cantwell, A.E. Millen, R. Carroll, B.L. Mittl, S. Hermansen, L.A. Brinton, et al., A debriefing session with a nutritionist can improve dietary assessment using food diaries, J. Nutr. 136 (2006) 440−445.

[7] R.S. Gibson, Principles of Nutritional Assessment, 2nd ed, Oxford University Press, New York, NY, 2005.

[8] I.T. Lillegaard, E.B. Loken, L.F. Andersen, Relative validation of a pre-coded food diary among children, under-reporting varies with reporting day and time of the day, Eur. J. Clin. Nutr. 61 (2007) 61−68.

[9] R.R. Couris, G.R. Tataronis, S.L. Booth, G.E. Dallal, J.B. Blumberg, J.T. Dwyer, Development of a self-assessment instrument to determine daily intake and variability of dietary vitamin K, J. Am. Coll. Nutr. 19 (2000) 801−807.

[10] F.E. Thompson, A.F. Subar, C.C. Brown, A.F. Smith, C.O. Sharbaugh, J.B. Jobe, et al., Cognitive research enhances accuracy of food frequency questionnaire reports: results of an experimental validation study, J. Am. Diet. Assoc. 102 (2002) 212−225.

[11] K.W. Smith, D.M. Hoelscher, L.A. Lytle, J.T. Dwyer, T.A. Nicklas, M.M. Zive, et al., Reliability and validity of the Child and Adolescent Trial for Cardiovascular Health (CATCH) Food Checklist: a self-report instrument to measure fat and sodium intake by middle school students, J. Am. Diet. Assoc. 101 (2001) 635−647.

[12] D.L. MacIntosh, C. Kabiru, K.A. Scanlon, P.B. Ryan, Longitudinal investigation of exposure to arsenic, cadmium, chromium and lead via beverage consumption, J. Expo. Anal. Environ. Epidemiol. 10 (2000) 196−205.

[13] S.M. Rebro, R.E. Patterson, A.R. Kristal, C.L. Cheney, The effect of keeping food records on eating patterns, J. Am. Diet. Assoc. 98 (1998) 1163−1165.

[14] L.F. Andersen, L. Johansson, K. Solvoll, Usefulness of a short food frequency questionnaire for screening of low intake of fruit and vegetable and for intake of fat, Eur. J. Public Health 12 (2002) 208−213.

[15] A.G. Kristjansdottir, L.F. Andersen, J. Haraldsdottir, M.D. de Almeida, I. Thorsdottir, Validity of a questionnaire to assess fruit and vegetable intake in adults, Eur. J. Clin. Nutr. 60 (2006) 408−415.

[16] N. Vuckovic, C. Ritenbaugh, D.L. Taren, M. Tobar, A qualitative study of participants' experiences with dietary assessment, J. Am. Diet. Assoc. 100 (2000) 1023−1028.

[17] K. Glanz, S. Murphy, J. Moylan, D. Evensen, J.D. Curb, Improving dietary self-monitoring and adherence with hand-held computers: a pilot study, Am. J. Health Promot. 20 (2006) 165−170.

[18] A.H. Goris, M.S. Westerterp-Plantenga, K.R. Westerterp, Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake, Am. J. Clin. Nutr. 71 (2000) 130−134.

[19] J.F. Hollis, C.M. Gullion, V.J. Stevens, P.J. Brantley, L.J. Appel, J.D. Ard, et al., Weight loss during the intensive intervention phase of the weight-loss maintenance trial, Am. J. Prev. Med. 35 (2008) 118−126.

[20] L.E. Burke, M.B. Conroy, S.M. Sereika, O.U. Elci, M.A. Styn, S. D. Acharya, et al., The effect of electronic self-monitoring on weight loss and dietary intake: a randomized behavioral weight loss trial, Obesity (Silver Spring) 19 (2011) 338−344.

[21] S. Goodman, B. Morrongiello, J. Randall Simpson, K. Meckling, Vitamin D intake among young Canadian adults: validation of a mobile vitamin D calculator app, J. Nutr. Educ. Behav. 47 (2015) 242−247.

[22] J. Di Noia, I.R. Contento, S.P. Schinke, Criterion validity of the Healthy Eating Self-monitoring Tool (HEST) for black adolescents, J. Am. Diet. Assoc. 107 (2007) 321−324.

[23] J. Di Noia, I.R. Contento, Criterion validity and user acceptability of a CD-ROM-mediated food record for measuring fruit and vegetable consumption among black adolescents, Public Health Nutr 12 (2009) 3−11.

[24] M.A. Murtaugh, K.N. Ma, T. Greene, D. Redwood, S. Edwards, J. Johnson, et al., Validation of a dietary history questionnaire for American Indian and Alaska Native people, Ethn. Dis. 20 (2010) 429−436.

[25] D.H. Wang, M. Kogashiwa, S. Kira, Development of a new instrument for evaluating individuals' dietary intakes, J. Am. Diet. Assoc. 106 (2006) 1588−1593.

[26] L. Arab, A. Winter, Automated camera-phone experience with the frequency of imaging necessary to capture diet, J. Am. Diet. Assoc. 110 (2010) 1238−1241.

[27] M. Sun, J.D. Fernstrom, W. Jia, S.A. Hackworth, N. Yao, Y. Li, et al., A wearable electronic system for objective dietary assessment, J. Am. Diet. Assoc. 110 (2010) 45−47.

[28] Y. He, C. Xu, N. Khanna, C.J. Boushey, E.J. Delp, Analysis of food images: features and classification. Proceedings of the IEEE International Conference on Image Processing (ICIP), Paris, France, October 27−30, 2014, pp. 2744−2748.

[29] H.C. Chen, W. Jia, X. Sun, Z. Li, Y. Li, J.D. Fernstrom, et al., Saliency-aware food image segmentation for personal dietary assessment using a wearable computer, Meas. Sci. Technol. 26 (2015).

[30] L. Gemming, J. Utter, C. Ni Mhurchu, Image-assisted dietary assessment: a systematic review of the evidence, J. Acad. Nutr. Diet. 115 (2015) 64−77.

[31] S.I. Kirkpatrick, D. Midthune, K.W. Dodd, N. Potischman, A.F. Subar, F.E. Thompson, Reactivity and its association with body mass index across days on food checklists, J. Acad. Nutr. Diet. 112 (2012) 110−118.

[32] B. Holmes, K. Dick, M. Nelson, A comparison of four dietary assessment methods in materially deprived households in England, Public Health Nutr. 11 (2008) 444−456.

[33] V.K. Knudsen, M.B. Gille, T.H. Nielsen, T. Christensen, S. Fagt, A. Biltoft-Jensen, Relative validity of the pre-coded food diary used in the Danish National Survey of Diet and Physical Activity, Public Health Nutr. 14 (2011) 2110−2116.

[34] T.H. Stea, L.F. Andersen, G. Paulsen, K.J. Hetlelid, H. Lohne-Seiler, S. Adnanes, et al., Validation of a pre-coded food diary used among 60−80 year old men: comparison of self-reported energy intake with objectively recorded energy expenditure, PLoS One 9 (2014) e102029.

[35] M.B. Livingstone, A.E. Black, Markers of the validity of reported energy intake, J. Nutr. 133 (2003) 895S−920S.

[36] S.A. Bingham, Urine nitrogen as a biomarker for the validation of dietary protein intake, J. Nutr. 133 (2003) 921S−924S.

[37] N. Tasevska, S.A. Runswick, S.A. Bingham, Urinary potassium is as reliable as urinary nitrogen for use as a recovery biomarker in dietary studies of free living individuals, J. Nutr. 136 (2006) 1334−1340.

[38] R.M. McLean, Measuring population sodium intake: a review of methods, Nutrients 6 (2014) 4651−4662.

[39] J. Trabulsi, D.A. Schoeller, Evaluation of dietary assessment instruments against doubly labeled water, a biomarker of habitual energy intake, Am. J. Physiol. Endocrinol. Metab. 281 (2001) E891−E899.

[40] R.J. Hill, P.S. Davies, The validity of self-reported energy intake as determined using the doubly labelled water technique, Br. J. Nutr. 85 (2001) 415−430.

[41] D.L. Taren, M. Tobar, A. Hill, W. Howell, C. Shisslak, I. Bell, et al., The association of energy intake bias with psychological scores of women, Eur. J. Clin. Nutr. 53 (1999) 570−578.

[42] A.L. Sawaya, K. Tucker, R. Tsay, W. Willett, E. Saltzman, G.E. Dallal, et al., Evaluation of four methods for determining energy intake in young and older women: comparison with doubly labeled water measurements of total energy expenditure, Am. J. Clin. Nutr. 63 (1996) 491−499.

[43] A.E. Black, A.M. Prentice, G.R. Goldberg, S.A. Jebb, S.A. Bingham, M.B. Livingstone, et al., Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake, J. Am. Diet. Assoc. 93 (1993) 572−579.

[44] A.E. Black, S.A. Bingham, G. Johansson, W.A. Coward, Validation of dietary intakes of protein and energy against 24 hour urinary N and DLW energy expenditure in middle-aged women, retired men and post-obese subjects: comparisons with validation against presumed energy requirements, Eur. J. Clin. Nutr. 51 (1997) 405−413.

[45] L.J. Martin, W. Su, P.J. Jones, G.A. Lockwood, D.L. Tritchler, N.F. Boyd, Comparison of energy intakes determined by food records and doubly labeled water in women participating in a dietary-intervention trial, Am. J. Clin. Nutr. 63 (1996) 483−490.

[46] E. Rothenberg, Validation of the food frequency questionnaire with the 4-day record method and analysis of 24-h urinary nitrogen, Eur. J. Clin. Nutr. 48 (1994) 725−735.

[47] S.A. Bingham, C. Gill, A. Welch, A. Cassidy, S.A. Runswick, S. Oakes, et al., Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers, Int. J. Epidemiol. 26 (1997) S137−S151.

[48] G.P. Bathalon, K.L. Tucker, N.P. Hays, A.G. Vinken, A.S. Greenberg, M.A. McCrory, et al., Psychological measures of eating behavior and the accuracy of 3 common dietary assessment methods in healthy postmenopausal women, Am. J. Clin. Nutr. 71 (2000) 739−745.

[49] J.L. Seale, W.V. Rumpler, Comparison of energy expenditure measurements by diet records, energy intake balance, doubly labeled water and room calorimetry, Eur. J. Clin. Nutr. 51 (1997) 856−863.

[50] J.L. Seale, G. Klein, J. Friedmann, G.L. Jensen, D.C. Mitchell, H. Smiciklas-Wright, Energy expenditure measured by doubly labeled water, activity recall, and diet records in the rural elderly, Nutrition 18 (2002) 568−573.

[51] S. Mahabir, D.J. Baer, C. Giffen, A. Subar, W. Campbell, T.J. Hartman, et al., Calorie intake misreporting by diet record and food frequency questionnaire compared to doubly labeled water among postmenopausal women, Eur. J. Clin. Nutr. 60 (2006) 561−565.

[52] K. Poslusna, J. Ruprich, J.H. de Vries, M. Jakubikova, P. van't Veer, Misreporting of energy and micronutrient intake estimated by food records and 24 hour recalls, control and adjustment methods in practice, Br. J. Nutr. 101 (2009) S73−S85.

[53] M.E. Rollo, S. Ash, P. Lyons-Wall, A.W. Russell, Evaluation of a mobile phone image-based dietary assessment method in adults with type 2 diabetes, Nutrients 7 (2015) 4897−4910.

[54] R.L. Prentice, Y. Mossavar-Rahmani, Y. Huang, L. Van Horn, S. A. Beresford, B. Caan, et al., Evaluation and comparison of food records, recalls, and frequencies for energy and protein assessment by using recovery biomarkers, Am. J. Epidemiol. 174 (2011) 591−603.

[55] K.R. Westerterp, A.H. Goris, Validity of the assessment of dietary intake: problems of misreporting, Curr. Opin. Clin. Nutr. Metab. Care 5 (2002) 489−493.

[56] J. Maurer, D.L. Taren, P.J. Teixeira, C.A. Thomson, T.G. Lohman, S.B. Going, et al., The psychosocial and behavioral characteristics related to energy misreporting, Nutr. Rev 64 (2006) 53−66.

[57] S.W. Lichtman, K. Pisarska, E.R. Berman, M. Pestone, H. Dowling, E. Offenbacher, et al., Discrepancy between self-reported and actual caloric intake and exercise in obese subjects, N. Engl. J. Med. 327 (1992) 1893−1898.

[58] J.A. Pryer, M. Vrijheid, R. Nichols, M. Kiggins, P. Elliott, Who are the 'low energy reporters' in the dietary and nutritional survey of British adults? Int. J. Epidemiol. 26 (1997) 146−154.

[59] R.K. Johnson, M.I. Goran, E.T. Poehlman, Correlates of over- and underreporting of energy intake in healthy older men and women, Am. J. Clin. Nutr. 59 (1994) 1286−1290.

[60] T. Hirvonen, S. Mannisto, E. Roos, P. Pietinen, Increasing prevalence of underreporting does not necessarily distort dietary surveys, Eur. J. Clin. Nutr. 51 (1997) 297−301.

[61] L. Lafay, A. Basdevant, M.A. Charles, M. Vray, B. Balkau, J.M. Borys, et al., Determinants and nature of dietary underreporting in a free-living population: the Fleurbaix Laventie Ville Sante (FLVS) Study, Int. J. Obes. Relat. Metab. Disord. 21 (1997) 567−573.

[62] R. Ballard-Barbash, I. Graubard, S.M. Krebs-Smith, A. Schatzkin, F.E. Thompson, Contribution of dieting to the inverse association between energy intake and body mass index, Eur. J. Clin. Nutr. 50 (1996) 98−106.

[63] C. Bazelmans, C. Matthys, S. De Henauw, M. Dramaix, M. Kornitzer, G. De Backer, et al., Predictors of misreporting in an elderly population: the 'Quality of life after 65' study, Public Health Nutr. 10 (2007) 185−191.

[64] J.R. Hebert, L. Clemow, L. Pbert, I.S. Ockene, J.K. Ockene, Social desirability bias in dietary self-report may compromise the validity of dietary intake measures, Int. J. Epidemiol. 24 (1995) 389−398.

[65] D.D. Stallone, E.J. Brunner, S.A. Bingham, M.G. Marmot, Dietary assessment in Whitehall II: the influence of reporting bias on apparent socioeconomic variation in nutrient intakes, Eur. J. Clin. Nutr. 51 (1997) 815−825.

[66] C.M. Champagne, G.A. Bray, A.A. Kurtz, J.B. Monteiro, E. Tucker, J. Volaufova, et al., Energy intake and energy expenditure: a controlled study comparing dietitians and non-dietitians, J. Am. Diet. Assoc. 102 (2002) 1428−1432.

[67] J.M. Abbot, C.A. Thomson, J. Ranger-Moore, P.J. Teixeira, T.G. Lohman, D.L. Taren, et al., Psychosocial and behavioral profile and predictors of self-reported energy underreporting in obese middle-aged women, J. Am. Diet Assoc. 108 (2008) 114−119.

[68] I. Kortzinger, A. Bierwag, M. Mast, M.J. Muller, Dietary underreporting: validity of dietary measurements of energy intake using a 7-day dietary record and a diet history in non-obese subjects, Ann. Nutr. Metab. 41 (1997) 37−44.

[69] L. Lafay, L. Mennen, A. Basdevant, M.A. Charles, J.M. Borys, E. Eschwege, et al., Does energy intake underreporting involve all kinds of food or only specific food items? Results from the Fleurbaix Laventie Ville Sante (FLVS) study, Int. J. Obes. Relat. Metab. Disord. 24 (2000) 1500−1506.

[70] A. Biltoft-Jensen, J. Matthiessen, L.B. Rasmussen, S. Fagt, M.V. Groth, O. Hels, Validation of the Danish 7-day pre-coded food diary among adults: energy intake v. energy expenditure and recording length, Br. J. Nutr. 102 (2009) 1838−1846.

[71] S.J. Zhou, M.J. Schilling, M. Makrides, Evaluation of an iron specific checklist for the assessment of dietary iron intake in pregnant and postpartum women, Nutrition 21 (2005) 908−913.

[72] J.L. Seale, Predicting total energy expenditure from self-reported dietary records and physical characteristics in adult and elderly men and women, Am. J. Clin. Nutr. 76 (2002) 529−534.

[73] I.M. Buzzard, C.L. Faucett, R.W. Jeffery, L. McBane, P. McGovern, J.S. Baxter, et al., Monitoring dietary change in a low-fat diet intervention study: advantages of using 24-hour dietary recalls vs food records, J. Am. Diet. Assoc. 96 (1996) 574−579.

[74] P.H. Casey, S.L. Goolsby, S.Y. Lensing, B.P. Perloff, M.L. Bogle, The use of telephone interview methodology to obtain 24-hour dietary recalls, J. Am. Diet. Assoc. 99 (1999) 1406−1411.

