TAB 3

GUIDELINES

CHAPTER **1**

Dietary Assessment Methodology

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Contents

I. INTRODUCTION

This chapter is a revision of the similarly named chapter in the 2001 edition of this book [1], which itself was based on the ''Dietary Assessment Resource Manual'' [2] by Frances E. Thompson and Tim Byers, adapted with permission from the *Journal of Nutrition.* Dietary assessment encompasses food consumption at the national level (e.g., food supply and production), household level, and individual level. This review focuses only on individual-level food intake assessment. It is intended as a resource for those who wish to assess diet in a research study. 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. The intent of this chapter is to contribute to an understanding of various dietary assessment methods so that the most appropriate method for a particular need is chosen.

II. DIETARY ASSESSMENT METHODS

A. Dietary Records

For the dietary record approach, the respondent records the foods and beverages and the amounts of each consumed over one or more days. The amounts consumed may be measured, using a scale or household measures (such as cups, tablespoons), or estimated, using models, pictures, or no particular aid. Typically, if multiple days are recorded, they are consecutive, and no more than 3 or 4 days are included. Recording periods of more than 4 consecutive days are usually unsatisfactory, as reported intakes decrease [3] because of respondent fatigue. Theoretically, the information is recorded at the time of the eating occasion, but it need not be done on paper. Dictaphones, computer recording, and self-recording scales have been used [4–7] and hold special promise for low-literacy groups and other difficult-to-assess populations because of their ease of administration and potential accuracy, though tape recording has not been shown to be useful among school-aged children [8]. A recently developed prototype of a computer-administered instrument illustrates the potential benefits of technology, particularly for low-literacy groups: the respondent selects the food consumed and subsequently the appropriate portion size of the selected foods via food photographs on the computer screen [6]. Computerized programs for recording food intake may be delivered on the Internet [9], a CD-ROM [6], or on a hand-held personal digital assistant (PDA) [5, 10]. A PDA itself can be coupled with a camera that photographs foods selected [11]. When these programs are linked with appropriate databases (see Section V.D), the burden of coding data can be dramatically relieved. However, response problems, particularly accurate estimation of portion size, remain [10].

To complete a dietary record, the 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 by contact and review of 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. Someone other than the subject can also record dietary records. This is often the method used with children or people in institutions.

While intake data using dietary records are typically collected in an open-ended form, close-ended forms have also been developed [5, 12–15]. These forms consist of listings of food groups; the respondent indicates whether that food group has been consumed. Portion size can also be asked, either in an open-ended manner or in categories. In format, these "checklist" forms resemble the food frequency questionnaire (FFQ) (see Section II.C). Unlike FFQs, which generally query about intake over a specified time period such as the past year or month, they are filled out either concurrently with actual intake (for precoded records) or at the end of a day for that day's intake (daily recall).

The dietary record method has the potential for providing quantitatively accurate information on food consumed during the recording period [16]. Recording foods as they are consumed lessens the problem of omission and the foods are more fully described. Further, the measurement of amounts of food consumed at each occasion should provide more accurate portion sizes than if the respondents were recalling portion sizes of foods previously eaten.

A major disadvantage of the dietary record method is that it is subject to bias both in the selection of the sample and in the measurement of the diet. Dietary record keeping requires that respondents or respondent proxies be both motivated and literate (if done on paper), which can potentially limit use of the method in some population groups (e.g., those of low socioeconomic status, the poorly educated, recent immigrants, children, and some elderly groups). The requirements for cooperation in keeping records can limit the generalizability of the findings from the dietary records to the broader population from which the study sample was drawn. Research indicates that there is a significant increase in incomplete records 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 collected information in the earlier days [3]. Part of this decrease may occur because many respondents develop the practice of filling out the record at one time for a previous period.

When respondents record only once per day, the record method approaches the 24-hour recall in terms of respondents relying on memory rather than concurrent recording. More important, recording foods as they are being eaten can affect both the types of food chosen and the quantities consumed [17]. The knowledge that food requires recording and the demanding task of doing it, therefore, may alter the dietary behaviors the tool is intended to measure [18]. This effect is a weakness when the aim is to measure unaltered dietary behavior. However, when the aim is to enhance awareness of dietary behavior and change that behavior, as in some intervention studies, this effect can be seen as an advantage [19]. Recording, by itself, is an effective weight-loss technique [20]. Recent interest in "real time" assessment [21] has led to the development and testing of a dietary intake self-monitoring system delivered through a personal digital assistant that enables concurrent recording and immediate, automated feedback. A pilot study testing this approach found improved self-monitoring and adherence to dietary goals [19].

As is true with all quantitative dietary information, the information collected on dietary records 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 is often not recorded consistently from respondent to respondent.

These weaknesses may be less pronounced for the hybrid method of the "checklist" form, because checking off a food item may be easier than recording a complete description of the food, and the costs of data processing can be minimal, especially if the form is machine scannable. The checklist can be developed to assess particular "core foods," which contribute substantially to intakes of some nutrients. However, as the comprehensiveness of the nutrients to be assessed increases, the length of the form also increases and becomes more burdensome to complete at each eating occasion. The checklist method may be most appropriate in settings with limited diets or for assessment of a limited set of foods or nutrients.

Several studies indicate that reported energy and protein intakes on diet records for selected small samples of adults are underestimated in the range of 4% to 37% when compared to energy expenditure as measured by doubly-labeled water or protein intake as measured by urinary nitrogen [20, 22–34]. Because of these findings, the record is considered an imperfect gold standard. Underreporting on food records is probably a result of the combined effects of incomplete recording and the impact of the recording process on dietary choices leading to undereating [20, 31]. The highest levels of underreporting on food records have been found among individuals with higher body mass indexes (BMIs) [24, 26, 27, 35, 36], particularly women [24, 26, 27, 37–39]. This relationship has been found among elderly individuals also [40]. This effect, however, may arise, in part, because heavier individuals are more likely to be dieting on any given individual day [41]. Other research shows that demographic or psychological indices such as education, employment grade, social desirability, body image, or dietary restraint may also be important factors related to underreporting on diet records [24, 31, 38, 39, 42–44]. The research evidence for the psychosocial factors related to energy misreporting is reviewed in Mauer *et al.* [45]. A few studies suggest that low-energy reporters compared to non-low-energy reporters have intakes that are lower in absolute intake of most nutrients [36], higher in percentage of energy from protein [36, 39], and lower in percentage of energy as carbohydrate [36, 39, 46, 47] and in percentage of energy from fat [47]. Underreporters may also report lower intakes of desserts, sweet baked goods, butter, and alcoholic beverages [36, 47] but more grains, meats, salads, and vegetables [36].

Some approaches have been suggested to overcome the underreporting in the record approach. Some suggest enhanced training of respondents. A different approach is to incorporate psychosocial questions known to be related to underreporting in order to estimate the level of underreporting [45]. Another suggested approach is to calibrate dietary records to doubly-labeled water (DLW), a biological indicator of energy expenditure, including covariates of gender, weight, and height, to more accurately predict individuals' energy intakes [48]. Further research is needed to develop and test these and other ideas.