[75] U.S. Department of Agriculture. What We Eat in America (WWEIA), NHANES, Agricultural Research Service, U.S. Department of Agriculture. Available from <http://www.ars.usda.gov/Services/docs.htm?docid = 13793>, 2010.

[76] National Cancer Institute. ASA24™ Automated Self-Administered 24-Hour Recall, Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://epi.grants.cancer.gov/asa24//>, 2015.

[77] J.F. Sallis, N. Owen, Ecological models of health behavior, in: K. Glanz, B.K. Rimer, F.M. Lewis (Eds.), Health Behavior and Health Education: Theory, Research, and Practice, Jossey-Bass, San Francisco, CA, 2002, pp. 462−484.

[78] L. Arab, K. Wesseling-Perry, P. Jardack, J. Henry, A. Winter, Eight self-administered 24-hour dietary recalls using the Internet are feasible in African Americans and Whites: the energetics study, J. Am. Diet. Assoc. 110 (2010) 857−864.

[79] L. Arab, C.H. Tseng, A. Ang, P. Jardack, Validity of a multipass, web-based, 24-hour self-administered recall for assessment of total energy intake in blacks and whites, Am. J. Epidemiol. 174 (2011) 1256−1265.

[80] C.A. Vereecken, M. Covents, W. Sichert-Hellert, J.M. Alvira, C. Le Donne, S. De Henauw, et al., Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe, Int. J. Obes. (Lond.) 32 (2008) S26−S34.

[81] V.A. Campbell, M.L. Dodds, Collecting dietary information from groups of older people, J. Am. Diet. Assoc. 51 (1967) 29−33.

[82] N. Raper, B. Perloff, L. Ingwersen, L. Steinfeldt, J. Anand, An overview of USDA's dietary intake data system, J. Food Compost. Anal. 17 (2004) 545−555.

[83] A.J. Moshfegh, D.G. Rhodes, D.J. Baer, T. Murayi, J.C. Clemens, W.V. Rumpler, et al., The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes, Am. J. Clin. Nutr. 88 (2008) 324−332.

[84] J. McBride, Was it a slab, a slice, or a sliver? High-tech innovations take food survey to new level, Agric. Res. 49 (2001) 4−7.

[85] Y.C. Probst, L.C. Tapsell, Overview of computerized dietary assessment programs for research and practice in nutrition education, J. Nutr. Educ. Behav. 37 (2005) 20−26.

[86] U.S. Department of Agriculture. AMPM - USDA Automated Multiple-Pass Method, Agricultural Research Service, U.S. Department of Agriculture. Available from <http://www.ars.usda.gov/Services/docs.htm?docid = 7710>, 2014.

[87] L.I. Mennen, S. Bertrais, P. Galan, N. Arnault, G. Potier de Couray, S. Hercberg, The use of computerised 24 h dietary recalls in the French SU.VI.MAX Study: number of recalls required, Eur. J. Clin. Nutr. 56 (2002) 659−665.

[88] T. Baranowski, N. Islam, J. Baranowski, K.W. Cullen, D. Myres, T. Marsh, et al., The Food Intake Recording Software System is valid among fourth-grade children, J. Am. Diet. Assoc. 102 (2002) 380−385.

[89] C.A. Vereecken, M. Covents, C. Matthys, L. Maes, Young Adolescents' Nutrition Assessment on Computer (YANA-C), Eur. J. Clin. Nutr. 59 (2005) 658−667.

[90] A.F. Subar, F.E. Thompson, N. Potischman, B.H. Forsyth, R. Buday, D. Richards, et al., Formative research of a quick list for an automated self-administered 24-hour dietary recall, J. Am. Diet. Assoc. 107 (2007) 1002−1007.

[91] A.F. Subar, J. Crafts, T.P. Zimmerman, M. Wilson, B. Mittl, N.G. Islam, et al., Assessment of the accuracy of portion size reports using computer-based food photography aids in the development of an automated self-administered 24-hour recall, J. Am. Diet. Assoc. 110 (2010) 55−64.

[92] U.S. Department of Agriculture. USDA Food and Nutrient Database for Dietary Studies (FNDDS), Agricultural Research Service, U.S. Department of Agriculture. Available from <http://ghdx.healthdata.org/record/united-states-usda-food-and-nutrient-database-dietary-studies-fndds>, 2015.

[93] S.I. Kirkpatrick, A.F. Subar, D. Douglass, T.P. Zimmerman, F.E. Thompson, L.L. Kahle, et al., Performance of the automated self-administered 24-hour recall relative to a measure of true intakes and to an interviewer-administered 24-h recall, Am. J. Clin. Nutr. 100 (2014) 233−240.

[94] F.E. Thompson, S. Dixit-Joshi, N. Potischman, K.W. Dodd, S.I. Kirkpatrick, L.H. Kushi, et al., Comparison of interviewer-administered and automated self-administered 24-hour dietary recalls in 3 diverse integrated health systems, Am. J. Epidemiol. 181 (2015) 970−978.

[95] J.P. Madden, S.J. Goodman, H.A. Guthrie, Validity of the 24-hr. recall. Analysis of data obtained from elderly subjects, J. Am. Diet. Assoc. 68 (1976) 143−147.

[96] S.S. Jonnalagadda, D.C. Mitchell, H. Smiciklas-Wright, K.B. Meaker, N. Van Heel, W. Karmally, et al., Accuracy of energy intake data estimated by a multiple-pass, 24-hour dietary recall technique, J. Am. Diet. Assoc. 100 (2000) 303−308.

[97] A. Kroke, K. Klipstein-Grobusch, S. Voss, J. Moseneder, F. Thielecke, R. Noack, et al., Validation of a self-administered food-frequency questionnaire administered in the European Prospective Investigation into Cancer and Nutrition (EPIC) Study: comparison of energy, protein, and macronutrient intakes estimated with the doubly labeled water, urinary nitrogen, and repeated 24-h dietary recall methods, Am. J. Clin. Nutr. 70 (1999) 439−447.

[98] R.K. Johnson, R.P. Soultanakis, D.E. Matthews, Literacy and body fatness are associated with underreporting of energy intake in US low-income women using the multiple-pass 24-hour recall: a doubly labeled water study, J. Am. Diet. Assoc. 98 (1998) 1136−1140.

[99] J.R. Hebert, C.B. Ebbeling, C.E. Matthews, T.G. Hurley, Y. Ma, S. Druker, et al., Systematic errors in middle-aged women's estimates of energy intake: comparing three self-report measures to total energy expenditure from doubly labeled water, Ann. Epidemiol. 12 (2002) 577−586.

[100] A.F. Subar, V. Kipnis, R.P. Troiano, D. Midthune, D.A. Schoeller, S. Bingham, et al., Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study, Am. J. Epidemiol. 158 (2003) 1−13.

[101] S.R. Preis, D. Spiegelman, B.B. Zhao, A. Moshfegh, D.J. Baer, W.C. Willett, Application of a repeat-measure biomarker measurement error model to 2 validation studies: examination of the effect of within-person variation in biomarker measurements, Am. J. Epidemiol. 173 (2011) 683−694.

[102] F.B. Scagliusi, E. Ferriolli, K. Pfrimer, C. Laureano, C.S. Cunha, B. Gualano, et al., Underreporting of energy intake in Brazilian women varies according to dietary assessment: a cross-sectional study using doubly labeled water, J. Am. Diet. Assoc. 108 (2008) 2031−2040.

[103] M.L. Neuhouser, L. Tinker, P.A. Shaw, D. Schoeller, S.A. Bingham, L.V. Horn, et al., Use of recovery biomarkers to calibrate nutrient consumption self-reports in the Women's Health Initiative, Am. J. Epidemiol. 167 (2008) 1247−1259.

[104] N. Slimani, S. Bingham, S. Runswick, P. Ferrari, N.E. Day, A.A. Welch, et al., Group level validation of protein intakes estimated by 24-hour diet recall and dietary questionnaires against 24-hour urinary nitrogen in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study, Cancer Epidemiol. Biomarkers Prev. 12 (2003) 784−795.

[105] S.P. Crispim, A. Geelen, J.H. de Vries, H. Freisling, O.W. Souverein, P.J. Hulshof, et al., Bias in protein and potassium intake collected with 24-h recalls (EPIC-Soft) is rather comparable across European populations, Eur. J. Nutr. 51 (2012) 997−1010.

[106] H. Freisling, M.M. van Bakel, C. Biessy, A.M. May, G. Byrnes, T. Norat, et al., Dietary reporting errors on 24 h recalls and dietary questionnaires are associated with BMI across six European countries as evaluated with recovery biomarkers for protein and potassium intake, Br. J. Nutr. 107 (2012) 910−920.

[107] S.P. Crispim, J.H. de Vries, A. Geelen, O.W. Souverein, P.J. Hulshof, L. Lafay, et al., 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, Br. J. Nutr. 105 (2011) 447−458.

[108] L.S. Freedman, J.M. Commins, J.E. Moler, L. Arab, D.J. Baer, V. Kipnis, et al., Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for energy and protein intake, Am. J. Epidemiol. 180 (2014) 172–188.

[109] C. Montgomery, J.J. Reilly, D.M. Jackson, L.A. Kelly, C. Slater, J.Y. Paton, et al., Validation of energy intake by 24-hour multiple pass recall: comparison with total energy expenditure in children aged 5–7 years, Br. J. Nutr. 93 (2005) 671–676.

[110] B. Bokhof, A.E. Buyken, C. Dogan, A. Karaboga, J. Kaiser, A. Sonntag, et al., Validation of protein and potassium intakes assessed from 24 h recalls against levels estimated from 24 h urine samples in children and adolescents of Turkish descent living in Germany: results from the EVET! Study, Public Health Nutr. 15 (2012) 640–647.

[111] G.G. Harrison, O.M. Galal, N. Ibrahim, A. Khorshid, A. Stormer, J. Leslie, et al., Underreporting of food intake by dietary recall is not universal: a comparison of data from Egyptian and American women, J. Nutr. 130 (2000) 2049–2054.

[112] S.M. Krebs-Smith, B.I. Graubard, L.L. Kahle, A.F. Subar, L.E. Cleveland, R. Ballard-Barbash, Low energy reporters vs others: a comparison of reported food intakes, Eur. J. Clin. Nutr. 54 (2000) 281–287.

[113] R.R. Briefel, M.A. McDowell, K. Alaimo, C.R. Caughman, A.L. Bischof, M.D. Carroll, et al., Total energy intake of the US population: the third National Health and Nutrition Examination Survey, 1988–1991, Am. J. Clin. Nutr. 62 (1995) 1072S–1080S.

[114] R.C. Klesges, L.H. Eck, J.W. Ray, Who underreports dietary intake in a dietary recall? Evidence from the Second National Health and Nutrition Examination Survey, J. Consult. Clin. Psychol. 63 (1995) 438–444.

[115] S.D. Poppitt, D. Swann, A.E. Black, A.M. Prentice, Assessment of selective under-reporting of food intake by both obese and non-obese women in a metabolic facility, Int. J. Obes. Relat. Metab. Disord. 22 (1998) 303–311.

[116] J.A. Tooze, A.F. Subar, F.E. Thompson, R. Troiano, A. Schatzkin, V. Kipnis, Psychosocial predictors of energy underreporting in a large doubly labeled water study, Am. J. Clin. Nutr. 79 (2004) 795–804.

[117] National Cancer Institute. Dietary assessment primer, Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <https://dietassessmentprimer.cancer.gov/>.

[118] NutritionQuest. Block questionnaires. Available from <http://nutritionquest.com/>, 2014.

[119] Harvard School of Public Health. Harvard T.H. Chan School of Public Health Nutrition Department's File Download Site: Directory Listing of /Health/FFQ/Files. Available from <https://regepi.bwh.harvard.edu/health/FFQ/files>, 2015.

[120] Fred Hutchinson Cancer Research Center. Food Frequency Questionnaires (FFQs), Fred Hutchinson Cancer Research Center. Available from <http://sharedresources.fhcrc.org/services/food-frequency-questionnaires-ffq>.

[121] R.E. Patterson, A.R. Kristal, L.F. Tinker, R.A. Carter, M.P. Bolton, T. Agurs-Collins, Measurement characteristics of the Women's Health Initiative food frequency questionnaire, Ann. Epidemiol. 9 (1999) 178–187.

[122] National Cancer Institute. Diet History Questionnaire II and Canadian Diet History Questionnaire II (C-DHQII), Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://epi.grants.cancer.gov/dhq2/>, 2015.

[123] A.F. Subar, F.E. Thompson, A.F. Smith, J.B. Jobe, R.G. Ziegler, N. Potischman, et al., Improving food frequency questionnaires: a qualitative approach using cognitive interviewing, J. Am. Diet. Assoc. 95 (1995) 781–788.

[124] A.F. Subar, R.G. Ziegler, F.E. Thompson, C.C. Johnson, J.L. Weissfeld, D. Reding, et al., Is shorter always better? Relative importance of questionnaire length and cognitive ease on response rates and data quality for two dietary questionnaires, Am. J. Epidemiol. 153 (2001) 404–409.

[125] F.E. Thompson, G.B. Willis, O.M. Thompson, A.L. Yaroch, The meaning of 'fruits' and 'vegetables', Public Health Nutr. 14 (2011) 1222–1228.

[126] W. Willett, L. Sampson, Foods and nutrients, in: W. Willett (Ed.), Nutritional Epidemiology, Oxford University Press, New York, NY, 2013, pp. 17–33.

[127] M.L. Molag, J.H. de Vries, M.C. Ocke, P.C. Dagnelie, P.A. van den Brandt, M.C. Jansen, et al., Design characteristics of food frequency questionnaires in relation to their validity, Am. J. Epidemiol. 166 (2007) 1468–1478.

[128] A.R. Kristal, K. Glanz, Z. Feng, J.R. Hebert, C. Probart, M. Eriksen, et al., Does using a short dietary questionnaire instead of a food frequency improve response rates to a health assessment survey? J. Nutr. Educ. 26 (1994) 224–227.

[129] A. Kuskowska-Wolk, S. Holte, E.M. Ohlander, A. Bruce, L. Holmberg, H.O. Adami, et al., Effects of different designs and extension of a food frequency questionnaire on response rate, completeness of data and food frequency responses, Int. J. Epidemiol. 21 (1992) 1144–1150.

[130] J.C. Gerdessen, O.W. Souverein, P. van 't Veer, J.H. de Vries, Optimising the selection of food items for FFQs using Mixed Integer Linear Programming, Public Health Nutr. 18 (2015) 68–74.

[131] J.A. Heady, Diets of bank clerks. Development of a method of classifying the diets of individuals for use in epidemiological studies, J. R. Stat. Soc. Ser. A 124 (1961) 336–371.

[132] K.M. Flegal, F.A. Larkin, Partitioning macronutrient intake estimates from a food frequency questionnaire, Am. J. Epidemiol. 131 (1990) 1046–1058.

[133] S.R. Cummings, G. Block, K. McHenry, R.B. Baron, Evaluation of two food frequency methods of measuring dietary calcium intake, Am. J. Epidemiol. 126 (1987) 796–802.

[134] G. Block, F.E. Thompson, A.M. Hartman, F.A. Larkin, K.E. Guire, Comparison of two dietary questionnaires validated against multiple dietary records collected during a 1-year period, J. Am. Diet. Assoc. 92 (1992) 686–693.

[135] W.C. Willett, Nutritional Epidemiology, 2nd ed, Oxford University Press, New York, NY, 1998.

[136] S.K. Kumanyika, D. Mauger, D.C. Mitchell, B. Phillips, H. Smiciklas-Wright, J.R. Palmer, Relative validity of food frequency questionnaire nutrient estimates in the Black Women's Health Study, Ann. Epidemiol. 13 (2003) 111–118.

[137] J.A. Clapp, R.S. McPherson, D.B. Reed, B.P. Hsi, Comparison of a food frequency questionnaire using reported vs standard portion sizes for classifying individuals according to nutrient intake, J. Am. Diet. Assoc. 91 (1991) 316–320.

[138] L.H. Eck, L.M. Klesges, R.C. Klesges, Precision and estimated accuracy of two short-term food frequency questionnaires compared with recalls and records, J. Clin. Epidemiol. 49 (1996) 1195–1200.

[139] A.F. Subar, C.M. Frey, L.C. Harlan, L. Kahle, Differences in reported food frequency by season of questionnaire administration: the 1987 National Health Interview Survey, Epidemiology 5 (1994) 226–233.

[140] Y. Tsubono, Y. Nishino, A. Fukao, S. Hisamichi, S. Tsugane, Temporal change in the reproducibility of a self-administered food frequency questionnaire, Am. J. Epidemiol. 142 (1995) 1231–1235.