B. 24-Hour Dietary Recall

For 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 in the preceding day. The recall typically is conducted by interview, in person or by telephone [49, 50], either computer assisted [51] or using a paper-and-pencil form. Well-trained interviewers are crucial in administering a 24-hour recall because much of the dietary information is collected by asking probing questions. Ideally, interviewers would be dietitians with education in foods and nutrition; however, non-nutritionists who have been trained in the use of a standardized instrument can be effective. All 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 [52]. 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 instrument is the United States Department of Agriculture's (USDA) Automated Multiple Pass Method (AMPM) [51], and it is used in the U.S. National Health and Nutrition Examination Survey (NHANES), the only nationally representative dietary survey in the United States. In the AMPM, intake is reviewed more than once in an effort to retrieve forgotten eating occasions and foods. The process consists of (1) an initial "quick list," where the respondent reports all the foods and beverages consumed without interruption from the interviewer; (2) a forgotten foods list of 9 food categories commonly omitted in 24-hour recall reporting; (3) time and occasion, where the respondent reports the time each eating occasion began and names the occasion; (4) a detail pass, where probing questions ask for more detailed information about each food and the portion size, in addition to review of the eating occasions and times between the eating occasions; and (5) final review, where questions about any other item not already reported are asked [51]. Research at the USDA allowed development of the Food Model Booklet [53], a portion size booklet used in the NHANES to facilitate more accurate portion size estimation. A 24-hour recall interview using the multiple pass approach typically requires between 30 and 45 minutes.

A quality control system to minimize error and increase reliability of interviewing and coding 24-hour recalls is essential. Such a system should include a detailed protocol for administration, training, and retraining sessions for interviewers, duplicate collection and coding of some of the recalls throughout the study period, and the use of a computerized database system for nutrient analysis. A research study among girls evaluated the marginal gains in accuracy of the estimates of mean and variance with increasing levels of quality control [54]. The authors recommended that the extent of quality control procedures adopted for a particular study should be carefully considered in light of that study's desired accuracy and precision and its resource constraints.

There are many advantages to the 24-hour recall. An interviewer administers the tool and records the responses, so literacy of the respondent is not required. Because of the immediacy of the recall period, respondents are generally able to recall most of their dietary intakes. Because there is relatively little burden on the respondents, those who agree to give 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 the foods eaten by any population 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, so there is less potential for the assessment method to interfere with dietary behavior.

Computerized software systems allow direct coding of the foods reported during the interview. The potential benefits of automated software include substantial cost reductions for processing dietary data, less missing data, and greater standardization of interviews [55, 56]. However, a potential problem in direct coding of interview responses is the loss of the respondent's reported name and description of the food, in contrast to paper records of the interview, which are then available for later review and editing. If direct coding is used for the interview, methods for the interviewer to easily enter those foods not found in the system should be available, and these methods should be reinforced by interviewer training and quality control procedures.

Another technological advance in 24-hour dietary recall methodology is the increasing development of automated data collection systems [57–62]. These systems vary in the number of foods in their databases, the approach to asking about portion size, and their inclusion of probes regarding details of foods consumed and possible additions. One system, designed to assess heavy metal and pesticide use in children, has been developed for a hand-held device with wireless Internet access [61]. The National Cancer Institute (NCI) is currently developing a Web-based automated self-administered 24-hour dietary recall [62]. The goal is to create software that respondents can use to complete a dietary recall with the aid of multimedia visual cues, prompts, and animated characters, versus standard methods that require a trained interviewer. The system design relies on the most current USDA survey database [63] and includes many elements of the AMPM 24-hour interview developed by the USDA [64] and currently used in the NHANES. Respondents will be asked about portion sizes with the help of digital photographs depicting up to eight sizes. The instrument will be delivered via the Internet and will be available to researchers at a nominal cost.

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.F. Because most individuals' diets vary greatly from day to day, it is not appropriate to use data from a single 24-hour recall to characterize an individual's usual diet. Neither should a single day's intake, whether it is determined by a recall or food record, be used to estimate the proportion of the population that has adequate or inadequate diets (e.g., the proportion of individuals with less than 30% of energy from fat, or who are deficient in vitamin C intake) [65]. This is because the true distribution of usual diets is much narrower than is the distribution of daily diets (there is variation not only among people in usual diet but also in the day-to-day for each person). The principal use of a single 24-hour recall is to describe the average dietary intake of a group because the means are robust and unaffected by within-person variation. Multiple days of recalls or records can better assess the individual's usual intake and population distributions but require special statistical procedures designed for that purpose (see Section V.C).

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 biological markers. Numerous observational studies of the effectiveness of the 24-hour recall have been conducted with children (see Section IV.C). In some studies with adults, group mean nutrient estimates from 24-hour recalls have been found to be similar to observed intakes [3, 66], although respondents with lower observed intakes have tended to overreport, and those with higher observed intakes have tended to underreport their intakes [66]. 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 this controlled diet in women; underestimates of portion sizes accounted for much of the underreporting [67]. Similar to findings for food records, studies with biological markers such as doubly-labeled water and urinary nitrogen generally have found underreporting using 24-hour dietary recalls, for energy in the range of 3% to 26% [6, 22, 25, 31, 68–72] and for protein in the range of 11% to 28% [69, 72, 73]. However, underreporting is not always found. Some have found overreporting of energy from 24-hour dietary recalls compared to DLW in the proxy reports for young children [74]. One study found overreporting of protein from 13% to 25% depending on level of BMI [75]. 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.* reported that 24-hour recalls collected from Egyptian women were well within expected amounts [76]. Finally, energy adjustment has been found in many studies to reduce error. For example, for protein density (i.e., percentage energy from protein), 24-hour dietary recall reports in the large NCI-funded Observing Protein and Energy Nutrition (OPEN) study were in close agreement to the biomarkers-based measure [72]. Evaluation of the USDA AMPM in two small observational studies indicated good agreement in mean intakes of macronutrients among men [77] and among obese women [78] and some overreporting of mean energy and carbohydrate intakes among normal and overweight women [78]. In a small, highly selected group of normal-weight women in energy balance, mean intake of energy using AMPM agreed with energy expenditure measured by DLW [79]. A large DLW study using recalls collected with the AMPM is currently being analyzed.

In past national dietary surveys using multiple-pass methods, data suggested that underreporting may have affected up to 15% of all 24 hour recalls [80, 81]. 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 [80]. As was found for records, factors such as obesity, gender, 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 [31, 41, 42, 70, 80–84].

C. Food Frequency

The food frequency approach [85, 86] asks respondents to report their usual frequency of consumption of each food from a list of foods for a specific period of time. Information is collected on frequency and sometimes portion size, 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. To estimate relative or absolute nutrient intakes, many FFQs also incorporate 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.

Many FFQs are available, and many continue to be adapted and developed for different populations and different purposes. Among those evaluated and commonly used for U.S. adults are the Health Habits and History Questionnaire (HHHQ) or Block questionnaires [87–97], the Fred Hutchinson Cancer Research Center Food Frequency Questionnaire (a revised HHHQ) [98, 99], the Harvard University Food Frequency Questionnaires or Willett questionnaires [85, 95–97, 100, 101–107], and the NCI's Diet History Questionnaire [72, 97, 108, 109]. The latter was designed with an emphasis on cognitive ease for respondents [110–112]. Other instruments have been developed for specific populations. Two FFQs have been developed by researchers at the University of Arizona, the University of Arizona Food Frequency Questionnaire and the Southwest Food Frequency Questionnaire, to capture the diverse diets of Latinos and Native Americans [113–115]. Other investigators have developed FFQs for Hispanic adults [116, 117]. Investigators at the University of Hawaii have developed a questionnaire for assessing the diverse diets of Hawaiian, Japanese, Chinese, Filipino, and non-Hispanic white ethnic groups [118, 119]. This instrument was adapted for use in a multiethnic cohort study conducted in Hawaii and Los Angeles [120]. In Europe, a number of FFQs have been developed within Western European countries for the European Prospective Investigation into Cancer and Nutrition (EPIC) [30, 121–126]. In addition, abbreviated FFQs attempting to assess total diet have been developed composed of shorter lists of 40 to 60 line items from the original 100 or so items [127–131]. "Brief" FFQs that assess a limited number of dietary exposures are discussed in the next section. Because of the number of FFQs available, investigators need to carefully consider which best suits their research needs.

The appropriateness of the food list is crucial in the food frequency method [88]. The full variability of an individual's diet, which includes many 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 to report either a combined frequency for a particular food eaten both alone and in mixtures or separate frequencies for each food use (e.g., one could ask about beans eaten alone and in mixtures, or one could ask separate questions about refried beans, bean soups, beans in burritos). 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 both as beans and as a Mexican mixture). Often FFQs 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). In addition, when a single question is applied to a group of foods, 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 for the estimation of nutrient intakes for an assumed or reported portion size of each food queried. For example, the FFQ item of macaroni and cheese encompasses a wide variety of recipes with different nutrient compositions, yet the FFQ database must have a single nutrient composition profile. Several approaches are used to construct such a database [85]. A database 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) estimated. Values can also be calculated by gender and age. Dietary analyses 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 Hutchinson FFQs and are publicly available for the NCI FFQ.

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 to 60 minutes to complete. This raises concern about length and its effect on response rates. Though respondent burden is a factor in obtaining reasonable response rates for studies in general, a few studies have shown this not to be a decisive factor for FFQs [111, 132–136]. 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. The increasing use of optically scanned instruments has necessitated the use of closed-ended response categories forcing a loss in specificity [137].

Although the amounts consumed by individuals are considered an important component in estimating dietary intakes, for the FFQ instrument it is controversial as to whether or not portion size questions should be included. Frequency has been found to be a greater contributor than typical serving size to the variance in intake of most foods [138]; therefore, some prefer to use FFQs without the additional respondent burden of reporting serving sizes [85]. Others cite small improvements in the performance of FFQs that ask the respondents to report a usual serving size for each food [90, 91]. Some incorporate portion size and frequency into one question, asking how often a particular portion of the food is consumed [85]. Although some research has been conducted to determine the best ways to ask about portion size on FFQs [110, 139, 140], the marginal benefit of such information in a particular study may depend on the study objective and population characteristics.

Another design issue is the time frame about which intake is queried. Many instruments inquire about usual intakes over the past year [88, 101], but it is possible to ask about the past week or month [141] depending on specific research situations. Even when respondents are asked about intake over the past year, some studies indicate that the season in which the questionnaire is administered influences reporting over the entire year [142, 143].

Finally, analytical decisions are required in how food frequency data are processed. In research applications where there are no automated quality checks to assure 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, as some research indicates that respondents selectively omit answering questions about foods they seldom or never eat [144, 145]. Another approach is to assign the median value from those who did provide valid answers. One study compared these two approaches within a case-control setting and found that the two were equivalent in terms of introducing bias into the relative risk estimates [146].

Strengths of the FFQ approach are that it is inexpensive to administer and process and aims to estimate 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 resulting from 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, require 30 to 60 minutes to complete depending on the instrument and the respondent, and are either optically scanned paper versions or automated to be administered electronically [87, 98, 113, 147, 148]. Because the costs of data collection and processing and the respondent burden are typically much lower for FFQs than for multiple diet records or recalls, FFQs have become 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 [72, 109]. 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 [149]. 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 [150], but it is unclear as to whether or how this applies to nutrients and other food groups.

The serving size of foods consumed is difficult for respondents to evaluate and is thus problematic for all assessment instruments (see Section V.A). However, the inaccuracies involved in respondents attempting to estimate usual serving 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 [151].

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 [101, 152–156]. Although some FFQs seem to produce estimates of population average intakes that are reasonable [152], 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 [153]. FFQs are generally 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 [157–159]. For estimating relative risks, the degree of misclassification of subjects is more important than is the quantitative scale on which the ranking is made [160].

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. No such studies have ever been done. 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 as compared to the Willett FFQ for several fat components, mostly in the direction of underestimation by the FFQ [161]. The most practical approach to examining the concordance of food frequency responses and usual diet is to use multiple food recalls or records over a period as an indicator of usual diet. This approach has been used in many studies examining various FFQs (see [162] for register of such studies). In these studies, the correlations between the methods for most foods and nutrients are in the range of 0.4 to 0.7. However, recalls and records cannot be considered as accurate reference instruments as they themselves suffer from error that may be correlated with error in the FFQ and, in addition, may not represent the time period of interest. Biomarkers that do represent usual intake without bias are available for energy (doubly-labeled water) [163] and protein (urinary nitrogen) [164]. Validation studies of various FFQs using these biomarkers have found large underestimates of self-reported energy intake [25, 31, 34, 69, 71, 72] and some underestimation of protein intake [29, 30, 69, 72, 126, 165–168]. Correlations of FFQs and the biomarkers have ranged from 0.1 to 0.5 for energy [25, 69, 72] and from 0.2 to 0.7 for protein [29, 30, 69, 72, 126, 165–168]. One study showed that protein density (kcal of protein as a percentage of total kcal) was less problematic—a slight overestimation among women and similar estimates among men [72], and correlations of 0.3 to 0.4 [109]—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 [169–179]. 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 [109]. Furthermore, other analyses comparing relative risk estimation from FFQs to dietary records [180, 181] in prospective cohort studies indicate that observed relationships using an FFQ are severely attenuated, thereby obscuring associations that might exist. Accordingly, some epidemiologists have suggested that the error in FFQs is a serious enough problem that alternative means (such as food records) of collecting dietary data in large-scale prospective studies be considered [182, 183].