[141] J.H. Fowke, D. Schlundt, Y. Gong, F. Jin, X.O. Shu, W. Wen, et al., Impact of season of food frequency questionnaire administration on dietary reporting, Ann. Epidemiol. 14 (2004) 778–785.

[142] B. Caan, R.A. Hiatt, A.M. Owen, Mailed dietary surveys: response rates, error rates, and the effect of omitted food items on nutrient values, Epidemiology 2 (1991) 430–436.

[143] L. Holmberg, E.M. Ohlander, T. Byers, M. Zack, A. Wolk, A. Bruce, et al., A search for recall bias in a case-control study of diet and breast cancer, Int. J. Epidemiol. 25 (1996) 235–244.

[144] L.M. Hansson, M.R. Galanti, Diet-associated risks of disease and self-reported food consumption: how shall we treat partial nonresponse in a food frequency questionnaire? Nutr. Cancer 36 (2000) 1–6.

[145] C.L. Parr, A. Hjartaker, I. Scheel, E. Lund, P. Laake, M.B. Veierod, Comparing methods for handling missing values in food-frequency questionnaires and proposing *k* nearest neighbours imputation: effects on dietary intake in the Norwegian Women and Cancer study (NOWAC), Public Health Nutr. 11 (2008) 361–370.

[146] C. Matthys, I. Pynaert, W. De Keyzer, S. De Henauw, Validity and reproducibility of an adolescent web-based food frequency questionnaire, J. Am. Diet. Assoc. 107 (2007) 605–610.

[147] The University of Arizona Cancer Center. Questionnaires, The University of Arizona Health Sciences. Available from <http://uacc.arizona.edu/research/shared-resources/bmisr/questionnaires>, 2016.

[148] M.E. Labonte, A. Cyr, L. Baril-Gravel, M.M. Royer, B. Lamarche, Validity and reproducibility of a web-based, self-administered food frequency questionnaire, Eur. J. Clin. Nutr. 66 (2012) 166–173.

[149] V. Kipnis, A.F. Subar, D. Midthune, L.S. Freedman, R. Ballard-Barbash, R.P. Troiano, et al., Structure of dietary measurement error: results of the OPEN biomarker study, Am. J. Epidemiol. 158 (2003) 14–21.

[150] A.F. Smith, Cognitive psychological issues of relevance to the validity of dietary reports, Eur. J. Clin. Nutr. 47 (1993) S6–18.

[151] S.M. Krebs-Smith, J. Heimendinger, A.F. Subar, B.H. Patterson, E. Pivonka, Estimating fruit and vegetable intake using food frequency questionnaires: a comparison of instruments, Am. J. Clin. Nutr. 59 (1994) 283s.

[152] D.J. Hunter, L. Sampson, M.J. Stampfer, G.A. Colditz, B. Rosner, W.C. Willett, Variability in portion sizes of commonly consumed foods among a population of women in the United States, Am. J. Epidemiol. 127 (1988) 1240–1249.

[153] G. Block, A.F. Subar, Estimates of nutrient intake from a food frequency questionnaire: the 1987 National Health Interview Survey, J. Am. Diet. Assoc. 92 (1992) 969–977.

[154] R.R. Briefel, K.M. Flegal, D.M. Winn, C.M. Loria, C.L. Johnson, C.T. Sempos, Assessing the nation's diet: limitations of the food frequency questionnaire, J. Am. Diet. Assoc. 92 (1992) 959–962.

[155] E.B. Rimm, E.L. Giovannucci, M.J. Stampfer, G.A. Colditz, L.B. Litin, W.C. Willett, Reproducibility and validity of an expanded self-administered semiquantitative food frequency questionnaire among male health professionals, Am. J. Epidemiol. 135 (1992) 1114–1126.

[156] C.T. Sempos, Invited commentary: some limitations of semiquantitative food frequency questionnaires, Am. J. Epidemiol. 135 (1992) 1127–1132.

[157] E.B. Rimm, E.L. Giovannucci, M.J. Stampfer, G.A. Colditz, L.B. Litin, W.C. Willett, Authors' response to "Invited commentary: some limitations of semiquantitative food frequency questionnaires", Am. J. Epidemiol. 135 (1992) 1133–1136.

[158] R.J. Carroll, L.S. Freedman, A.M. Hartman, Use of semiquantitative food frequency questionnaires to estimate the distribution of usual intake, Am. J. Epidemiol. 143 (1996) 392–404.

[159] C. Lassale, C. Guilbert, J. Keogh, J. Syrette, K. Lange, D.N. Cox, Estimating food intakes in Australia: validation of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) food frequency questionnaire against weighed dietary intakes, J. Hum. Nutr. Diet. 22 (2009) 559–566.

[160] M. Haftenberger, T. Heuer, C. Heidemann, F. Kube, C. Krems, G.B. Mensink, Relative validation of a food frequency questionnaire for national health and nutrition monitoring, Nutr. J. 9 (2010) 36.

[161] L.H. Kushi, Gaps in epidemiologic research methods: design considerations for studies that use food-frequency questionnaires, Am. J. Clin. Nutr. 59 (1994) 180S–184S.

[162] G.H. Beaton, Approaches to analysis of dietary data: relationship between planned analyses and choice of methodology, Am. J. Clin. Nutr. 59 (1994) 253S–261S.

[163] C.T. Sempos, K. Liu, N.D. Ernst, Food and nutrient exposures: what to consider when evaluating epidemiologic evidence, Am. J. Clin. Nutr. 69 (1999) 1330S–1338S.

[164] L.S. Freedman, A. Schatzkin, Y. Wax, The impact of dietary measurement error on planning sample size required in a cohort study, Am. J. Epidemiol. 132 (1990) 1185–1195.

[165] E.J. Schaefer, J.L. Augustin, M.M. Schaefer, H. Rasmussen, J.M. Ordovas, G.E. Dallal, et al., Lack of efficacy of a food-frequency questionnaire in assessing dietary macronutrient intakes in subjects consuming diets of known composition, Am. J. Clin. Nutr. 71 (2000) 746–751.

[166] National Cancer Institute. Dietary Assessment Calibration/Validation Register: Studies and Their Associated Publications, Applied Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://appliedresearch.cancer.gov/cgi-bin/dacv/index.pl>, 2013.

[167] S.A. Bingham, A. Cassidy, T.J. Cole, A. Welch, S.A. Runswick, A.E. Black, et al., Validation of weighed records and other methods of dietary assessment using the 24 h urine nitrogen technique and other biological markers, Br. J. Nutr. 73 (1995) 531−550.

[168] L.T. Pijls, H. de Vries, A.J. Donker, J.T. van Eijk, Reproducibility and biomarker-based validity and responsiveness of a food frequency questionnaire to estimate protein intake, Am. J. Epidemiol. 150 (1999) 987−995.

[169] M.C. Ocke, H.B. Bueno-de-Mesquita, M.A. Pols, H.A. Smit, W. A. van Staveren, D. Kromhout, The Dutch EPIC food frequency questionnaire. II. Relative validity and reproducibility for nutrients, Int. J. Epidemiol. 26 (1997) S49−S58.

[170] P. Pisani, F. Faggiano, V. Krogh, D. Palli, P. Vineis, F. Berrino, Relative validity and reproducibility of a food frequency dietary questionnaire for use in the Italian EPIC centres, Int. J. Epidemiol .26 (1997) S152−S160.

[171] S.A. Bingham, Dietary assessments in the European prospective study of diet and cancer (EPIC), Eur. J. Cancer Prev. 6 (1997) 118−124.

[172] S.A. Bingham, N.E. Day, Using biochemical markers to assess the validity of prospective dietary assessment methods and the effect of energy adjustment, Am. J. Clin. Nutr. 65 (1997) 1130S−1137S.

[173] K.M. Flegal, Evaluating epidemiologic evidence of the effects of food and nutrient exposures, Am. J. Clin. Nutr. 69 (1999) 1339S−1344S.

[174] R.C. Burack, J. Liang, The early detection of cancer in the primary-care setting: factors associated with the acceptance and completion of recommended procedures, Prev. Med. 16 (1987) 739−751.

[175] R.L. Prentice, Measurement error and results from analytic epidemiology: dietary fat and breast cancer, J. Natl. Cancer Inst. 88 (1996) 1738−1747.

[176] V. Kipnis, L.S. Freedman, C.C. Brown, A.M. Hartman, A. Schatzkin, S. Wacholder, Effect of measurement error on energy-adjustment models in nutritional epidemiology, Am. J. Epidemiol. 146 (1997) 842−855.

[177] F.B. Hu, M.J. Stampfer, E. Rimm, A. Ascherio, B.A. Rosner, D. Spiegelman, et al., Dietary fat and coronary heart disease: a comparison of approaches for adjusting for total energy intake and modeling repeated dietary measurements, Am. J. Epidemiol. 149 (1999) 531−540.

[178] R.J. Carroll, L.S. Freedman, V. Kipnis, L. Li, A new class of measurement-error models, with applications to dietary data, Can. J. Stat. 26 (1998) 467−477.

[179] L. Kohlmeier, B. Bellach, Exposure assessment error and its handling in nutritional epidemiology, Annu. Rev. Public Health 16 (1995) 43−59.

[180] R. Kaaks, E. Riboli, W. van Staveren, Calibration of dietary intake measurements in prospective cohort studies, Am. J. Epidemiol. 142 (1995) 548−556.

[181] B. Bellach, L. Kohlmeier, Energy adjustment does not control for differential recall bias in nutritional epidemiology, J. Clin. Epidemiol. 51 (1998) 393−398.

[182] V. Kipnis, R.J. Carroll, L.S. Freedman, L. Li, Implications of a new dietary measurement error model for estimation of relative risk: application to four calibration studies, Am. J. Epidemiol. 150 (1999) 642−651.

[183] S.A. Bingham, R. Luben, A. Welch, N. Wareham, K.T. Khaw, N. Day, Are imprecise methods obscuring a relation between fat and breast cancer? Lancet 362 (2003) 212−214.

[184] L.S. Freedman, N. Potischman, V. Kipnis, D. Midthune, A. Schatzkin, F.E. Thompson, et al., A comparison of two dietary instruments for evaluating the fat-breast cancer relationship, Int. J. Epidemiol. 35 (2006) 1011−1021.

[185] T.J. Key, P.N. Appleby, B.J. Cairns, R. Luben, C.C. Dahm, T. Akbaraly, et al., Dietary fat and breast cancer: comparison of results from food diaries and food-frequency questionnaires in the UK Dietary Cohort Consortium, Am. J. Clin. Nutr. 94 (2011) 1043−1052.

[186] A.R. Kristal, U. Peters, J.D. Potter, Is it time to abandon the food frequency questionnaire? Cancer Epidemiol. Biomarkers Prev. 14 (2005) 2826−2828.

[187] A.R. Kristal, J.D. Potter, Not the time to abandon the food frequency questionnaire: counterpoint, Cancer Epidemiol. Biomarkers Prev. 15 (2006) 1759−1760.

[188] R.J. Carroll, D. Midthune, A.F. Subar, M. Shumakovich, L.S. Freedman, F.E. Thompson, et al., Taking advantage of the strengths of 2 different dietary assessment instruments to improve intake estimates for nutritional epidemiology, Am. J. Epidemiol. 175 (2012) 340−347.

[189] J. Haubrock, U. Nothlings, J.L. Volatier, A. Dekkers, M. Ocke, U. Harttig, et al., Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam Calibration Study, J. Nutr. 141 (2011) 914−920.

[190] V. Kipnis, D. Midthune, D.W. Buckman, K.W. Dodd, P.M. Guenther, S.M. Krebs-Smith, et al., Modeling data with excess zeros and measurement error: application to evaluating relationships between episodically consumed foods and health outcomes, Biometrics 65 (2009) 1003−1010.

[191] A.R. Kristal, C.H. Andrilla, T.D. Koepsell, P.H. Diehr, A. Cheadle, Dietary assessment instruments are susceptible to intervention-associated response set bias, J. Am. Diet. Assoc. 98 (1998) 40−43.

[192] M.L. Neuhouser, A.R. Kristal, D. McLerran, R.E. Patterson, J. Atkinson, Validity of short food frequency questionnaires used in cancer chemoprevention trials: results from the Prostate Cancer Prevention Trial, Cancer Epidemiol. Biomarkers Prev. 8 (1999) 721−725.

[193] Centers for Disease Control and Prevention. Behavioral Risk Factor Surveillance System (BRFSS), National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention. Available from <http://www.cdc.gov/brfss/>, 2016.

[194] L.V. Moore, K.W. Dodd, F.E. Thompson, K.A. Grimm, S.A. Kim, K.S. Scanlon, Using Behavioral Risk Factor Surveillance System data to estimate the percentage of the population meeting US Department of Agriculture food patterns fruit and vegetable intake recommendations, Am. J. Epidemiol. 181 (2015) 979−988.

[195] UCLA Center for Health Policy Research. California Health Interview Survey, UCLA Center for Health Policy Research. Available from <http://www.chis.ucla.edu/>, 2016.

[196] F.E. Thompson, D. Midthune, A.F. Subar, T. McNeel, D. Berrigan, V. Kipnis, Dietary intake estimates in the National Health Interview Survey, 2000: methodology, results, and interpretation, J. Am. Diet. Assoc. 105 (2005) 352−363.

[197] M.L. Neuhouser, S. Lilley, A. Lund, D.B. Johnson, Development and validation of a beverage and snack questionnaire for use in evaluation of school nutrition policies, J. Am. Diet. Assoc. 109 (2009) 1587–1592.

[198] S. Holtby, E. Zahnd, D. Grant, Majority of young children in California eat fast food regularly but drink less soda, Policy Brief UCLA Cent. Health Policy Res November (2013) 1–8.

[199] S.I. Kirkpatrick, J. Reedy, E.N. Butler, K.W. Dodd, A.F. Subar, F.E. Thompson, et al., Dietary assessment in food environment research: a systematic review, Am. J. Prev. Med. 46 (2014) 94–102.

[200] L.W. Pickle, A.M. Hartman, Indicator foods for vitamin A assessment, Nutr. Cancer 7 (1985) 3–23.

[201] T. Byers, J. Marshall, R. Fiedler, M. Zielezny, S. Graham, Assessing nutrient intake with an abbreviated dietary interview, Am. J. Epidemiol. 122 (1985) 41–50.

[202] National Cancer Institute. Register of Validated Short Dietary Assessment Instruments, Applied Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://appliedresearch.cancer.gov/diet/shortreg/>, 2015.

[203] A.E. Field, G.A. Colditz, M.K. Fox, T. Byers, M. Serdula, R.J. Bosch, et al., Comparison of 4 questionnaires for assessment of fruit and vegetable intake, Am. J. Public Health 88 (1998) 1216–1218.

[204] K.W. Cullen, T. Baranowski, J. Baranowski, D. Hebert, C. de Moor, Pilot study of the validity and reliability of brief fruit, juice and vegetable screeners among inner city African-American boys and 17 to 20 year old adults, J. Am. Coll. Nutr. 18 (1999) 442–450.

[205] K. Resnicow, E. Odom, T. Wang, W.N. Dudley, D. Mitchell, R. Vaughan, et al., Validation of three food frequency questionnaires and 24-hour recalls with serum carotenoid levels in a sample of African-American adults, Am. J. Epidemiol. 152 (2000) 1072–1080.

[206] J.J. Prochaska, J.F. Sallis, Reliability and validity of a fruit and vegetable screening measure for adolescents, J. Adolesc. Health 34 (2004) 163–165.

[207] L.F. Andersen, M.B. Veierod, L. Johansson, A. Sakhi, K. Solvoll, C.A. Drevon, Evaluation of three dietary assessment methods and serum biomarkers as measures of fruit and vegetable intake, using the method of triads, Br. J. Nutr. 93 (2005) 519–527.

[208] M.K. Campbell, B. Polhamus, J.W. McClelland, K. Bennett, W. Kalsbeek, D. Coole, et al., Assessing fruit and vegetable consumption in a 5 a day study targeting rural blacks: the issue of portion size, J. Am. Diet. Assoc. 96 (1996) 1040–1042.

[209] T. Baranowski, M. Smith, J. Baranowski, D.T. Wang, C. Doyle, L.S. Lin, et al., Low validity of a seven-item fruit and vegetable food frequency questionnaire among third-grade students, J. Am. Diet. Assoc. 97 (1997) 66–68.

[210] M.K. Hunt, A.M. Stoddard, K. Peterson, G. Sorensen, J.R. Hebert, N. Cohen, Comparison of dietary assessment measures in the Treatwell 5 A Day worksite study, J. Am. Diet. Assoc. 98 (1998) 1021–1023.

[211] M. Serdula, R. Coates, T. Byers, A. Mokdad, S. Jewell, N. Chavez, et al., Evaluation of a brief telephone questionnaire to estimate fruit and vegetable consumption in diverse study populations, Epidemiology 4 (1993) 455–463.