D. Brief Dietary Assessment Instruments

Many brief dietary assessment instruments 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 components might 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, no matter how crude, can also activate interest in the respondent to facilitate nutrition education. These brief instruments may, therefore, have utility in clinical settings or in situations where health promotion and health education are the goals. In the intervention setting, brief instruments focusing on specific aspects of a dietary intervention have also been used to track changes in diet, although there is concern that responses to questions of intake that directly evolve from intervention messages may be biased [184] and that these instruments lack sensitivity to detect change [185]. Brief instruments of specific dietary components such as fruits and vegetables are used often 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 [186] and the California Health Interview Survey [187] (see Section III.A). Brief instruments can be used to examine relationships between some specific aspects of diet and other exposures, as in the National Health Interview Survey [188]. Finally, some groups use short screeners to evaluate the effectiveness of policy initiatives [187].

Brief instruments can be simplified/targeted FFQs or questionnaires that focus on specific eating behaviors other than the frequency of consuming specific foods. Complete FFQs typically contain 100 or more food items to capture the range of foods contributing to the many nutrients in the diet. If an investigator is interested only in estimating the intake of a single nutrient or food group, however, then fewer foods need to be assessed. Often, only 15 to 30 foods might be required to account for most of the intake of a particular nutrient [189, 190].

Numerous short questionnaires using a food frequency approach have been developed and compared with multiple days of food records, dietary recalls, complete FFQs, or biological indicators of diet. Single-exposure abbreviated FFQs have been developed and tested for protein [191], calcium [90, 192–194], iron [195], isoflavones [196], phytoestrogens [197], soy foods [196, 198], folate [199–201], sugar snacks [202], heterocyclic aromatic amines [203], and alcohol [204, 205]. Much of the focus in brief instrument development has been on fruits and vegetables and fats.

Food frequency type instruments to measure fruit and vegetable consumption range from a single overall question to 45 or more individual questions [206–210]. An early seven-item tool developed by the NCI and private grantees for the NCI's 5 A Day for Better Health Program effort has been used widely in the United States [211–213]. The tool is similar to one used in CDC's Behavioral Risk Factor Surveillance System (BRFSS) [186, 214, 215]. Validation studies of the CDC and 5 A Day brief instruments to assess fruit and vegetable intake have suggested that, without portion size adjustments, they often underestimate actual intake [206, 215–217] (see also [211]). Using cognitive interviewing findings (see Section V.F), NCI has revised the tool, including adding portion size questions. Using the revised tool, some studies indicate improved performance [218] and utility in surveillance studies. However, its performance in community interventions was mixed; in six of eight site/gender comparisons, fruit and vegetable consumption was significantly overestimated relative to multiple 24-hour recalls [219]. More important, the screener indicated change in consumption in both men and women when none was seen with the 24-hour recalls [220].

A fat screener, originally developed by Block [221] and currently composed of 17 items [87], was designed to account for most of the intake of fat using information about sources of fat intake in the U.S. population. The fat screener was useful as an initial screen for high fat intake in the Women's Health Trial [221] and in the CDC's Behavioral Risk Factor and Surveillance System for nutritional surveillance [222]. However, the screener did not perform well among young, low-income Hispanic women [222], and it substantially underestimated percentage energy from fat and was only modestly correlated ($r = 0.36$) with multiple 24-hour recalls in a sample of medical students [223]. In samples of men participating in intervention trials, the screener was not as precise [185] or as sensitive [224] as complete FFQs, possibly because the foods were not selected to preserve between-person variability [185]. 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-fat ($\leq$30% energy from fat) diets [225], asks about frequency of intake and portion size of 20 individual foods, major food sources of fat and saturated fat in the U.S. diet. Its initial evaluation showed high correlations with food records [225]. In additional cross-sectional studies, the MEDFICTS underestimated percentage energy from fat; it was effective in identifying individuals with very high fat intakes, but it was not effective in identifying individuals with moderately high fat diets [226] or correctly identifying those individuals consuming low-fat diets [227]. 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 [228]. Other fat screeners have been developed to preserve the between-person variability of intake [229–231]. A 20-item screener developed and tested in the German site of the EPIC study correlated with a complete FFQ [229, 230]. A 16-item percentage energy from fat screener correlated 0.6 with 24-hour recalls in an older U.S. population [231]; however, its performance in intervention studies was variable [232].

Often, interventions are designed to target specific food preparation or consumption behaviors rather than frequency of consuming specific foods. Examples of such behaviors might be 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 [222, 233–239], and many have been found to correlate with fat intake estimated from other more detailed dietary instruments [240, 241] or with blood lipids [237, 242, 243]. In addition, some studies have found that changes in dietary behavior scores have correlated with changes in blood lipids [242, 244, 245]. The Kristal Food Habits Questionnaire, sometimes also called the Eating Behaviors Questionnaire, was originally developed in 1990 [246]. It measures five dimensions of fat-related behavior: avoid fat as a spread or flavoring, substitute low-fat foods, modify meats, replace high-fat foods with fruits and vegetables, and replace high-fat foods with lower-fat alternatives. The instrument has been updated and modified for use in different settings and populations [243, 247, 248]. A modification tested in African-American adolescent girls was correlated with multiple 24-hour dietary recalls [249]. In another modification developed for African-American women [250], a subset of 30 items from the *SisterTalk* Food Habits Questionnaire correlated with change in BMI as strongly as did the original 91 items [251].

Recognizing the utility of assessing a few dimensions of diet simultaneously, several multifactor short instruments have been developed and evaluated, many combining fruits and vegetables with fiber or fat components [252–257]. Others assess additional components of the diet. For example, Prime-Screen is composed of 18 FFQ items asking about the respondents' 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 (and seven supplement questions); the average correlation with nutrient estimates from a full FFQ was 0.6 [258]. The 5-Factor Screener used in the 2005 National Health Interview Survey Cancer Control Supplement assessed fruits and vegetables, fiber, added sugar, calcium, and dairy servings [259], and the dietary screener used in the 2005 California Health Interview Survey assessed fruits and vegetables and added sugar [260].

Some multicomponent behavioral questionnaires have also been developed. The Kristal Food Habits Questionnaire was expanded to not only measure the five fat factors (described above) but also to measure three factors related to fiber: consumption of cereals and grains, consumption of fruits and vegetables, and substitution of high-fiber for low-fiber foods [261]. This fat- and fiber-related eating behavior questionnaire correlated with food frequency measures of fat and fiber among participants from a health maintenance organization in Seattle, Washington [261]. Schlundt *et al.* have developed a 51-item Eating Behavior Patterns Questionnaire targeted at fat and fiber assessment in African-American women [262]. Newly incorporated in this questionnaire are 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 (REAP), composed of 27 items assessing consumption of whole grains, calcium-rich foods, fruits and vegetables, fats, sugary beverages and foods, sodium, and alcohol, correlated moderately with records and an FFQ [263].