[212] S.A. Smith-Warner, P.J. Elmer, L. Fosdick, T.M. Tharp, B. Randall, Reliability and comparability of three dietary assessment methods for estimating fruit and vegetable intakes, Epidemiology 8 (1997) 196–201.

[213] B. Armstrong, Diet and hormones in the epidemiology of breast and endometrial cancers, Nutr. Cancer 1 (1979) 90–95.

[214] A.R. Kristal, N.C. Vizenor, R.E. Patterson, M.L. Neuhouser, A. L. Shattuck, D. McLerran, Precision and bias of food frequency-based measures of fruit and vegetable intakes, Cancer Epidemiol. Biomarkers Prev. 9 (2000) 939–944.

[215] F.E. Thompson, A.F. Subar, A.F. Smith, D. Midthune, K.L. Radimer, L.L. Kahle, et al., Fruit and vegetable assessment: performance of 2 new short instruments and a food frequency questionnaire, J. Am. Diet. Assoc. 102 (2002) 1764–1772.

[216] G.W. Greene, K. Resnicow, F.E. Thompson, K.E. Peterson, T.G. Hurley, J.R. Hebert, et al., Correspondence of the NCI Fruit and Vegetable Screener to repeat 24-H recalls and serum carotenoids in behavioral intervention trials, J. Nutr. 138 (2008) 200S–204S.

[217] K.E. Peterson, J.R. Hebert, T.G. Hurley, K. Resnicow, F.E. Thompson, G.W. Greene, et al., Accuracy and precision of two short screeners to assess change in fruit and vegetable consumption among diverse populations participating in health promotion intervention trials, J. Nutr. 138 (2008) 218S–225S.

[218] Office of Disease Prevention and Health Promotion, U.S. Department of Health and Human Services (2011). Dietary Guidelines for Americans, 2010, U.S. Department of Health and Human Services. Available from <http://www.health.gov/dietaryguidelines/2010.asp>.

[219] P. Kris-Etherton, B. Eissenstat, S. Jaax, U. Srinath, L. Scott, J. Rader, et al., Validation for MEDFICTS, a dietary assessment instrument for evaluating adherence to total and saturated fat recommendations of the National Cholesterol Education Program Step 1 and Step 2 diets, J. Am. Diet. Assoc. 101 (2001) 81–86.

[220] A.J. Taylor, H. Wong, K. Wish, J. Carrow, D. Bell, J. Bindeman, et al., Validation of the MEDFICTS dietary questionnaire: a clinical tool to assess adherence to American Heart Association dietary fat intake guidelines, Nutr. J. 2 (2003) 4.

[221] C.R. Teal, D.L. Baham, B.J. Gor, L.A. Jones, Is the MEDFICTS Rapid Dietary Fat Screener valid for premenopausal African-American women? J. Am. Diet. Assoc. 107 (2007) 773–781.

[222] A.L. Holmes, B. Sanderson, R. Maisiak, A. Brown, V. Bittner, Dietitian services are associated with improved patient outcomes and the MEDFICTS dietary assessment questionnaire is a suitable outcome measure in cardiac rehabilitation, J. Am. Diet. Assoc. 105 (2005) 1533–1540.

[223] F.A. Wenhold, U.E. MacIntyre, P. Rheeder, Reliability and validity of a modified MEDFICTS dietary fat screener in South African schoolchildren are determined by use and outcome measures, J. Acad. Nutr. Diet. 114 (2014) 870–880.

[224] S. Rohrmann, G. Klein, Validation of a short questionnaire to qualitatively assess the intake of total fat, saturated, monounsaturated, polyunsaturated fatty acids, and cholesterol, J. Hum. Nutr. Diet. 16 (2003) 111–117.

[225] S. Rohrmann, G. Klein, Development and validation of a short food list to assess the intake of total fat, saturated,

mono-unsaturated, polyunsaturated fatty acids and cholesterol, Eur. J. Public Health 13 (2003) 262−268.
[226] F.E. Thompson, D. Midthune, A.F. Subar, V. Kipnis, L.L. Kahle, A. Schatzkin, Development and evaluation of a short instrument to estimate usual dietary intake of percentage energy from fat, J. Am. Diet. Assoc. 107 (2007) 760−767.
[227] I. Alcantara, R. Haardorfer, J.A. Gazmararian, T.J. Hartman, B. Greene, M.C. Kegler, Relative validation of fruit and vegetable intake and fat intake among overweight and obese African-American women, Public Health Nutr. 18 (2015) 1932−1940.
[228] F.E. Thompson, D. Midthune, G.C. Williams, A.L. Yaroch, T.G. Hurley, K. Resnicow, et al., Evaluation of a short dietary assessment instrument for percentage energy from fat in an intervention study, J. Nutr. 138 (2008) 193S−199S.
[229] A.L. Yaroch, K. Resnicow, L.K. Khan, Validity and reliability of qualitative dietary fat index questionnaires: a review, J. Am. Diet. Assoc. 100 (2000) 240−244.
[230] P. van Assema, J. Brug, G. Kok, H. Brants, The reliability and validity of a Dutch questionnaire on fat consumption as a means to rank subjects according to individual fat intake, Eur. J. Cancer Prev. 1 (1992) 375−380.
[231] A.S. Ammerman, P.S. Haines, R.F. DeVellis, D.S. Strogatz, T.C. Keyserling, R.J. Simpson Jr., et al., A brief dietary assessment to guide cholesterol reduction in low-income individuals: design and validation, J. Am. Diet. Assoc. 91 (1991) 1385−1390.
[232] P.N. Hopkins, R.R. Williams, H. Kuida, B.M. Stults, S.C. Hunt, G.K. Barlow, et al., Predictive value of a short dietary questionnaire for changes in serum lipids in high-risk Utah families, Am. J. Clin. Nutr. 50 (1989) 292−300.
[233] T. Kemppainen, A. Rosendahl, O. Nuutinen, T. Ebeling, P. Pietinen, M. Uusitupa, Validation of a short dietary questionnaire and a qualitative fat index for the assessment of fat intake, Eur. J. Clin. Nutr. 47 (1993) 765−775.
[234] B.M. Retzlaff, A.A. Dowdy, C.E. Walden, V.E. Bovbjerg, R.H. Knopp, The Northwest Lipid Research Clinic Fat Intake Scale: validation and utility, Am. J. Public Health 87 (1997) 181−185.
[235] P. Little, J. Barnett, B. Margetts, A.L. Kinmonth, J. Gabbay, R. Thompson, et al., The validity of dietary assessment in general practice, J. Epidemiol. Community Health 53 (1999) 165−172.
[236] R.J. Coates, M.K. Serdula, T. Byers, A. Mokdad, S. Jewell, S.B. Leonard, et al., A brief, telephone-administered food frequency questionnaire can be useful for surveillance of dietary fat intakes, J. Nutr. 125 (1995) 1473−1483.
[237] S.P. Murphy, L.L. Kaiser, M.S. Townsend, L.H. Allen, Evaluation of validity of items for a food behavior checklist, J. Am. Diet. Assoc. 101 (2001) 751−761.
[238] S. Fernandez, B. Olendzki, M.C. Rosal, A dietary behaviors measure for use with low-income, Spanish-speaking Caribbean Latinos with type 2 diabetes: the Latino Dietary Behaviors Questionnaire, J. Am. Diet. Assoc. 111 (2011) 589−599.
[239] S. Kinlay, R.F. Heller, J.A. Halliday, A simple score and questionnaire to measure group changes in dietary fat intake, Prev. Med. 20 (1991) 378−388.
[240] S.A. Beresford, E.M. Farmer, L. Feingold, K.L. Graves, S.K. Sumner, R.M. Baker, Evaluation of a self-help dietary intervention in a primary care setting, Am. J. Public Health 82 (1992) 79−84.
[241] S.L. Connor, J.R. Gustafson, G. Sexton, N. Becker, S. Artaud-Wild, W.E. Connor, The Diet Habit Survey: a new method of dietary assessment that relates to plasma cholesterol changes, J. Am. Diet. Assoc. 92 (1992) 41−47.
[242] R.E. Glasgow, J.D. Perry, D.J. Toobert, J.F. Hollis, Brief assessments of dietary behavior in field settings, Addict. Behav. 21 (1996) 239−247.
[243] R.F. Heller, H.D. Pedoe, G. Rose, A simple method of assessing the effect of dietary advice to reduce plasma cholesterol, Prev. Med. 10 (1981) 364−370.
[244] A.R. Kristal, E. White, A.L. Shattuck, S. Curry, G.L. Anderson, A. Fowler, et al., Long-term maintenance of a low-fat diet: durability of fat-related dietary habits in the Women's Health Trial, J. Am. Diet. Assoc. 92 (1992) 553−559.
[245] A.R. Kristal, S.A. Beresford, D. Lazovich, Assessing change in diet-intervention research, Am. J. Clin. Nutr. 59 (1994) 185S−189S.
[246] A.L. Yaroch, K. Resnicow, A.D. Petty, L.K. Khan, Validity and reliability of a modified qualitative dietary fat index in low-income, overweight, African American adolescent girls, J. Am. Diet. Assoc. 100 (2000) 1525−1529.
[247] P.M. Risica, G. Burkholder, K.M. Gans, T.M. Lasater, S. Acharyya, C. Davis, et al., Assessing fat-related dietary behaviors among black women: reliability and validity of a new Food Habits Questionnaire, J. Nutr. Educ. Behav. 39 (2007) 197−204.
[248] C.A. Anderson, S.K. Kumanyika, J. Shults, M.J. Kallan, K.M. Gans, P.M. Risica, Assessing change in dietary-fat behaviors in a weight-loss program for African Americans: a potential short method, J. Am. Diet. Assoc. 107 (2007) 838−842.
[249] S.L. Rifas-Shiman, W.C. Willett, R. Lobb, J. Kotch, C. Dart, M. W. Gillman, PrimeScreen, a brief dietary screening tool: reproducibility and comparability with both a longer food frequency questionnaire and biomarkers, Public Health Nutr 4 (2001) 249−254.
[250] National Cancer Institute. Dietary Screener Questionnaire in the NHANES 2009-10: Background, Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://epi.grants.cancer.gov/nhanes/dietscreen/>, 2015.
[251] D.G. Schlundt, M.K. Hargreaves, M.S. Buchowski, The Eating Behavior Patterns Questionnaire predicts dietary fat intake in African American women, J. Am. Diet. Assoc. 103 (2003) 338−345.
[252] U.S. Department of Agriculture. Healthy Eating Index, Center for Nutrition Policy and Promotion, U.S. Department of Agriculture. Available from <http://www.cnpp.usda.gov/healthyeatingindex>, 2015.
[253] K.M. Gans, P.M. Risica, J. Wylie-Rosett, E.M. Ross, L.O. Strolla, J. McMurray, et al., Development and evaluation of the nutrition component of the Rapid Eating and Activity Assessment for Patients (REAP): a new tool for primary care providers, J. Nutr. Educ. Behav. 38 (2006) 286−292.
[254] A.R. Kristal, B.F. Abrams, M.D. Thornquist, L. Disogra, R.T. Croyle, A.L. Shattuck, et al., Development and validation of a food use checklist for evaluation of community nutrition interventions, Am. J. Public Health 80 (1990) 1318−1322.
[255] M.L. Neuhouser, R.E. Patterson, A.R. Kristal, A.L. Eldridge, N. C. Vizenor, A brief dietary assessment instrument for assessing target foods, nutrients and eating patterns, Public Health Nutr. 4 (2001) 73−78.

[256] J. Yen, C. Zoumas-Morse, B. Pakiz, C.L. Rock, Folate intake assessment: validation of a new approach, J. Am. Diet. Assoc. 103 (2003) 991−1000.

[257] J. Haraldsdottir, I. Thorsdottir, M.D. de Almeida, L. Maes, R.C. Perez, I. Elmadfa, et al., Validity and reproducibility of a precoded questionnaire to assess fruit and vegetable intake in European 11- to 12-year-old schoolchildren, Ann. Nutr. Metab. 49 (2005) 221−227.

[258] C.M. Apovian, M.C. Murphy, D. Cullum-Dugan, P.H. Lin, K.M. Gilbert, G. Coffman, et al., Validation of a web-based dietary questionnaire designed for the DASH (dietary approaches to stop hypertension) diet: the DASH online questionnaire, Public Health Nutr. 13 (2010) 615−622.

[259] M.C. Nelson, L.A. Lytle, Development and evaluation of a brief screener to estimate fast-food and beverage consumption among adolescents, J. Am. Diet. Assoc. 109 (2009) 730−734.

[260] J.N. Davis, M.C. Nelson, E.E. Ventura, L.A. Lytle, M.I. Goran, A brief dietary screener: appropriate for overweight Latino adolescents? J. Am. Diet. Assoc. 109 (2009) 725−729.

[261] B.S. Burke, The dietary history as a tool in research, J. Am. Diet. Assoc. 23 (1947) 1041−1046.

[262] B.S. Burke, H.C. Stuart, A method of diet analysis: application in research and pediatric practice, J. Pediatr. 12 (1938) 493−503.

[263] A. McDonald, L. Van Horn, M. Slattery, J. Hilner, C. Bragg, B. Caan, et al., The CARDIA dietary history: development, implementation, and evaluation, J. Am. Diet. Assoc. 91 (1991) 1104−1112.

[264] M. Visser, L.C. De Groot, P. Deurenberg, W.A. van Staveren, Validation of dietary history method in a group of elderly women using measurements of total energy expenditure, Br. J. Nutr. 74 (1995) 775−785.

[265] L. Kohlmeier, M. Mendez, J. McDuffie, M. Miller, Computer-assisted self-interviewing: a multimedia approach to dietary assessment, Am. J. Clin. Nutr. 65 (1997) 1275S−1281S.

[266] J. Landig, J.G. Erhardt, J.C. Bode, C. Bode, Validation and comparison of two computerized methods of obtaining a diet history, Clin. Nutr. 17 (1998) 113−117.

[267] L. Kohlmeier, Gaps in dietary assessment methodology: meal- vs list-based methods, Am. J. Clin. Nutr. 59 (1994) 175s−179s.

[268] W.A. van Staveren, J.O. de Boer, J. Burema, Validity and reproducibility of a dietary history method estimating the usual food intake during one month, Am. J. Clin. Nutr. 42 (1985) 554−559.

[269] M. Jain, Diet history: questionnaire and interview techniques used in some retrospective studies of cancer, J. Am. Diet. Assoc. 89 (1989) 1647−1652.

[270] S. Kune, G.A. Kune, L.F. Watson, Observations on the reliability and validity of the design and diet history method in the Melbourne Colorectal Cancer Study, Nutr. Cancer 9 (1987) 5−20.

[271] L.C. Tapsell, V. Brenninger, J. Barnard, Applying conversation analysis to foster accurate reporting in the diet history interview, J. Am. Diet. Assoc. 100 (2000) 818−824.

[272] A. Chinnock, Validation of a diet history questionnaire for use with Costa Rican adults, Public Health Nutr. 11 (2008) 65−75.

[273] E.C. van Beresteyn, M.A. van't Hof, H.J. van der Heiden-Winkeldermaat, A. ten Have-Witjes, R. Neeter, Evaluation of the usefulness of the cross-check dietary history method in longitudinal studies, J. Chronic Dis. 40 (1987) 1051−1058.

[274] B.P. Bloemberg, D. Kromhout, G.L. Obermann-De Boer, M. van Kampen-Donker, The reproducibility of dietary intake data assessed with the cross-check dietary history method, Am. J. Epidemiol. 130 (1989) 1047−1056.

[275] G.B. Mensink, M. Haftenberger, M. Thamm, Validity of DISHES 98, a computerised dietary history interview: energy and macronutrient intake, Eur. J. Clin. Nutr. 55 (2001) 409−417.

[276] M.L. Slattery, B.J. Caan, D. Duncan, T.D. Berry, A. Coates, R. Kerber, A computerized diet history questionnaire for epidemiologic studies, J. Am. Diet. Assoc. 94 (1994) 761−766.

[277] EPIC Group of Spain, Relative validity and reproducibility of a diet history questionnaire in Spain. I. Foods, Int. J. Epidemiol. 26 (1997) S91−S99.

[278] E. Rothenberg, I. Bosaeus, B. Lernfelt, S. Landahl, B. Steen, Energy intake and expenditure: validation of a diet history by heart rate monitoring, activity diary and doubly labeled water, Eur. J. Clin. Nutr. 52 (1998) 832−838.

[279] A.E. Black, A.A. Welch, S.A. Bingham, Validation of dietary intakes measured by diet history against 24 h urinary nitrogen excretion and energy expenditure measured by the doubly-labelled water method in middle-aged women, Br. J. Nutr. 83 (2000) 341−354.

[280] J.A. Barnard, L.C. Tapsell, P.S. Davies, V.L. Brenninger, L.H. Storlien, Relationship of high energy expenditure and variation in dietary intake with reporting accuracy on 7 day food records and diet histories in a group of healthy adult volunteers, Eur. J. Clin. Nutr. 56 (2002) 358−367.