Because the cognitive processes for answering food frequency–type questions can be complex, some attempts have been made to reduce respondent burden by asking questions that require only yes or no answers. Kristal *et al.* developed a questionnaire to assess total fat, saturated fat, fiber, and percent energy from fat; the questionnaire contains 44 food items for which respondents are asked whether they eat the items at a specified frequency. A simple index based on the number of yes responses was found to correlate well with diet as measured by 4-day records and with an FFQ assessing total diet [264]. This same yes-no approach to questioning for a food list has also been used as a modification of the 24-hour recall [265]. These ‘‘targeted’’ 24-hour recall instruments aim to assess particular foods, not the whole diet [266–269]. 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.

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 the goal is to estimate total intake, the estimates are not precise 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 in another time period. For example, behavioral questionnaires developed and tested in middle-class, middle-aged U.S. women [246] were found to perform very differently when applied to Canadian male manual laborers [270]; to a low-income, low-education adult Canadian population [271]; and to participants in a worksite intervention program in Nevada [272]. Investigators should carefully consider the needs of their study and their target population’s dietary patterns before choosing an off-the-shelf instrument designed to briefly measure either food frequency or specific dietary behaviors.

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 [273, 274]. 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 [275–278]. Some of these instruments characterize foods in 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 [277, 279]. 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 diet record [273, 274]. 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 has not often been exactly reproduced, because of the effort and expertise involved in capturing and coding the information if it is collected by an interviewer. However, many variations of the Burke method have been developed and used in a variety of settings [275–278, 280–283]. 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 [284, 285]. Some diet history instruments have been automated and adapted for self-administration, thus eliminating the need for an interviewer to ask the questions [277, 286]. Other diet histories have been automated but still continue to be administered by an interviewer [287]. 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 both about the usual foods 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 small bits throughout the day, rather than eat at defined meals). The approach, when conducted by interviewers, requires trained nutrition professionals.

The validity of diet history approaches is difficult to assess because we lack independent knowledge of the individual's usual long-term intake. Nutrient estimates from diet histories have often been found to be higher than nutrient estimates from tools that measure intakes over short periods, such as recalls or records [288–293]. However, results for these types of comparisons depend on both the approach used and study characteristics. Validation studies that estimate correlations between reference data from recalls, records, or observations and diet histories are limited and show correlations in ranges similar to those for FFQs [278, 292, 294]. There are few validations of diet history questionnaires using biological markers as a basis of comparison. One study showed that, on average, 12 adults completing a diet history underreported by 12% in comparison to energy expenditure (measured by doubly-labeled water) [295]; another showed that, in comparison to protein intake as measured by urinary nitrogen (UN), 64 respondents completing a diet history questionnaire underreported by 3% [296].

F. Blended Instruments

Better understanding of various instruments' strengths and weaknesses has led to creative blending of approaches, in hopes of maximizing the strengths of each instrument. For example, a record-assisted 24-hour dietary recall has been used in several studies with children [297, 298]. The child keeps notes of what she or he has eaten and then uses these notes as memory prompts in a later 24-hour dietary recall. Several researchers have combined elements of a 24-hour dietary recall and FFQ, often to assess specific dietary components. For example, in the assessment of fruits and vegetables, a limited set of questions is asked about yesterday's intake and is combined with usual frequency of consumption of common fruits and vegetables [299, 300]. Similarly, the Nutritionist Five Collection Form combines a 2-day dietary recall with food frequency questions [301]. Thompson *et al.* have combined information from a series of daily checklists (i.e., precoded records) with frequency reports from a food frequency instrument to form checklist-adjusted estimates of intake. In a validation study of this approach, validity improved for energy and protein, but it was unchanged for protein density [302].

One advance is the development of statistical methods that seek to better estimate usual intake of episodically consumed foods. A two-part statistical model uses information from two or more 24-hour recalls, allowing for the inclusion of daily frequency estimates derived from an FFQ, as well as any other potentially contributing characteristic (such as age, race/ethnicity), as covariates [303]. Frequency information contributes to the model by providing additional information about an individual's propensity to consume a food—information not available from only a few recalls. 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.C).

The development of these hybrid instruments in addition to developing new analytical techniques combining information from different assessment methods may hold great promise for furthering our ability to accurately assess diets. Table 1 summarizes the information related to the dietary assessment methods outlined in this section.

III. DIETARY ASSESSMENT IN SPECIFIC SITUATIONS

The choice of the most appropriate dietary assessment method for a specific research question requires careful 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 [158] the following: (1) Is information needed about foods, nutrients, other food constituents or specific dietary behaviors? (2) Is the average intake of a group or the intake of each individual needed? (3) Is absolute or relative intake needed? (4) What level of accuracy is needed? (5) What time period is of interest? (6) What are the research constraints in terms of money, time, staff, and respondent characteristics?

A. Cross-Sectional Surveys

One of the most common types of population-level studies is the simple cross-sectional survey, a set of measurements of a population at a particular point in time. When measurements are collected on a cross-section at two or more times, the data can be used for purposes of monitoring or surveillance. Data collected in cross-sectional surveys are used at the national, state, and local levels as the bases for assessment of risk of deficiency, toxicity, overconsumption, adherence to dietary guidelines and public health programs, and food and nutrition policy. These cross-sectional surveys assess food and nutrient intakes of individuals as well as

TABLE 1 Advantages and Disadvantages of Dietary Assessment Instruments

Instrument	Advantages	Disadvantages
Food record	1. Intake quantified 2. Could enhance self-monitoring for weight control or other behavior change 3. Does not require recall of foods eaten	1. High investigator cost 2. High respondent burden 3. Extensive respondent training and motivation required 4. Many days needed to capture individual's usual intake 5. Affects eating behavior 6. Intake often underreported 7. Reports of intake decrease with time 8. Attrition increases with number of daily records requested 9. May lead to nonrepresentative sample and subsequent nonresponse bias
24-hour dietary recall	1. Intake quantified 2. Appropriate for most populations, thus less potential for nonresponse bias 3. Relatively low respondent burden 4. Does not affect eating behavior	1. High investigator cost 2. Many days needed to capture individual's usual intake 3. Intake often underreported
Food frequency questionnaire	1. Usual individual intake asked 2. Information on total diet obtained 3. Low investigator cost 4. Does not affect eating behavior	1. Not quantifiably precise 2. Difficult cognitive task for respondent 3. Intake often misreported
Brief instruments	1. Usual individual intake often asked 2. Low investigator cost 3. Low respondent burden 4. Does not affect eating behavior	1. Not quantifiably precise 2. Difficult cognitive task for respondent 3. Assessment limited to small number of nutrients/ foods 4. Intake often misreported
Diet history	1. Usual individual intake asked 2. Information on total diet obtained 3. Information often available on foods consumed by meal 4. Can have low investigator cost 5. Does not affect eating behavior	1. Not quantifiably precise 2. Difficult cognitive task for respondent 3. Intake often misreported 4. Can have high investigator burden

intake distributions of populations (see Section V.C) at one point in time. To assess trends in intakes over time, it would be ideal for the data collection methods, sampling procedures, and food composition databases used in dietary surveillance to be similar from survey to survey. As a practical matter, however, this is difficult. The dietary assessment method used consistently over the years in national dietary surveillance is the interviewer-administered 24-hour dietary recall. However, recall methodology has changed over time based on cognitive research, the addition of multiple interviewing passes, standardization of probes, and automation of the interview [304]. Another issue that affects the assessment of trends over time is changes in the nutrient/food grouping databases and specification of default foods. Changes in the food supply are reflected in additions or subtractions to food databases, whereas changes in consumption trends lead to subsequent reassignment of default choices for some foods (e.g., type of milk or fat addition). Food composition databases, too, are modified over time because of true changes in food composition or improved analytic methods for particular nutrients. More recently, databases have included values for food groups. The first of these for a public use dataset was the Pyramid Servings Database, produced by the USDA [305]. This database is available in national dietary surveys conducted in 1994–1996, 1998, and 1999–2002 and translates quantities of all foods (disaggregating ingredients of mixed dishes at the commodity level) into servings of food groups consistent with the 2000 Dietary Guidelines for Americans [306]. This has recently been updated to the MyPyramid Equivalents Database [305] modified to reflect the recommendations in the 2005 Dietary Guidelines [307].

In the past, there were two major cross-sectional surveillance surveys, the NHANES and the Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the National Center for Health Statistics (NCHS) and the USDA, respectively [308–327]. Starting in 1999, these two surveys were merged into a single national dietary surveillance survey called What We Eat in America, NHANES [51]. The 24-hour dietary recalls are collected using USDA's AMPM and the data are analyzed and processed by the USDA. The 24-hour recalls in NHANES also query the intake of dietary supplements. In the NHANES 2003–2004 and 2005–2006, two 24-hour dietary recalls were conducted along with an extensive FFQ without portion size (called the Food Propensity Questionnaire or FPQ) [328]. Frequency data from the FPQ are intended to be used as covariates in a new model to assess usual dietary intakes [303] (see Section V.C). Information about the NHANES surveys is available on both the USDA and NCHS websites [329, 330].

The type of information required for a surveillance or monitoring system can vary. For some purposes, quantitative estimates of intake are needed, whereas for other purposes, only qualitative estimates of intake, like food frequency or behavioral indicators, are needed. There is a particular need to monitor dietary trends at the local level. To help provide local data, brief FFQs to assess fruit and vegetable intake developed by the CDC for telephone administration have been used periodically within BRFSS [186]. The California Department of Health, in its California Dietary Practices Survey, has assessed dietary practices since 1989 [331]. The California Health Interview Survey has assessed fruit and vegetable intake in 2001 and 2005 [187].

B. Case-Control Studies

A case-control study design classifies individuals with regard to disease status currently (as cases or controls) and relates this to past (retrospective) exposures. For dietary exposure, the period of interest could be either the recent past (e.g., the year before diagnosis) or the distant past (e.g., 10 years ago or in childhood). Because of the need for information about diet before the onset of disease, dietary assessment methods that focus on current behavior, such as the 24-hour recall, are not useful in retrospective studies. The food frequency and diet history methods are well suited for assessing past diet and are therefore the only good choices for case-control studies.

In any food frequency or diet history interview, the respondent is not asked to call up specific memories of each eating occasion but 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 period.

The validity of recalled diet from the distant past is difficult to assess, because definitive recovery biomarker information (e.g., DLW or UN), 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 diets from that earlier time [332, 333]. These studies have found that correlations between past and current reports about the past vary by nutrient and by food group [85], with higher correspondence for very frequently consumed and rarely consumed foods compared to that for moderately consumed foods [334]. Correspondence of retrospective diet reports with the diet as measured in the original study has usually been greater than correspondence with diet reported by subjects for the current (later) period. 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 simply consider current diet as a proxy for past diet. 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 [332, 335]. 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 [336, 337].

C. Prospective (Cohort) Studies

In the prospective study design, exposures of interest are assessed at baseline in a group (cohort) of people and disease outcomes occurring over time (prospectively) are then related to the baseline exposure levels. In prospective dietary studies, dietary status at baseline is measured and related to later incidence of disease. In studies of many chronic diseases, large numbers of individuals need to be followed for years before enough new cases with that disease accrue for statistical analyses. A broad assessment of diet is usually desirable in prospective studies, as 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 prospective study.

To relate diet at baseline to the eventual occurrence of disease, a measure of the usual intake of foods by study subjects is needed. Although a single 24-hour recall or a food record for a single day would not adequately characterize the usual diet of study subjects in a cohort study, such information could be later analyzed at the group level for contrasting the average dietary intakes of subsequent cases with those who did not acquire the disease. Multiple dietary recalls, records, diet histories, and food frequency methods have all been used effectively in prospective studies. Cost and logistic issues tend to favor food frequency methods, as many prospective studies require thousands of respondents. However, because of concern about significant measurement error and attenuation attributed to the FFQ [180, 181, 183, 338, 339], other approaches are being sought. One potential approach is the use of automated self-administered 24-hour recall instruments (see Section II.B). Another approach is collection of multiple days of food records at baseline, with later coding and analysis of records for those respondents selected for analysis, using a nested case-control design.

Even in large studies using FFQs, it is desirable to include multiple recalls or records in subsamples of the population (preferably before beginning the study) to construct or modify the food frequency instrument and to calibrate it (see Section V.G). Information on the foods consumed could be used to ensure that the questionnaire includes the major food sources of key nutrients, with reasonable portion sizes. Because the diets of individuals change over time, it is desirable to measure diet throughout the follow-up period rather than just at baseline. One study revealed that data from annual administrations of FFQs showed only small dietary changes over time and that repeat administrations more than 5 years apart would be acceptable to assess dietary change over time [340]. If diet is measured repeatedly over the years, repeated calibration is also desirable. Information from calibration studies can be used for three purposes: to give design information (e.g., the sample size needed [341]), to show how values from the food frequency tool (or a brief food list thus derived) relate to values from the recalls/records [156, 160], and to determine the degree of attenuation/measurement error in the estimates of association observed in the study (e.g., between diet and disease) [172, 173, 175, 177, 179, 342–344] (see Section V.G).

D. Intervention Studies

Intervention studies range from relatively small, highly controlled clinical studies of targeted participants to large trials of population groups. Intervention studies may use dietary assessment for two purposes: initial screening for inclusion (or exclusion) into the study and measurement of dietary changes resulting from an intervention. Not all intervention trials require initial screening. For those that do, screening can be performed using either detailed instruments or less burdensome instruments. For example, food frequency instruments have been used in the Women's Health Trial [221] and in the Women's Health Initiative Dietary Modification Trial [345] to identify groups with high fat intake.