[281] L. Hagfors, K. Westerterp, L. Skoldstam, G. Johansson, Validity of reported energy expenditure and reported intake of energy, protein, sodium and potassium in rheumatoid arthritis patients in a dietary intervention study, Eur. J. Clin. Nutr. 59 (2005) 238−245.

[282] EPIC Group of Spain, Relative validity and reproducibility of a diet history questionnaire in Spain. III. Biochemical markers, Int. J. Epidemiol. 26 (1997) S110−S117.

[283] K. Murakami, S. Sasaki, Y. Takahashi, K. Uenishi, M. Yamasaki, H. Hayabuchi, et al., Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women, Eur. J. Clin. Nutr. 62 (2008) 111−118.

[284] M.U. Waling, C.L. Larsson, Energy intake of Swedish overweight and obese children is underestimated using a diet history interview, J. Nutr. 139 (2009) 522−527.

[285] C.L. Larsson, G.K. Johansson, Dietary intake and nutritional status of young vegans and omnivores in Sweden, Am. J. Clin. Nutr. 76 (2002) 100−106.

[286] C.L. Larsson, K.R. Westerterp, G.K. Johansson, Validity of reported energy expenditure and energy and protein intakes in Swedish adolescent vegans and omnivores, Am. J. Clin. Nutr. 75 (2002) 268−274.

[287] A. Sjoberg, F. Slinde, D. Arvidsson, L. Ellegard, E. Gramatkovski, L. Hallberg, et al., Energy intake in Swedish adolescents: validation of diet history with doubly labelled water, Eur. J. Clin. Nutr. 57 (2003) 1643−1652.

[288] U. Toft, L. Kristoffersen, S. Ladelund, A. Bysted, J. Jakobsen, C. Lau, et al., Relative validity of a food frequency questionnaire used in the Inter99 study, Eur. J. Clin. Nutr. 62 (2008) 1038−1046.

[289] L.A. Mainvil, C.C. Horwath, J.E. McKenzie, R. Lawson, Validation of brief instruments to measure adult fruit and vegetable consumption, Appetite 56 (2011) 111−117.

[290] M. van den Heuvel, R. Horchner, A. Wijtsma, N. Bourhim, D. Willemsen, E.M. Mathus-Vliegen, Sweet eating: a definition and the development of the Dutch Sweet Eating Questionnaire, Obes. Surg. 21 (2011) 714–721.
[291] L.A. Lytle, M.Z. Nichaman, E. Obarzanek, E. Glovsky, D. Montgomery, T. Nicklas, et al., Validation of 24-hour recalls assisted by food records in third-grade children. The CATCH Collaborative Group, J. Am. Diet. Assoc. 93 (1993) 1431–1436.
[292] J.L. Weber, L. Lytle, J. Gittelsohn, L. Cunningham-Sabo, K. Heller, J.A. Anliker, et al., Validity of self-reported dietary intake at school meals by American Indian children: the Pathways Study, J. Am. Diet. Assoc. 104 (2004) 746–752.
[293] S.L. Casperson, J. Sieling, J. Moon, L. Johnson, J.N. Roemmich, L. Whigham, A mobile phone food record app to digitally capture dietary intake for adolescents in a free-living environment: usability study, JMIR Mhealth Uhealth 3 (2015) e30.
[294] F. Thompson, A. Subar, N. Potischman, D. Midthune, V. Kipnis, R.P. Troiano, et al., A checklist-adjusted food frequency method for assessing dietary intake, Sixth International Conference on Dietary Assessment Methods: Complementary Advances in Diet and Physical Activity Assessment Methodologies, Diet Research Foundation, The Danish Network of Nutritional Epidemiologists, Copenhagen, Denmark, 2006.
[295] J.A. Tooze, D. Midthune, K.W. Dodd, L.S. Freedman, S.M. Krebs-Smith, A.F. Subar, et al., A new statistical method for estimating the usual intake of episodically consumed foods with application to their distribution, J. Am. Diet. Assoc. 106 (2006) 1575–1587.
[296] National Cancer Institute. Usual dietary intakes: The NCI Method, Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://epi.grants.cancer.gov/diet/usualintakes/method.html>, 2015.
[297] L.S. Freedman, D. Midthune, R.J. Carroll, N. Tasevska, A. Schatzkin, J. Mares, et al., Using regression calibration equations that combine self-reported intake and biomarker measures to obtain unbiased estimates and more powerful tests of dietary associations, Am. J. Epidemiol. 174 (2011) 1238–1245.
[298] N. Tasevska, D. Midthune, N. Potischman, A.F. Subar, A.J. Cross, S.A. Bingham, et al., Use of the predictive sugars biomarker to evaluate self-reported total sugars intake in the Observing Protein and Energy Nutrition (OPEN) study, Cancer Epidemiol. Biomarkers Prev. 20 (2011) 490–500.
[299] Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey: Questionnaires, Datasets, and Related Documentation, National Center for Health Statistics, Centers for Disease Control and Prevention. Available from <http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm>, 2011.
[300] T. Byers, M. Serdula, S. Kuester, J. Mendlein, C. Ballew, R.S. McPherson, Dietary surveillance for states and communities, Am. J. Clin. Nutr. 65 (1997) 1210S–1214S.
[301] California Department of Public Health. California Dietary Practices Surveys (CDPS), California Department of Public Health. Available from <http://www.cdph.ca.gov/programs/cpns/Pages/CaliforniaStatewideSurveys.aspx#1>, 2012.
[302] C.M. Friedenreich, N. Slimani, E. Riboli, Measurement of past diet: review of previous and proposed methods, Epidemiol. Rev. 14 (1992) 177–196.
[303] S.S. Maruti, D. Feskanich, H.R. Rockett, G.A. Colditz, L.A. Sampson, W.C. Willett, Validation of adolescent diet recalled by adults, Epidemiology 17 (2006) 226–229.
[304] W. Willett, Recall of remote diet, in: W. Willett (Ed.), Nutritional Epidemiology, Oxford University Press, New York, NY, 2013, pp. 142–149.
[305] T. Eysteinsdottir, I. Gunnarsdottir, I. Thorsdottir, T. Harris, L.J. Launer, V. Gudnason, et al., Validity of retrospective diet history: assessing recall of midlife diet using food frequency questionnaire in later life, J. Nutr. Health Aging 15 (2011) 809–814.
[306] F.E. Thompson, D.E. Lamphiear, H.L. Metzner, V.M. Hawthorne, M.S. Oh, Reproducibility of reports of frequency of food use in the Tecumseh Diet Methodology Study, Am. J. Epidemiol. 125 (1987) 658–671.
[307] M.C. Teixeira Martins, K. Jaceldo-Siegl, J. Fan, P. Singh, G.E. Fraser, Short- and long-term reliability of adult recall of vegetarian dietary patterns in the Adventist Health Study-2 (AHS-2), J. Nutr. Sci 4 (2015) e11.
[308] J.T. Dwyer, K.A. Coleman, Insights into dietary recall from a longitudinal study: accuracy over four decades, Am. J. Clin. Nutr. 65 (1997) 1153S–1158S.
[309] J.E. Chavarro, B.A. Rosner, L. Sampson, C. Willey, P. Tocco, W.C. Willett, et al., Validity of adolescent diet recall 48 years later, Am. J. Epidemiol. 170 (2009) 1563–1570.
[310] A. Wolk, R. Bergstrom, L.E. Hansson, O. Nyren, Reliability of retrospective information on diet 20 years ago and consistency of independent measurements of remote adolescent diet, Nutr. Cancer 29 (1997) 234–241.
[311] J.E. Chavarro, K.B. Michels, S. Isaq, B.A. Rosner, L. Sampson, C. Willey, et al., Validity of maternal recall of preschool diet after 43 years, Am. J. Epidemiol. 169 (2009) 1148–1157.
[312] N. Malila, M. Virtanen, P. Pietinen, J. Virtamo, D. Albanes, A.M. Hartman, et al., A comparison of prospective and retrospective assessments of diet in a study of colorectal cancer, Nutr. Cancer 32 (1998) 146–153.
[313] C.M. Friedenreich, G.R. Howe, A.B. Miller, An investigation of recall bias in the reporting of past food intake among breast cancer cases and controls, Ann. Epidemiol. 1 (1991) 439–453.
[314] C.M. Friedenreich, G.R. Howe, A.B. Miller, The effect of recall bias on the association of calorie-providing nutrients and breast cancer, Epidemiology 2 (1991) 424–429.
[315] P.G. Persson, A. Ahlbom, S.E. Norell, Retrospective versus original information on diet: implications for epidemiological studies, Int. J. Epidemiol. 19 (1990) 343–348.
[316] E. Giovannucci, M.J. Stampfer, G.A. Colditz, J.E. Manson, B.A. Rosner, M. Longnecker, et al., A comparison of prospective and retrospective assessments of diet in the study of breast cancer, Am. J. Epidemiol. 137 (1993) 502–511.
[317] W.C. Willett, F.B. Hu, Not the time to abandon the food frequency questionnaire: point, Cancer Epidemiol. Biomarkers Prev. 15 (2006) 1757–1758.
[318] W.C. Willett, F.B. Hu, The food frequency questionnaire, Cancer Epidemiol. Biomarkers Prev. 16 (2007) 182–183.
[319] L.S. Freedman, A. Schatzkin, A.C. Thiebaut, N. Potischman, A.F. Subar, F.E. Thompson, et al., Abandon neither the food frequency questionnaire nor the dietary fat-breast cancer hypothesis, Cancer Epidemiol. Biomarkers Prev. 16 (2007) 1321–1322.

[320] A. Schatzkin, A.F. Subar, S. Moore, Y. Park, N. Potischman, F.E. Thompson, et al., Observational epidemiologic studies of nutrition and cancer: the next generation (with better observation), Cancer Epidemiol. Biomarkers Prev. 18 (2009) 1026−1032.
[321] A.S. Kolar, R.E. Patterson, E. White, M.L. Neuhouser, L.L. Frank, J. Standley, et al., A practical method for collecting 3-day food records in a large cohort, Epidemiology 16 (2005) 579−583.
[322] M.L. Kwan, L.H. Kushi, J. Song, A.W. Timperi, A.M. Boynton, K.M. Johnson, et al., A practical method for collecting food record data in a prospective cohort study of breast cancer survivors, Am. J. Epidemiol. 172 (2010) 1315−1323.
[323] B. Rosner, W.C. Willett, D. Spiegelman, Correction of logistic regression relative risk estimates and confidence intervals for systematic within-person measurement error, Stat. Med. 8 (1989) 1051−1069.
[324] R. Kaaks, M. Plummer, E. Riboli, J. Esteve, W. van Staveren, Adjustment for bias due to errors in exposure assessments in multicenter cohort studies on diet and cancer: a calibration approach, Am. J. Clin. Nutr. 59 (1994) 245S−250S.
[325] R.J. Carroll, L.S. Freedman, V. Kipnis, Measurement error and dietary intake, Adv. Exp. Med. Biol 445 (1998) 139−145.
[326] A.C. Thiebaut, V. Kipnis, A. Schatzkin, L.S. Freedman, The role of dietary measurement error in investigating the hypothesized link between dietary fat intake and breast cancer—a story with twists and turns, Cancer Invest. 26 (2008) 68−73.
[327] L.S. Freedman, A. Schatzkin, D. Midthune, V. Kipnis, Dealing with dietary measurement error in nutritional cohort studies, J. Natl. Cancer Inst. 103 (2011) 1086−1092.
[328] T. Baranowski, E. Cerin, J. Baranowski, Steps in the design, development and formative evaluation of obesity prevention-related behavior change trials, Int. J. Behav. Nutr. Phys. Act. 6 (2009) 6.
[329] J.O. Prochaska, C.C. DiClemente, J.C. Norcross, In search of how people change: applications to addictive behaviors, Am. Psychol. 47 (1992) 1102−1114.
[330] K. Glanz, R.E. Patterson, A.R. Kristal, C.C. DiClemente, J. Heimendinger, L. Linnan, et al., Stages of change in adopting healthy diets: fat, fiber, and correlates of nutrient intake, Health Educ. Q. 21 (1994) 499−519.
[331] G. Block, C. Clifford, M.D. Naughton, M. Henderson, M. McAdams, A brief dietary screen for high fat intake, J. Nutr. Educ. 21 (1989) 199−207.
[332] C. Ritenbaugh, R.E. Patterson, R.T. Chlebowski, B. Caan, L. Fels-Tinker, B. Howard, et al., The Women's Health Initiative Dietary Modification trial: overview and baseline characteristics of participants, Ann. Epidemiol. 13 (2003) S87−S97.
[333] J.R. Hebert, K.E. Peterson, T.G. Hurley, A.M. Stoddard, N. Cohen, A.E. Field, et al., The effect of social desirability trait on self-reported dietary measures among multi-ethnic female health center employees, Ann. Epidemiol. 11 (2001) 417−427.
[334] T.M. Miller, M.F. Abdel-Maksoud, L.A. Crane, A.C. Marcus, T. E. Byers, Effects of social approval bias on self-reported fruit and vegetable consumption: a randomized controlled trial, Nutr. J. 7 (2008) 18.
[335] L. Natarajan, M. Pu, J. Fan, R.A. Levine, R.E. Patterson, C.A. Thomson, et al., Measurement error of dietary self-report in intervention trials, Am. J. Epidemiol. 172 (2010) 819−827.
[336] T. Baranowski, D.D. Allen, L.C. Masse, M. Wilson, Does participation in an intervention affect responses on self-report questionnaires? Health Educ. Res. 21 (2006) i98−109.
[337] J.L. Forster, R.W. Jeffery, M. VanNatta, P. Pirie, Hypertension prevention trial: do 24-h food records capture usual eating behavior in a dietary change study? Am. J. Clin. Nutr. 51 (1990) 253−257.
[338] D.D. Gorder, G.E. Bartsch, J.L. Tillotson, G.A. Grandits, J. Stamler, Food group and macronutrient intakes, trial years 1−6, in the special intervention and usual care groups in the Multiple Risk Factor Intervention Trial, Am. J. Clin. Nutr. 65 (1997) 258S−271S.
[339] B. Caan, R. Ballard-Barbash, M.L. Slattery, J.L. Pinsky, F.L. Iber, D.J. Mateski, et al., Low energy reporting may increase in intervention participants enrolled in dietary intervention trials, J. Am. Diet. Assoc. 104 (2004) 357−366.
[340] G.C. Williams, T.G. Hurley, F.E. Thompson, D. Midthune, A.L. Yaroch, K. Resnicow, et al., Performance of a short percentage energy from fat tool in measuring change in dietary intervention studies, J. Nutr. 138 (2008) 212S−217S.
[341] A. Cheadle, B.M. Psaty, P. Diehr, T. Koepsell, E. Wagner, S. Curry, et al., Evaluating community-based nutrition programs: comparing grocery store and individual-level survey measures of program impact, Prev. Med. 24 (1995) 71−79.
[342] A. Cheadle, B.M. Psaty, S. Curry, E. Wagner, P. Diehr, T. Koepsell, et al., Can measures of the grocery store environment be used to track community-level dietary changes? Prev. Med. 22 (1993) 361−372.
[343] S.A. Smith-Warner, P.J. Elmer, T.M. Tharp, L. Fosdick, B. Randall, M. Gross, et al., Increasing vegetable and fruit intake: randomized intervention and monitoring in an at-risk population, Cancer Epidemiol. Biomarkers Prev. 9 (2000) 307−317.
[344] S. Sasaki, T. Ishikawa, R. Yanagibori, K. Amano, Responsiveness to a self-administered diet history questionnaire in a work-site dietary intervention trial for mildly hypercholesterolemic Japanese subjects: correlation between change in dietary habits and serum cholesterol levels, J. Cardiol. 33 (1999) 327−338.
[345] J.M. Samet, A.J. Alberg, Surrogate sources of dietary information, in: W. Willett (Ed.), Nutritional Epidemiology, Oxford University Press, New York, NY, 1998.
[346] P. Emmett, Workshop 2: The use of surrogate reporters in the assessment of dietary intake, Eur. J. Clin. Nutr. 63 (2009) S78−S79.
[347] L.N. Kolonel, T. Hirohata, A.M. Nomura, Adequacy of survey data collected from substitute respondents, Am. J. Epidemiol. 106 (1977) 476−484.
[348] J. Marshall, R. Priore, B. Haughey, T. Rzepka, S. Graham, Spouse-subject interviews and the reliability of diet studies, Am. J. Epidemiol. 112 (1980) 675−683.
[349] C.G. Humble, J.M. Samet, B.E. Skipper, Comparison of self- and surrogate-reported dietary information, Am. J. Epidemiol. 119 (1984) 86−98.
[350] H.L. Metzner, D.E. Lamphiear, F.E. Thompson, M.S. Oh, V.M. Hawthorne, Comparison of surrogate and subject reports of dietary practices, smoking habits and weight among married couples in the Tecumseh Diet Methodology Study, J. Clin. Epidemiol. 42 (1989) 367−375.

[351] T.G. Hislop, A.J. Coldman, Y.Y. Zheng, V.T. Ng, T. Labo, Reliability of dietary information from surrogate respondents, Nutr. Cancer 18 (1992) 123−129.

[352] N. Herrmann, Retrospective information from questionnaires. I. Comparability of primary respondents and their next-of-kin, Am. J. Epidemiol. 121 (1985) 937−947.

[353] G.J. Petot, S.M. Debanne, T.M. Riedel, K.A. Smyth, E. Koss, A. J. Lerner, et al., Use of surrogate respondents in a case control study of dietary risk factors for Alzheimer's disease, J. Am. Diet. Assoc. 102 (2002) 848−850.

[354] J.P. Fryzek, L. Lipworth, L.B. Signorello, J.K. McLaughlin, The reliability of dietary data for self- and next-of-kin respondents, Ann. Epidemiol. 12 (2002) 278−283.

[355] J.H. Hankin, L.R. Wilkens, Development and validation of dietary assessment methods for culturally diverse populations, Am. J. Clin. Nutr. 59 (1994) 198S−200S.

[356] G.K. Lyons, S.I. Woodruff, J.I. Candelaria, J.W. Rupp, J.P. Elder, Development of a protocol to assess dietary intake among Hispanics who have low literacy skills in English, J. Am. Diet. Assoc. 96 (1996) 1276−1279.

[357] C.M. Loria, M.A. McDowell, C.L. Johnson, C.E. Woteki, Nutrient data for Mexican-American foods: are current data adequate? J. Am. Diet. Assoc. 91 (1991) 919−922.

[358] K. Levin, G.B. Willis, B.H. Forsyth, A. Norberg, M.S. Kudela, D. Stark, et al., Using cognitive interviews to evaluate the Spanish-language translation of a dietary questionnaire, Surv. Res. Methods 3 (2009) 13−25.

[359] M. Johnson-Kozlow, G.E. Matt, C.L. Rock, R. de la Rosa, T.L. Conway, R.A. Romero, Assessment of dietary intakes of Filipino-Americans: implications for food frequency questionnaire design, J. Nutr. Educ. Behav. 43 (2011) 505−510.

[360] J.S. Johnson, E.D. Nobmann, E. Asay, A.P. Lanier, Developing a validated Alaska Native food frequency questionnaire for western Alaska, 2002-2006, Int. J. Circumpolar Health 68 (2009) 99−108.

[361] D. Taren, M. de Tobar, C. Ritenbaugh, E. Graver, R. Whitacre, M. Aickin, Evaluation of the Southwest Food Frequency Questionnaire, Ecol. Food Nutr. 38 (2000) 515−547.

[362] G. Block, P. Wakimoto, C. Jensen, S. Mandel, R.R. Green, Validation of a food frequency questionnaire for Hispanics, Prev. Chronic Dis. 3 (2006) A77.

[363] A.C. Bovell-Benjamin, N. Dawkin, R.D. Pace, J.M. Shikany, Use of focus groups to understand African-Americans' dietary practices: Implications for modifying a food frequency questionnaire, Prev. Med. 48 (2009) 549−554.

[364] S. Sharma, J. Cade, J. Landman, J.K. Cruickshank, Assessing the diet of the British African-Caribbean population: frequency of consumption of foods and food portion sizes, Int. J. Food Sci. Nutr. 53 (2002) 439−444.

[365] K.L. Tucker, L.A. Bianchi, J. Maras, O.I. Bermudez, Adaptation of a food frequency questionnaire to assess diets of Puerto Rican and non-Hispanic adults, Am. J. Epidemiol. 148 (1998) 507−518.

[366] K.L. Tucker, J. Maras, C. Champagne, C. Connell, S. Goolsby, J. Weber, et al., A regional food-frequency questionnaire for the US Mississippi Delta, Public Health Nutr. 8 (2005) 87−96.

[367] D.O. Stram, J.H. Hankin, L.R. Wilkens, M.C. Pike, K.R. Monroe, S. Park, et al., Calibration of the dietary questionnaire for a multiethnic cohort in Hawaii and Los Angeles, Am. J. Epidemiol. 151 (2000) 358−370.

[368] L.B. Signorello, H.M. Munro, M.S. Buchowski, D.G. Schlundt, S.S. Cohen, M.K. Hargreaves, et al., Estimating nutrient intake from a food frequency questionnaire: incorporating the elements of race and geographic region, Am. J. Epidemiol. 170 (2009) 104−111.

[369] H. Mochari, Q. Gao, L. Mosca, Validation of the MEDFICTS dietary assessment questionnaire in a diverse population, J. Am. Diet. Assoc. 108 (2008) 817−822.

[370] E.J. Mayer-Davis, M.Z. Vitolins, S.L. Carmichael, S. Hemphill, G. Tsaroucha, J. Rushing, et al., Validity and reproducibility of a food frequency interview in a multi-cultural epidemiologic study, Ann. Epidemiol. 9 (1999) 314−324.

[371] A.R. Kristal, Z. Feng, R.J. Coates, A. Oberman, V. George, Associations of race/ethnicity, education, and dietary intervention with the validity and reliability of a food frequency questionnaire: the Women's Health Trial Feasibility Study in Minority Populations, Am. J. Epidemiol. 146 (1997) 856−869.

[372] K.B. Baumgartner, F.D. Gilliland, C.S. Nicholson, R.S. McPherson, W.C. Hunt, D.R. Pathak, et al., Validity and reproducibility of a food frequency questionnaire among Hispanic and non-Hispanic white women in New Mexico, Ethn. Dis. 8 (1998) 81−92.

[373] K.W. Cullen, I. Zakeri, The youth/adolescent questionnaire has low validity and modest reliability among low-income African-American and Hispanic seventh- and eighth-grade youth, J. Am. Diet. Assoc. 104 (2004) 1415−1419.

[374] K. Jaceldo-Siegl, J. Fan, J. Sabate, S.F. Knutsen, E. Haddad, W. L. Beeson, et al., Race-specific validation of food intake obtained from a comprehensive FFQ: the Adventist Health Study-2, Public Health Nutr 14 (2011) 1988−1997.

[375] A.F. Smith, S.D. Baxter, J.W. Hardin, C.H. Guinn, J.A. Royer, Relation of children's dietary reporting accuracy to cognitive ability, Am. J. Epidemiol. 173 (2011) 103−109.

[376] T. Baranowski, S.B. Domel, A cognitive model of children's reporting of food intake, Am. J. Clin. Nutr. 59 (1994) 212S−217S.

[377] National Cancer Institute. NCS Dietary Assessment Literature Review, Applied Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://appliedresearch.cancer.gov/assess_wc/review/>, 2014.

[378] T.L. Burrows, R.J. Martin, C.E. Collins, A systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labeled water, J. Am. Diet. Assoc. 110 (2010) 1501−1510.

[379] S.G. Forrestal, Energy intake misreporting among children and adolescents: a literature review, Matern. Child Nutr. 7 (2011) 112−127.

[380] C. Perez-Rodrigo, B. Artiach Escauriaza, J. Artiach Escauriaza, I. Polanco Allue, Dietary assessment in children and adolescents: issues and recommendations, Nutr. Hosp. 31 (2015) 76−83.

[381] M.B. Livingstone, P.J. Robson, J.M. Wallace, Issues in dietary intake assessment of children and adolescents, Br. J. Nutr. 92 (2004) S213−S222.

[382] A.F. Smith, Validation studies of diets of children and adolescents, J. Am. Diet. Assoc. 111 (2011) 1124−1125; author's reply 1125−1126

[383] B.A. Dennison, P.L. Jenkins, H.L. Rockwell, Development and validation of an instrument to assess child dietary fat intake, Prev. Med. 31 (2000) 214−224.

[384] K.M. Koehler, L. Cunningham-Sabo, L.C. Lambert, R. McCalman, B.J. Skipper, S.M. Davis, Assessing food selection in a health promotion program: validation of a brief instrument for American Indian children in the southwest United States, J. Am. Diet. Assoc. 100 (2000) 205−211.

[385] L.J. Harnack, L.A. Lytle, M. Story, D.A. Galuska, K. Schmitz, D.R. Jacobs Jr., et al., Reliability and validity of a brief questionnaire to assess calcium intake of middle-school-aged children, J. Am. Diet. Assoc. 106 (2006) 1790−1795.

[386] B.G. Simons-Morton, T. Baranowski, Observation in assessment of children's dietary practices, J. Sch. Health 61 (1991) 204−207.

[387] A.F. Smith, S.D. Baxter, J.W. Hardin, J.A. Royer, C.H. Guinn, Some intrusions in dietary reports by fourth-grade children are based on specific memories: data from a validation study of the effect of interview modality, Nutr. Res. 28 (2008) 600−608.

[388] D.M. Matheson, K.A. Hanson, T.E. McDonald, T.N. Robinson, Validity of children's food portion estimates: a comparison of 2 measurement aids, Arch. Pediatr. Adolesc. Med. 156 (2002) 867−871.

[389] C. Frobisher, S.M. Maxwell, The estimation of food portion sizes: a comparison between using descriptions of portion sizes and a photographic food atlas by children and adults, J. Hum. Nutr. Diet 16 (2003) 181−188.

[390] T. Baranowski, D. Sprague, J.H. Baranowski, J.A. Harrison, Accuracy of maternal dietary recall for preschool children, J. Am. Diet. Assoc. 91 (1991) 669−674.

[391] L.H. Eck, R.C. Klesges, C.L. Hanson, Recall of a child's intake from one meal: are parents accurate? J. Am. Diet. Assoc. 89 (1989) 784−789.

[392] E.J. Sobo, C.L. Rock, "You ate all that!?": caretaker-child interaction during children's assisted dietary recall interviews, Med. Anthropol. Q. 15 (2001) 222−244.

[393] L.F. Andersen, S. Lioret, H. Brants, A. Kaic-Rak, E.J. de Boer, P. Amiano, et al., Recommendations for a trans-European dietary assessment method in children between 4 and 14 years, Eur. J. Clin. Nutr. 65 (2011) S58−64.

[394] Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey: MEC In-Person Dietary Interviewers Procedures Manual, National Center for Health Statistics, Centers for Disease Control and Prevention. Available from <http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/DietaryInterviewers_Inperson.pdf>, 2009.

[395] S.D. Baxter, Cognitive processes in children's dietary recalls: insight from methodological studies, Eur. J. Clin. Nutr. 63 (2009) S19−S32.

[396] S.D. Baxter, J.W. Hardin, J.A. Royer, C.H. Guinn, A.F. Smith, Children's recalls from five dietary-reporting validation studies. Intrusions in correctly reported and misreported options in school breakfast reports, Appetite 51 (2008) 489−500.

[397] S.D. Baxter, A.F. Smith, M.S. Litaker, C.H. Guinn, N.M. Shaffer, M.L. Baglio, et al., Recency affects reporting accuracy of children's dietary recalls, Ann. Epidemiol. 14 (2004) 385−390.

[398] S.D. Baxter, J.W. Hardin, C.H. Guinn, J.A. Royer, A.J. Mackelprang, A.F. Smith, Fourth-grade children's dietary recall accuracy is influenced by retention interval (target period and interview time), J. Am. Diet. Assoc. 109 (2009) 846−856.

[399] T. Baranowski, J.C. Baranowski, K.B. Watson, S. Martin, A. Beltran, N. Islam, et al., Children's accuracy of portion size estimation using digital food images: effects of interface design and size of image on computer screen, Public Health Nutr. 14 (2010) 418−425.

[400] T. Baranowski, N. Islam, D. Douglass, H. Dadabhoy, A. Beltran, J. Baranowski, et al., Food Intake Recording Software System, version 4 (FIRSSt4): a self-completed 24-h dietary recall for children, J. Hum. Nutr. Diet 27 (2014) 66−71.

[401] A.S. Lu, J. Baranowski, N. Islam, T. Baranowski, How to engage children in self-administered dietary assessment programmes, J. Hum. Nutr. Diet 27 (2014) 5−9.

[402] E. Foster, A. Hawkins, J. Delve, A.J. Adamson, Reducing the cost of dietary assessment: self-completed recall and analysis of nutrition for use with children (SCRAN24), J. Hum. Nutr. Diet 27 (2014) 26−35.

[403] A. Biltoft-Jensen, M.F. Hjorth, E. Trolle, T. Christensen, P.B. Brockhoff, L.F. Andersen, et al., Comparison of estimated energy intake using Web-based Dietary Assessment Software with accelerometer-determined energy expenditure in children, Food Nutr. Res 57 (2013).

[404] C. Vereecken, M. Covents, L. Maes, T. Moyson, Formative evaluation of the dietary assessment component of Children's and Adolescents' Nutrition Assessment and Advice on the Web (CANAA-W), J. Hum. Nutr. Diet 27 (2014) 54−65.

[405] H.J. Moore, F.C. Hillier, A.M. Batterham, L.J. Ells, C.D. Summerbell, Technology-based dietary assessment: development of the Synchronised Nutrition and Activity Program (SNAP), J. Hum. Nutr. Diet 27 (2014) 36−42.

[406] E. Trolle, P. Amiano, M. Ege, E. Bower, S. Lioret, H. Brants, et al., Evaluation of 2 x 24-h dietary recalls combined with a food-recording booklet, against a 7-day food-record method among schoolchildren, Eur. J. Clin. Nutr. 65 (2011) S77−S83.

[407] J. Hammond, M. Nelson, S. Chinn, R.J. Rona, Validation of a food frequency questionnaire for assessing dietary intake in a study of coronary heart disease risk factors in children, Eur. J. Clin. Nutr. 47 (1993) 242−250.

[408] H.R. Rockett, M. Breitenbach, A.L. Frazier, J. Witschi, A.M. Wolf, A.E. Field, et al., Validation of a youth/adolescent food frequency questionnaire, Prev. Med. 26 (1997) 808−816.

[409] D.M. Klohe, K.K. Clarke, G.C. George, T.J. Milani, H. Hanss-Nuss, J. Freeland-Graves, Relative validity and reliability of a food frequency questionnaire for a triethnic population of 1-year-old to 3-year-old children from low-income families, J. Am. Diet. Assoc. 105 (2005) 727−734.

[410] H.R. Rockett, C.S. Berkey, G.A. Colditz, Comparison of a short food frequency questionnaire with the Youth/Adolescent Questionnaire in the Growing Up Today Study, Int. J. Pediatr. Obes. 2 (2007) 31−39.

[411] R.M. Hanning, D. Royall, J.E. Toews, L. Blashill, J. Wegener, P. Driezen, Web-based Food Behaviour Questionnaire: validation with grades six to eight students, Can. J. Diet. Pract. Res. 70 (2009) 172−178.

[412] D.A. Williamson, H.R. Allen, P.D. Martin, A.J. Alfonso, B. Gerald, A. Hunt, Comparison of digital photography to weighed and visual estimation of portion sizes, J. Am. Diet. Assoc. 103 (2003) 1139−1145.

[413] C.K. Martin, R.L. Newton Jr., S.D. Anton, H.R. Allen, A. Alfonso, H. Han, et al., Measurement of children's food intake with digital photography and the effects of second servings upon food intake, Eat. Behav. 8 (2007) 148−156.

[414] B.L. Six, T.E. Schap, F.M. Zhu, A. Mariappan, M. Bosch, E.J. Delp, et al., Evidence-based development of a mobile telephone food record, J. Am. Diet. Assoc. 110 (2010) 74−79.

[415] C.J. Boushey, D.A. Kerr, J. Wright, K.D. Lutes, D.S. Ebert, E.J. Delp, Use of technology in children's dietary assessment, Eur. J. Clin. Nutr. 63 (2009) S50−S57.

[416] C.K. Martin, T. Nicklas, B. Gunturk, J.B. Correa, H.R. Allen, C. Champagne, Measuring food intake with digital photography, J. Hum. Nutr. Diet 27 (2014) 72−81.

[417] T.E. Schap, F. Zhu, E.J. Delp, C.J. Boushey, Merging dietary assessment with the adolescent lifestyle, J. Hum. Nutr. Diet 27 (2014) 82−88.

[418] A. Magarey, J. Watson, R.K. Golley, T. Burrows, R. Sutherland, S.A. McNaughton, et al., Assessing dietary intake in children and adolescents: considerations and recommendations for obesity research, Int. J. Pediatr. Obes. 6 (2011) 2−11.

[419] J.H. de Vries, L.C. de Groot, W.A. van Staveren, Dietary assessment in elderly people: experiences gained from studies in the Netherlands, Eur. J. Clin. Nutr. 63 (2009) S69−S74.