Measurement of the effects of a dietary intervention requires a valid measure of diet before, during, and after the intervention period. In small, intense clinical studies, the expected intervention effect is usually relatively large, whereas in larger community dietary intervention trials, the expected intervention effect may be relatively small and thus difficult to detect. Some work has been done to examine the validity of methods to measure dietary change in individuals or in populations [248, 346–348]. In relatively small studies, dietary records, multiple 24-hour recalls, and diet history questionnaires have been used. Large intervention studies, because of resource constraints, usually rely on less precise measures of diet, including FFQs and brief instruments. However, these resource constraints may become less important as automated self-administered instruments become available. Measurement of specific dietary behaviors in addition to, or even in place of, dietary intake could be considered in intervention evaluations when the nature of the intervention involves education about specific behaviors. If, for instance, a community-wide campaign to choose low-fat dairy products were to be evaluated, food selection and shopping behaviors specific to choosing those items could be measured.

Intentional behavior change is a complex and sequential phenomenon, as has been shown for tobacco cessation [349]. A complex sequence of events may also lead to dietary change [350]. The effects of educational interventions might also be assessed by measuring knowledge, attitudes, beliefs, barriers, and perceptions of readiness for dietary change, although the reliability of these types of questions has not been well assessed.

Whether an intervention is targeting individuals or the entire population, repeated measures of diet among study subjects can reflect reporting bias in the direction of the change being promoted. Even though not intending to be deceptive, some respondents may tend to report what they think investigators want to hear. Social desirability bias and social approval bias can be measured and the resulting scales incorporated into intervention analyses. Behavioral questions and the food frequency method, because of their greater subjectivity, may be more susceptible to social desirability biases than is the 24-hour recall method [49, 184]. On the other hand, greater awareness of diet because of the intervention may enhance accuracy of report. Nonetheless, because self-reports of diet are subject to bias in the context of an intervention study, an independent assessment of dietary change should be considered. For example, food availability 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 [351]. Often, cooperation can be obtained from food retailers [352]. Because of the large number of food items, only a small number should be monitored, 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, for example, serum carotenoids [353] or serum cholesterol [354], in the population. Consistency of changes in self-reported diet and appropriate biomarkers provides further evidence for real changes in the diet. See Chapter 11 for a more in-depth

TABLE 2 Dietary Assessment in Different Study Situations

Study Situation	Methods Commonly Used
Cross-sectional/ surveillance	24-hour recall; FFQ; brief instruments
Case-control (retrospective)	FFQ; diet history
Cohort (prospective)	FFQ; diet history; 24-hour recall; record
Intervention	FFQ; brief instruments; 24-hour recall

discussion of evaluation of nutrition interventions and Chapter 12 for the use of biomarkers in intervention studies. A quick guide summarizing preferred dietary assessment methods based on study design is shown in Table 2.

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. For example, 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, comparability of reports by surrogates and subjects has been studied in hopes that surrogate information might be used interchangeably with information provided by subjects [355]. Common sense indicates that individuals who know most about a subject's lifestyle would make the best surrogate reporters. 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 [356–358], 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 other foods.

Although subjects reporting themselves in the extremes of the distribution are seldom reported by their surrogates in the opposite extreme, many subjects who report they are in an extreme are reported by their surrogates in the middle of the distribution [359]. This may limit the usefulness of surrogate information for analyses at the individual level that rely on proper ranking. Furthermore, there may be a substantial difference in the quality of surrogate reports between spouses of deceased subjects and spouses of surviving subjects [360]. Thus far, however, there is little evidence that dietary intakes are systematically overreported or underreported depending on case status of the subject [361–363]. 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 the higher frequency of missing data, inability to recruit surrogates for some number of cases, and reduced precision of dietary estimates.

B. Ethnic Populations

Special modifications are needed in the content of dietary assessment methods when the study population is composed of individuals whose cuisine or cooking practices are not mainstream [364]. 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 [365]. It is also necessary to examine the recipes and assumptions underlying the nutrient composition of certain ethnic foods. Very different foods may be called the same name, or similar foods may be called by different names [366]. 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, baseline recalls or records with accompanying interviews should be collected from individuals in the ethnic groups. These interviews should focus on all the kinds of food eaten and the ways in which foods are prepared in that culture. Recipes and alternative names of the same food should be collected, and interviewers should be familiarized with the results of these interviews. Recipes and food names that are relatively uniform should be included in the nutrient composition database. Even with these modifications, it may be preferable 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.

Use of FFQs developed for the majority population may be suboptimal for many individuals with ethnic eating patterns. Many members of ethnic groups consume both foods common in the mainstream culture and foods that are specific to their own ethnic group. A food list can be developed either by modifying an existing food list based on expert judgment of the diet of the target population or, preferably, by examining the frequency of reported foods in the population from a set of dietary records or recalls. FFQs for specific groups including Navajos [367], Chinese Americans [368], individuals in Northern India [369], Hispanics [117, 370], and Israelis [371] have been developed using these approaches.

Besides 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 [372]. 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 is illustrated for an elderly Puerto Rican population [373], for white and African-American adults in the Lower Mississippi Delta [374], and for the Hawaii–Los Angeles Multiethnic Cohort Study [120].

The performance of FFQs varies across ethnic groups [375]. Questionnaires aimed at allowing comparison of intakes across multiple cultures have been developed; however, studies done thus far indicate that there are validity differences among the various cultural groups [116, 120, 373, 376–378]. Understanding these validity differences is crucial to the appropriate interpretation of study results.

C. Children and Adolescents

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. Younger children are less able to recall, estimate, and cooperate in usual dietary assessment procedures, so much information by necessity has to be obtained by surrogate reporters. Adolescents, although more able to report, may be less interested in giving accurate reports. Baranowski and Domel have posited a cognitive model of how children report dietary information [379].

The literature about dietary assessment in children and adolescents has been reviewed [380–386]. The 24-hour dietary recall, food records (including precoded checklists [15]), dietary histories, food frequency instruments, brief instruments [193, 387, 388], and blended instruments, such as a record-assisted 24-hour dietary recall [297], have all been used to assess children's intakes. The use of direct observation of children's diets has also been used extensively, often as a reference method to compare with self-reported instruments [389]. As predicted from the model posited earlier, children's estimates of portion size had large errors [390], and children were found to be less able than adults to estimate portion sizes [391] (also see Section V.A).

For preschool-aged children, information is obtained from surrogates, usually the primary caretaker(s), who may typically be a parent or an external caregiver. If information can be 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 [392]. A ''consensus'' recall method, in which the child and parents report as a group on a 24-hour dietary recall, has been shown to give more accurate information than a recall from either parent alone [393]. Sobo and Rock [394] have described such interviews and suggested tips for interviewers to maximize data accuracy. For older children, 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, serving as a cue for the later 24-hour recall interview) has been developed and tested [297, 298]. However, for school-aged and adolescents, there is no consensus of which dietary assessment method is most accurate.