[420] A.J. Adamson, J. Collerton, K. Davies, E. Foster, C. Jagger, E. Stamp, et al., Nutrition in advanced age: dietary assessment in the Newcastle 85+ study, Eur. J. Clin. Nutr. 63 (2009) S6−18.

[421] E.M. Rothenberg, Experience of dietary assessment and validation from three Swedish studies in the elderly, Eur. J. Clin. Nutr. 63 (2009) S64−S68.

[422] D. Volkert, E. Schrader, Dietary assessment methods for older persons: what is the best approach? Curr. Opin. Clin. Nutr. Metab. Care 16 (2013) 534−540.

[423] R.L. Bailey, J.J. Gahche, C.V. Lentino, J.T. Dwyer, J.S. Engel, P.R. Thomas, et al., Dietary supplement use in the United States, 2003-2006, J. Nutr. 141 (2011) 261−266.

[424] T.C. Wallace, M. McBurney, V.L. Fulgoni 3rd, Multivitamin/mineral supplement contribution to micronutrient intakes in the United States, 2007-2010, J. Am. Coll. Nutr. 33 (2014) 94−102.

[425] C.H. Wu, C.C. Wang, M.T. Tsai, W.T. Huang, J. Kennedy, Trend and pattern of herb and supplement use in the United States: results from the 2002, 2007, and 2012 national health interview surveys, Evid. Based Complement. Alternat. Med. 2014 (2014) 872320.

[426] K.A. Poulia, M. Yannakoulia, D. Karageorgou, M. Gamaletsou, D.B. Panagiotakos, N.V. Sipsas, et al., Evaluation of the efficacy of six nutritional screening tools to predict malnutrition in the elderly, Clin. Nutr. 31 (2012) 378−385.

[427] Y. Guigoz, The Mini Nutritional Assessment (MNA) review of the literature—What does it tell us? J. Nutr. Health Aging 10 (2006) 466−485.

[428] M. Elia, R.J. Stratton, An analytic appraisal of nutrition screening tools supported by original data with particular reference to age, Nutrition 28 (2012) 477−494.

[429] S. Marshall, A. Young, J. Bauer, E. Isenring, Nutrition screening in geriatric rehabilitation: criterion (concurrent and predictive) validity of the Malnutrition Screening Tool and the Mini Nutritional Assessment-Short Form, J. Acad. Nutr. Diet. 116 (2016) 795−801.

[430] E. Cereda, C. Pedrolli, A. Zagami, A. Vanotti, S. Piffer, A. Opizzi, et al., Nutritional screening and mortality in newly institutionalised elderly: A comparison between the Geriatric Nutritional Risk Index and the Mini Nutritional Assessment, Clin. Nutr. 30 (2011) 793−798.

[431] P. Duran Alert, R. Mila Villarroel, F. Formiga, N. Virgili Casas, C. Vilarasau Farre, Assessing risk screening methods of malnutrition in geriatric patients: Mini Nutritional Assessment (MNA) versus Geriatric Nutritional Risk Index (GNRI), Nutr. Hosp. 27 (2012) 590−598.

[432] W.M. Abd-El-Gawad, R.M. Abou-Hashem, M.O. El Maraghy, G.E. Amin, The validity of Geriatric Nutrition Risk Index: simple tool for prediction of nutritional-related complication of hospitalized elderly patients. Comparison with Mini Nutritional Assessment, Clin. Nutr. 33 (2014) 1108−1116.

[433] S. Marshall, A. Young, J. Bauer, E. Isenring, Malnutrition in geriatric rehabilitation: prevalence, patient outcomes, and criterion validity of the Scored Patient-Generated Subjective Global Assessment and the Mini Nutritional Assessment, J. Acad. Nutr. Diet. 116 (2016) 785−794.

[434] N.J. Tomoyasu, M.J. Toth, E.T. Poehlman, Misreporting of total energy intake in older men and women, J. Am. Geriatr. Soc. 47 (1999) 710−715.

[435] P.M. Luhrmann, B.M. Herbert, M. Neuhauser-Berthold, Underreporting of energy intake in an elderly German population, Nutrition 17 (2001) 912−916.

[436] D.R. Shahar, B. Yu, D.K. Houston, S.B. Kritchevsky, A.B. Newman, D.E. Sellmeyer, et al., Misreporting of energy intake in the elderly using doubly labeled water to measure total energy expenditure and weight change, J. Am. Coll. Nutr. 29 (2010) 14−24.

[437] M.M. Chianetta, M.K. Head, Effect of prior notification on accuracy of dietary recall by the elderly, J. Am. Diet. Assoc. 92 (1992) 741−743.

[438] W.A. van Staveren, L.C. de Groot, Y.H. Blauw, R.P. van der Wielen, Assessing diets of elderly people: problems and approaches, Am. J. Clin. Nutr. 59 (1994) 221S−223S.

[439] K. Klipstein-Grobusch, J.H. den Breeijen, R.A. Goldbohm, J. M. Geleijnse, A. Hofman, D.E. Grobbee, et al., Dietary assessment in the elderly: validation of a semiquantitative food frequency questionnaire, Eur. J. Clin. Nutr. 52 (1998) 588−596.

[440] B. Shatenstein, H. Payette, S. Nadon, K. Gray-Donald, An approach for evaluating lifelong intakes of functional foods in elderly people, J. Nutr. 133 (2003) 2384−2391.

[441] K. Pfrimer, D.S. Sartorelli, F.T. Rosa, C.M. Mendes Resende, D. V. Viera, E.I. Rabito, et al., Calibration of the food list and portion sizes of a food frequency questionnaire applied to free-living elderly people, Nutrition 29 (2013) 760−764.

[442] M.C. Morris, C.C. Tangney, J.L. Bienias, D.A. Evans, R.S. Wilson, Validity and reproducibility of a food frequency questionnaire by cognition in an older biracial sample, Am. J. Epidemiol. 158 (2003) 1213−1217.

[443] D.C. Mitchell, K.L. Tucker, J. Maras, F.R. Lawrence, H. Smiciklas-Wright, G.L. Jensen, et al., Relative validity of the

Geisinger Rural Aging Study food frequency questionnaire, J. Nutr. Health Aging 16 (2012) 667−672.

[444] E. Kiesswetter, S. Pohlhausen, K. Uhlig, R. Diekmann, S. Lesser, H. Heseker, et al., Malnutrition is related to functional impairment in older adults receiving home care, J. Nutr. Health Aging 17 (2013) 345−350.

[445] D.A. Dillman, J.D. Smyth, L.M. Christian, Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method, 4th ed, John Wiley & Sons, Inc, Hoboken, NJ, 2014.

[446] R.J. Voogt, W.E. Saris, Mixed mode designs: finding the balance between nonresponse bias and mode effects, J. Off. Stat. 21 (2005) 367−387.

[447] J.T. Dwyer, E.A. Krall, K.A. Coleman, The problem of memory in nutritional epidemiology research, J. Am. Diet. Assoc. 87 (1987) 1509−1512.

[448] A.F. Smith, J.B. Jobe, D.J. Mingay, Retrieval from memory of dietary information, Appl. Cogn. Psychol. 5 (1991) 269−296.

[449] C.M. Friedenreich, Improving long-term recall in epidemiologic studies, Epidemiology 5 (1994) 1−4.

[450] J.A. Satia, R.E. Patterson, V.M. Taylor, C.L. Cheney, S. Shiu-Thornton, K. Chitnarong, et al., Use of qualitative methods to study diet, acculturation, and health in Chinese-American women, J. Am. Diet. Assoc. 100 (2000) 934−940.

[451] W.S. Wolfe, E.A. Frongillo, P.A. Cassano, Evaluating brief measures of fruit and vegetable consumption frequency and variety: cognition, interpretation, and other measurement issues, J. Am. Diet. Assoc. 101 (2001) 311−318.

[452] E. Chambers, S.L. Godwin, F.A. Vecchio, Cognitive strategies for reporting portion sizes using dietary recall procedures, J. Am. Diet. Assoc. 100 (2000) 891−897.

[453] M. Johnson-Kozlow, G.E. Matt, C.L. Rock, Recall strategies used by respondents to complete a food frequency questionnaire: an exploratory study, J. Am. Diet. Assoc. 106 (2006) 430−433.

[454] G.E. Matt, C.L. Rock, M. Johnson-Kozlow, Using recall cues to improve measurement of dietary intakes with a food frequency questionnaire in an ethnically diverse population: an exploratory study, J. Am. Diet. Assoc. 106 (2006) 1209−1217.

[455] C. Bonilla, P. Brauer, D. Royall, H. Keller, R.M. Hanning, A. DiCenso, Use of electronic dietary assessment tools in primary care: an interdisciplinary perspective, BMC Med. Inform. Decis. Mak. 15 (2015) 14.

[456] C.J. Boushey, A.J. Harray, D.A. Kerr, T.E. Schap, S. Paterson, T. Aflague, et al., How willing are adolescents to record their dietary intake? The mobile food record, JMIR Mhealth Uhealth 3 (2015) e47.

[457] S. Murali, L. Arab, R. Vargas, A. Rastogi, A. Ang, N. Shetty, Internet-based tools to assess diet and provide feedback in chronic kidney disease stage IV: a pilot study, J. Ren. Nutr. 23 (2013) e33−42.

[458] M.C. Carter, S.A. Albar, M.A. Morris, U.Z. Mulla, N. Hancock, C.E. Evans, et al., Development of a UK online 24-h dietary assessment tool: myfood24, Nutrients 7 (2015) 4016−4032.

[459] G.B. Willis, Cognitive Interviewing: A Tool for Improving Questionnaire Design, Sage Publications, Thousand Oaks, CA, 2005.

[460] G.B. Willis, Analysis of the Cognitive Interview in Questionnaire Design: Understanding Qualitative Research, Oxford University Press, New York, NY, 2015.

[461] I.M. Buzzard, Y.A. Sievert, Research priorities and recommendations for dietary assessment methodology. First International Conference on Dietary Assessment Methods, Am. J. Clin. Nutr. 59 (1994) 275S−280S.

[462] T. Baranowski, R. Dworkin, J.C. Henske, D.R. Clearman, J.K. Dunn, P.R. Nader, et al., The accuracy of children's self-reports of diet: Family Health Project, J. Am. Diet. Assoc. 86 (1986) 1381−1385.

[463] S.B. Domel, T. Baranowski, S.B. Leonard, H. Davis, P. Riley, J. Baranowski, Accuracy of fourth- and fifth-grade students' food records compared with school-lunch observations, Am. J. Clin. Nutr. 59 (1994) 218S−220S.

[464] S.D. Baxter, A.F. Smith, J.W. Hardin, M.D. Nichols, Conclusions about children's reporting accuracy for energy and macronutrients over multiple interviews depend on the analytic approach for comparing reported information to reference information, J. Am. Diet. Assoc. 107 (2007) 595−604.

[465] A.F. Smith, S. Domel Baxter, J.W. Hardin, M.D. Nichols, Conventional analyses of data from dietary validation studies may misestimate reporting accuracy: illustration from a study of the effect of interview modality on children's reporting accuracy, Public Health Nutr. 10 (2007) 1247−1256.

[466] S.A. Bingham, The use of 24-h urine samples and energy expenditure to validate dietary assessments, Am. J. Clin. Nutr. 59 (1994) 227S−231S.

[467] D.W. Heerstrass, M.C. Ocke, H.B. Bueno-de-Mesquita, P.H. Peeters, J.C. Seidell, Underreporting of energy, protein and potassium intake in relation to body mass index, Int. J. Epidemiol 27 (1998) 186−193.

[468] L.S. Freedman, R.J. Carroll, Y. Wax, Estimating the relation between dietary intake obtained from a food frequency questionnaire and true average intake, Am. J. Epidemiol. 134 (1991) 310−320.

[469] A.M. Hartman, G. Block, Dietary assessment methods for macronutrients, in: M.S. Micozzi, T.E. Moon (Eds.), Macronutrients: Investigating Their Role in Cancer, Marcel Dekker, New York, NY, 1992, pp. 87−124.

[470] S. Kirkpatrick, A. Subar, S. Krebs-Smith, F. Thompson, J. Reedy, T. Schap, et al., Evaluation of dietary assessment tools: what does 'validated' actually mean? International Conference on Diet and Activity Methods, Brisbane, Australia, 2015.

[471] B. Rosner, D. Spiegelman, W.C. Willett, Correction of logistic regression relative risk estimates and confidence intervals for measurement error: the case of multiple covariates measured with error, Am. J. Epidemiol. 132 (1990) 734−745.

[472] S. Paeratakul, B.M. Popkin, L. Kohlmeier, I. Hertz-Picciotto, X. Guo, L.J. Edwards, Measurement error in dietary data: implications for the epidemiologic study of the diet-disease relationship, Eur. J. Clin. Nutr. 52 (1998) 722−727.

[473] M. Plummer, D. Clayton, Measurement error in dietary assessment: an investigation using covariance structure models. Part II, Stat. Med. 12 (1993) 937−948.

[474] M. Plummer, D. Clayton, Measurement error in dietary assessment: an investigation using covariance structure models. Part I, Stat. Med. 12 (1993) 925−935.

[475] S.J. Blumberg, J.V. Luke, M.L. Cynamon, Telephone coverage and health survey estimates: evaluating the need for concern about wireless substitution, Am. J. Public Health 96 (2006) 926−931.

[476] L.C. Lyu, J.H. Hankin, L.Q. Liu, L.R. Wilkens, J.H. Lee, M.T. Goodman, et al., Telephone vs face-to-face interviews for quantitative food frequency assessment, J. Am. Diet. Assoc. 98 (1998) 44−48.

[477] M. Bogle, J. Stuff, L. Davis, I. Forrester, E. Strickland, P.H. Casey, et al., Validity of a telephone-administered 24-hour dietary recall in telephone and non-telephone households in the rural Lower Mississippi Delta region, J. Am. Diet. Assoc. 101 (2001) 216−222.

[478] M. Brustad, G. Skeie, T. Braaten, N. Slimani, E. Lund, Comparison of telephone vs face-to-face interviews in the assessment of dietary intake by the 24 h recall EPIC SOFT program—the Norwegian calibration study, Eur. J. Clin. Nutr. 57 (2003) 107−113.

[479] N.J. Krantzler, B.J. Mullen, H.G. Schutz, L.E. Grivetti, C.A. Holden, H.L. Meiselman, Validity of telephoned diet recalls and records for assessment of individual food intake, Am. J. Clin. Nutr. 36 (1982) 1234−1242.

[480] S.L. Godwin, E. Chambers, L. Cleveland, Accuracy of reporting dietary intake using various portion-size aids in-person and via telephone, J. Am. Diet. Assoc. 104 (2004) 585−594.

[481] L.R. Yanek, T.F. Moy, J.V. Raqueno, D.M. Becker, Comparison of the effectiveness of a telephone 24-hour dietary recall method vs an in-person method among urban African-American women, J. Am. Diet. Assoc. 100 (2000) 1172−1177.

[482] R. Tourangeau, L.J. Rips, K. Rasinski, The Psychology of Survey Response, Cambridge University Press, New York, NY, 2000.

[483] U.S. Census Bureau. Computer and internet access in the United States: 2013, U.S. Census Bureau, U.S. Department of Commerce. Available from <http://www.census.gov/hhes/computer/>, 2014.

[484] C. Matthys, I. Pynaert, M. Roe, S.J. Fairweather-Tait, A.L. Heath, S. De Henauw, Validity and reproducibility of a computerised tool for assessing the iron, calcium and vitamin C intake of Belgian women, Eur. J. Clin. Nutr. 58 (2004) 1297−1305.

[485] D.J. Toobert, L.A. Strycker, S.E. Hampson, E. Westling, S.M. Christiansen, T.G. Hurley, et al., Computerized portion-size estimation compared to multiple 24-hour dietary recalls for measurement of fat, fruit, and vegetable intake in overweight adults, J. Am. Diet. Assoc. 111 (2011) 1578−1583.

[486] K.E. Storey, L.E. Forbes, S.N. Fraser, J.C. Spence, R.C. Plotnikoff, K.D. Raine, et al., Diet quality, nutrition and physical activity among adolescents: the Web-SPAN (Web-Survey of Physical Activity and Nutrition) project, Public Health Nutr 12 (2009) 2009−2017.

[487] T.H. Shih, X. Fan, Comparing response rates from web and mail surveys: a meta-analysis, Field Methods 20 (2008) 249−271.

[488] K.A. Balter, O. Balter, E. Fondell, Y.T. Lagerros, Web-based and mailed questionnaires: a comparison of response rates and compliance, Epidemiology 16 (2005) 577−579.

[489] S. Fricker, M. Galesic, R. Tourangeau, T. Yan, An experimental comparison of web and telephone surveys, Public Opin. Q 69 (2005) 370−392.

[490] J.M. Beasley, A. Davis, W.T. Riley, Evaluation of a web-based, pictorial diet history questionnaire, Public Health Nutr. 12 (2009) 651−659.

[491] ESHA Research. Food Processor: The Food Processor Nutrition Analysis and Fitness Software. Available from <http://www.esha.com/products/food-processor/>, 2015.

[492] M.C. Carter, V.J. Burley, C. Nykjaer, J.E. Cade, 'My Meal Mate' (MMM): validation of the diet measures captured on a smartphone application to facilitate weight loss, Br. J. Nutr. 109 (2013) 539−546.

[493] D.B. Sharp, M. Allman-Farinelli, Feasibility and validity of mobile phones to assess dietary intake, Nutrition 30 (2014) 1257−1266.

[494] C.H. Thompson, M.K. Head, S.M. Rodman, Factors influencing accuracy in estimating plate waste, J. Am. Diet. Assoc. 87 (1987) 1219−1220.

[495] H.A. Guthrie, Selection and quantification of typical food portions by young adults, J. Am. Diet. Assoc. 84 (1984) 1440−1444.

[496] M. Nelson, M. Atkinson, S. Darbyshire, Food photography II: use of food photographs for estimating portion size and the nutrient content of meals, Br. J. Nutr. 76 (1996) 31−49.

[497] J.R. Hebert, P.C. Gupta, R. Bhonsle, F. Verghese, C. Ebbeling, R. Barrow, et al., Determinants of accuracy in estimating the weight and volume of commonly used foods: a cross-cultural comparison, Ecol. Food Nutr. 37 (1999) 475−502.

[498] L.R. Young, M.S. Nestle, Portion sizes in dietary assessment: issues and policy implications, Nutr. Rev 53 (1995) 149−158.

[499] L.R. Young, M. Nestle, Variation in perceptions of a medium' food portion: implications for dietary guidance, J. Am. Diet. Assoc. 98 (1998) 458−459.

[500] Y.S. Cypel, P.M. Guenther, G.J. Petot, Validity of portion-size measurement aids: a review, J. Am. Diet. Assoc. 97 (1997) 289−292.

[501] T. Hernandez, L. Wilder, D. Kuehn, K. Rubotzky, P.M. Veillon, S. Godwin, et al., Portion size estimation and expectation of accuracy, J. Food Compost. Anal. 19 (2006) S14−S21.

[502] E. Chambers, B. McGuire, S. Godwin, M. McDowell, F. Vecchio, Quantifying portion sizes for selected snack foods and beverages in 24-hour dietary recalls, Nutr. Res. 20 (2000) 315−326.

[503] F. Robinson, W. Morritz, P. McGuiness, A.F. Hackett, A study of the use of a photographic food atlas to estimate served and self-served portion sizes, J. Hum. Nutr. Diet. 10 (1997) 117−124.

[504] P.J. Robson, M.B. Livingstone, An evaluation of food photographs as a tool for quantifying food and nutrient intakes, Public Health Nutr 3 (2000) 183−192.

[505] C. Vereecken, S. Dohogne, M. Covents, L. Maes, How accurate are adolescents in portion-size estimation using the computer tool Young Adolescents' Nutrition Assessment on Computer (YANA-C)? Br. J. Nutr. 103 (2010) 1844−1850.

[506] E. Foster, J.N. Matthews, J. Lloyd, L. Marshall, J.C. Mathers, M. Nelson, et al., Children's estimates of food portion size: the development and evaluation of three portion size assessment tools for use with children, Br. J. Nutr. 99 (2008) 175−184.

[507] E. Foster, M. O'Keeffe, J.N. Matthews, J.C. Mathers, M. Nelson, K.L. Barton, et al., Children's estimates of food portion

size: the effect of timing of dietary interview on the accuracy of children's portion size estimates, Br. J. Nutr. 99 (2008) 185–190.

[508] M.L. Ovaskainen, M. Paturi, H. Reinivuo, M.L. Hannila, H. Sinkko, J. Lehtisalo, et al., Accuracy in the estimation of food servings against the portions in food photographs, Eur. J. Clin. Nutr. 62 (2008) 674–681.

[509] W. De Keyzer, I. Huybrechts, M. De Maeyer, M. Ocke, N. Slimani, P. van't Veer, et al., Food photographs in nutritional surveillance: errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption, Br. J. Nutr. 105 (2011) 1073–1083.

[510] T.E. Schap, B.L. Six, E.J. Delp, D.S. Ebert, D.A. Kerr, C.J. Boushey, Adolescents in the United States can identify familiar foods at the time of consumption and when prompted with an image 14 h postprandial, but poorly estimate portions, Public Health Nutr. 14 (2011) 1184–1191.

[511] M.M. Huizinga, A.J. Carlisle, K.L. Cavanaugh, D.L. Davis, R.P. Gregory, D.G. Schlundt, et al., Literacy, numeracy, and portion-size estimation skills, Am. J. Prev. Med. 36 (2009) 324–328.

[512] A.F. Smith, J.B. Jobe, D.J. Mingay, Question-induced cognitive biases in reports of dietary intake by college men and women, Health Psychol. 10 (1991) 244–251.

[513] L. Harnack, L. Steffen, D.K. Arnett, S. Gao, R.V. Luepker, Accuracy of estimation of large food portions, J. Am. Diet. Assoc. 104 (2004) 804–806.

[514] T. Thoradeniya, A. de Silva, C. Arambepola, S. Atukorala, P. Lanerolle, Portion size estimation aids for Asian foods, J. Hum. Nutr. Diet. 25 (2012) 497–504.

[515] Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey: Measuring Guides for the Dietary Recall Interview—2002 + , National Center for Health Statistics, Centers for Disease Control and Prevention. Available from <http://www.cdc.gov/nchs/nhanes/measuring_guides_dri/measuringguides02.htm>, 2010.

[516] Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey. 2002 + Measuring Guides: Food Model Booklet, National Center for Health Statistics, Centers for Disease Control and Prevention. Available from <http://www.cdc.gov/nchs/nhanes/measuring_guides_dri/2002/fmb.htm>, 2010.

[517] P. Lanerolle, T. Thoradeniya, A. de Silva, Food models for portion size estimation of Asian foods, J. Hum. Nutr. Diet. 26 (2013) 380–386.

[518] M.F. Bernal-Orozco, B. Vizmanos-Lamotte, N.P. Rodriguez-Rocha, G. Macedo-Ojeda, M. Orozco-Valerio, F. Roville-Sausse, et al., Validation of a Mexican food photograph album as a tool to visually estimate food amounts in adolescents, Br. J. Nutr. 109 (2013) 944–952.

[519] J.E. Bolland, J.A. Yuhas, T.W. Bolland, Estimation of food portion sizes: effectiveness of training, J. Am. Diet. Assoc. 88 (1988) 817–821.

[520] P.M. Howat, R. Mohan, C. Champagne, C. Monlezun, P. Wozniak, G.A. Bray, Validity and reliability of reported dietary intake data, J. Am. Diet. Assoc. 94 (1994) 169–173.

[521] J.L. Weber, A.M. Tinsley, L.B. Houtkooper, T.G. Lohman, Multimethod training increases portion-size estimation accuracy, J. Am. Diet. Assoc. 97 (1997) 176–179.

[522] J.E. Bolland, J.Y. Ward, T.W. Bolland, Improved accuracy of estimating food quantities up to 4 weeks after training, J. Am. Diet. Assoc. 90 (1990) 1402–14041407.

[523] E.M. Pao, Validation of food intake reporting by men, Human Nutrition Information Service, U.S. Department of Agriculture, Hyattsville, MD, 1987.

[524] B.M. Posner, C. Smigelski, A. Duggal, J.L. Morgan, J. Cobb, L. A. Cupples, Validation of two-dimensional models for estimation of portion size in nutrition research, J. Am. Diet. Assoc. 92 (1992) 738–741.

[525] J. Chae, I. Woo, S. Kim, R. Maciejewski, F. Zhu, E.J. Delp, et al., Volume estimation using food specific shape templates in mobile image-based dietary assessment, Proc. SPIE 7873 (2011) 78730K.

[526] M. Sun, Q. Liu, K. Schmidt, J. Yang, N. Yao, J.D. Fernstrom, et al., Determination of food portion size by image processing, Conf. Proc. IEEE Eng. Med. Biol. Soc. 2008 (2008) 871–874.

[527] W. Jia, H.C. Chen, Y. Yue, Z. Li, J. Fernstrom, Y. Bai, et al., Accuracy of food portion size estimation from digital pictures acquired by a chest-worn camera, Public Health Nutr 17 (2014) 1671–1681.

[528] C.D. Lee, J. Chae, T.E. Schap, D.A. Kerr, E.J. Delp, D.S. Ebert, et al., Comparison of known food weights with image-based portion-size automated estimation and adolescents' self-reported portion size, J. Diabetes Sci. Technol. 6 (2012) 428–434.

[529] S.F. Schakel, I.M. Buzzard, S.E. Gebhardt, Procedures for estimating nutrient values for food composition databases, J. Food Compost. Anal. 10 (1997) 102–114.

[530] G.R. Beecher, R.H. Matthews, Nutrient composition of foods, in: M.L. Brown (Ed.), Present Knowledge in Nutrition, International Life Sciences Institute, Nutrition Foundation, Washington, DC, 1990, pp. 430–439.

[531] Interagency Board for Nutrition Monitoring and Related Research, Third Report on Nutrition Monitoring in the United States, Volume 1, U.S. Government Printing Office, Washington, DC, 1995.

[532] K.K. Stewart, What are the variances of food composition data? J. Food Compost. Anal. 10 (1997) 89.

[533] B.P. Perloff, Analysis of dietary data, Am. J. Clin. Nutr. 50 (1989) 1128–1132.

[534] U.S. Department of Agriculture. USDA Nutrient Data Laboratory: Nutrient Data, Agricultural Research Service, U.S. Department of Agriculture. Available from <http://www.ars.usda.gov/main/site_main.htm?modecode = 80-40-05-25>, 2016.

[535] U.S. Department of Agriculture. USDA National Nutrient Database for Standard Reference, Release 28, Agricultural Research Service, U.S. Department of Agriculture. Available from <http://www.ars.usda.gov/Services/docs.htm?docid = 8964>, 2015.

[536] Food and Agricultural Organization of the United Nations. International Network of Food Data Systems (INFOODS): International Food Composition Table/Database Directory, Food and Agricultural Organization of the United Nations. Available from <http://www.fao.org/infoods/infoods/tables-and-databases/en/>, 2014.

[537] European Food Information Resource (EuroFIR). EuroFIR home page, European Food Information Resource. Available from <http://www.eurofir.org/>, 2016.

[538] P.M. Finglas, R. Berry, S. Astley, Assessing and improving the quality of food composition databases for nutrition and health

applications in Europe: the contribution of EuroFIR, Adv. Nutr. 5 (2014) 608s−614s.

[539] Steering Committee of the National Nutrient Databank Conference. International Nutrient Databank Directory, National Nutrient Database Conference. Available from <http://www.nutrientdataconf.org/indd/>, 2010.

[540] S.A. Smith, D.R. Campbell, P.J. Elmer, M.C. Martini, J.L. Slavin, J.D. Potter, The University of Minnesota Cancer Prevention Research Unit vegetable and fruit classification scheme (United States), Cancer Causes Control 6 (1995) 292−302.

[541] L.E. Cleveland, D.A. Cook, S.M. Krebs-Smith, J. Friday, Method for assessing food intakes in terms of servings based on food guidance, Am. J. Clin. Nutr. 65 (1997) 1254S−1263S.

[542] U.S. Department of Agriculture. USDA food patterns, Center for Nutrition Policy and Promotion, U. S. Department of Agriculture. Available from <http://www.cnpp.usda.gov/USDAFoodPatterns.htm>, 2012.

[543] U.S. Department of Agriculture. Food Patterns Equivalents Database, Agricultural Research Service, U.S. Department of Agriculture. Available from <http://www.ars.usda.gov/Services/docs.htm?docid = 23871>, 2014.

[544] University of Minnesota Nutrition Coordinating Center. Food and Nutrient Database, University of Minnesota. Available from <http://www.ncc.umn.edu/food-and-nutrient-database/>, 2016.

[545] J.K. Ahuja, L. Lemar, J.D. Goldman, A.J. Moshfegh, The impact of revising fats and oils data in the US Food and Nutrient Database for Dietary Studies, J. Food Compost. Anal. 22 (2009) S63−S67.

[546] A.J. Centi, M. Brown-Ramos, D.B. Haytowitz, S.L. Booth, Changes in the content and forms of vitamin K in processed foods, J. Food Compost. Anal. 41 (2015) 42−44.

[547] D.R. Jacobs Jr., P.J. Elmer, D. Gorder, Y. Hall, D. Moss, Comparison of nutrient calculation systems, Am. J. Epidemiol. 121 (1985) 580−592.

[548] R.D. Lee, D.C. Nieman, M. Rainwater, Comparison of eight microcomputer dietary analysis programs with the USDA Nutrient Data Base for Standard Reference, J. Am. Diet. Assoc. 95 (1995) 858−867.

[549] M.L. McCullough, N.M. Karanja, P.H. Lin, E. Obarzanek, K.M. Phillips, R.L. Laws, et al., Comparison of 4 nutrient databases with chemical composition data from the Dietary Approaches to Stop Hypertension trial. DASH Collaborative Research Group, J. Am. Diet. Assoc. 99 (1999) S45−S53.

[550] S. McNutt, T.P. Zimmerman, S.G. Hull, Development of food composition databases for food frequency questionnaires (FFQ), J. Food Compost. Anal. 21 (2008) S20−S26.

[551] G. Block, A.M. Hartman, C.M. Dresser, M.D. Carroll, J. Gannon, L. Gardner, A data-based approach to diet questionnaire design and testing, Am. J. Epidemiol. 124 (1986) 453−469.

[552] A.F. Subar, D. Midthune, M. Kulldorff, C.C. Brown, F.E. Thompson, V. Kipnis, et al., Evaluation of alternative approaches to assign nutrient values to food groups in food frequency questionnaires, Am. J. Epidemiol. 152 (2000) 279−286.

[553] A.R. Kristal, A.L. Shattuck, A.E. Williams, Current issues and concerns on the users of food composition data: food frequency questionnaires for diet intervention research. 17th National Nutrient Databank Conference Proceedings, June 7−10, 1992, Baltimore, MD, International Life Sciences Institute, Washington, DC, 1992, pp. 110−125.

[554] I.M. Buzzard, K.S. Price, R.A. Warren, Considerations for selecting nutrient calculation software: evaluation of the nutrient database, Am. J. Clin. Nutr. 54 (1991) 7−9.

[555] K.W. Dodd, P.M. Guenther, L.S. Freedman, A.F. Subar, V. Kipnis, D. Midthune, et al., Statistical methods for estimating usual intake of nutrients and foods: a review of the theory, J. Am. Diet. Assoc. 106 (2006) 1640−1650.

[556] Institute of Medicine, Dietary Reference Intakes: Applications in Dietary Planning, The National Academies Press, Washington, DC, 2003.

[557] S.M. Nusser, A.L. Carriquiry, K.W. Dodd, W.A. Fuller, A semi-parametric transformation approach to estimating usual daily intake distributions, J. Am. Stat. Assoc. 91 (1996) 1440−1449.

[558] P.M. Guenther, P.S. Kott, A.L. Carriquiry, Development of an approach for estimating usual nutrient intake distributions at the population level, J. Nutr. 127 (1997) 1106−1112.

[559] S.M. Nusser, W.A. Fuller, P.M. Guenther, Estimating usual dietary intake distributions: adjusting for measurement error and non-normality in 24-hour food intake data, in: L. Lyberg, P. Biemer, M. Collins, E. deLeeuw, C. Dippo, N. Schwartz, D. Trewin (Eds.), Survey Measurement and Process Quality, John Wiley & Sons, Inc, New York, NY, 1997, pp. 689−709.

[560] W.J. de Boer, H. van der Voet, B.G. Bokkers, M.I. Bakker, P.E. Boon, Comparison of two models for the estimation of usual intake addressing zero consumption and non-normality, Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess 26 (2009) 1433−1449.

[561] U. Harttig, J. Haubrock, S. Knuppel, H. Boeing, The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method, Eur. J. Clin. Nutr. 65 (2011) S87−S91.

[562] J.A. Tooze, V. Kipnis, D.W. Buckman, R.J. Carroll, L.S. Freedman, P.M. Guenther, et al., A mixed-effects model approach for estimating the distribution of usual intake of nutrients: the NCI method, Stat. Med. 29 (2010) 2857−2868.

[563] O.W. Souverein, A.L. Dekkers, A. Geelen, J. Haubrock, J.H. de Vries, M.C. Ocke, et al., Comparing four methods to estimate usual intake distributions, Eur. J. Clin. Nutr. 65 (2011) S92−101.

[564] National Cancer Institute. Measurement ERROR Webinar Series, Epidemiology and Genomics Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute. Available from <http://epi.grants.cancer.gov/events/measurement-error/>, 2016.