Adaptation of food frequency instruments originally developed for adults requires consideration of the instrument itself (food list, question wording and format, portion size categories) and the database for converting responses to nutrient intakes. Food frequency instruments have been especially developed and tested for use in child and adolescent populations [13, 395, 396]. Generally correlations between the criterion instrument and food frequency instruments have been lower in child and adolescent populations than in adult populations.

D. Elderly

Measuring diets among the elderly can, but does not necessarily, present special problems [397, 398]. Both recall and food frequency techniques are inappropriate if memory is impaired or if the use of medications impairs cognitive functioning, Similarly, self-administered tools may be inappropriate if physical disabilities including poor vision are present. Direct observation in institutional care facilities or shelf inventories for elders who live at home can be useful. Even when cognitive integrity is not impaired, other factors can affect the assessment of diet among the elderly. Because of the frequency of chronic illness in this age group, special diets (e.g., low sodium, low fat, high fiber) have often been recommended. Such recommendations could not only affect actual dietary intake but could also bias reporting, as individuals may report what they should

TABLE 3 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.
Elderly	Assess any special considerations, including memory, special diets, dentition, use of supplements, and so on, and adapt methods accordingly.

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 for foods that are prepared or consumed in different ways. Elderly individuals frequently take multiple types of nutritional supplements, which present special problems in dietary assessment (see Chapter 2). Because of the concern of malnutrition among the elderly, specific instruments to detect risk of malnutrition, such as the Nutrition Screening Initiative [399] and the Mini Nutritional Assessment [400], have been developed.

Adaptations of standard dietary assessment methods have been suggested and evaluated, including the use of memory strategies, prior notification of a dietary interview [401], combining methods [300], adapting existing instruments [402], and developing new approaches. Research suggests that under many circumstances the validity of dietary information collected from the elderly is comparable to that collected from younger adults [403].

The principles discussed in this section are summarized in Table 3.

V. SELECTED ISSUES IN DIETARY ASSESSMENT METHODS

A. Estimation of Portion Size

Research has shown that untrained individuals have difficulty estimating portion sizes of foods, both when examining displayed foods and when reporting about foods previously consumed [391, 404–415], and that children are worse than adults [391]. Further, respondents appear to be relatively insensitive to changes made in portion size amounts shown in reference categories asked on FFQs [416]. Portion sizes of foods that are commonly bought or consumed in defined units (e.g., bread by the slice, pieces of fruit, beverages in cans or bottles) may be more easily reported than amorphous foods (e.g., steak, lettuce, pasta) or poured liquids. Other studies indicate that small portion sizes tend to be overestimated and large portion sizes underestimated [406, 417].

Aids are commonly used to help respondents estimate portion size. NHANES, What We Eat in America, uses an extensive set of three-dimensional models for an initial in-person 24-hour dietary recall; respondents are then given a Food Model Booklet developed by the USDA [53] along with a limited number of three-dimensional models (such as measuring cups and spoons) for recalls collected by telephone. Studies that have compared three-dimensional food models to two-dimensional photographs have shown that there is little difference in the reporting accuracy between methods [390, 415, 418, 419]. The accuracy of reporting using either models or household measures can be improved with training [420–423], but the effects deteriorate with time [424].

B. Mode of Administration

For interviewer-administered instruments, one way that the costs of collecting dietary information may be reduced is to administer the instrument by telephone. Costs can be further reduced by use of self-administered questionnaires by mail. Both telephone and mail surveys are less invasive than are face-to-face interviews. The use of telephone surveys to collect dietary information has been reviewed [425]. Telephone surveys have higher response rates than do mail surveys [426] and have been used in a variety of public health research settings [427]. However, there is increasing concern about response rates in telephone surveys given the prevalence of telemarketing and technology, which allows for the screening of calls. Nevertheless, interviews by telephone can be substantially less expensive than face-to-face interviews. The difficulty of reporting serving sizes by telephone can be eased by mailing picture booklets or other portion size estimation aids to the participants before the interview.

Many studies have evaluated the comparability of data from telephone versus in-person 24-hour dietary 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 [50, 428–433], expected intakes [434], or observed intakes [435]. Accuracy of portion size estimates for known quantities of foods consumed assessed by telephone and by in-person interviews was examined and found to be similarly accurate [415, 436]. One study found comparability of telephone and in-person interviews among urban African-American women [437]. However, some segments of the population do not have telephones, and some persons will not answer their telephones under certain circumstances. In addition, an increasing proportion of the population has only wireless phones; this is particularly prevalent among young adults [438]. Therefore, it is important to consider sampling schemes that account for these concerns so that potential respondents without landline telephones are included [427].

For FFQs or brief instruments, self-administration is less costly than interviewer-administration. However, self-administration may be unfeasible for large portions of the population who have low literacy levels or limited motivation. Thus, selection bias is a potential problem.

Self-administered tools can be completed on paper or electronically. Various FFQs [147] and dietary history questionnaires [439] are available for completion on the computer. Web-administered dietary assessment with wireless phone and PDA technology is also an area of great potential. As this mode of administration becomes more prevalent, it will be important to examine the comparability with in-person and telephone-administered modes, as well as the potential for selection effects. One study in Sweden found a lower initial response rate to a Web questionnaire compared to a mailed printed questionnaire, but there was a greater compliance in answering follow-up questions with Web respondents [440].

C. Estimating Usual Intakes of Nutrients and Foods

Knowledge of the usual intakes of foods and nutrients are of interest to assess both individual intakes and population distributions. To assess risk of chronic disease for epidemiological research or in clinical settings, it is individual level data that are of interest. To assess the proportion of the population at risk for deficiency or toxicity, however, usual intake distributions are necessary. In theory, usual intake is defined as the long-run average intake of a food or nutrient. A major problem is that true usual intake is not observable.

Data from FFQs, 24-hour recalls, and records have all been used as surrogates to estimate usual intake. Dietary recalls are most often used in surveillance, and FFQs, which ask about usual intake over a specified time period, are primarily used in epidemiological research investigating diet and disease relationships. FFQs, however, are limited in their ability to estimate usual intake well and are known to contain a substantial amount of measurement error [72, 109]. Recalls or records, which also contain error, focus on short time periods but provide richer detail about types of foods and amounts consumed. Importantly, intakes reported for only a few days do not capture day-to-day variation in intakes, an important factor when attempting to estimate usual intakes. Although usual intake estimations can be improved with additional days of data collection, averaging intakes across a few days does not adequately represent usual intakes [441]. Thus, more sophisticated methods based on statistical modeling have evolved [442]. Without such methods, as many as 7 to 14 days of data collection might be necessary for most nutrients and food groups [443], a number that is impractical in most large-scale nutrition research.

When only a few days are used to represent usual intake distributions, the lack of information regarding within-person variation is considerable, leading to biased estimates. Distributions generated from averaging only a few days of data are generally substantially wider than true usual intakes, thereby overestimating the proportion of the population above or below a certain cut point. Statistical modeling mitigates some of the limitation of having only a few days of intake by analytically estimating and removing the effects of within-person variation in dietary intake [441]. The earliest efforts at statistical modeling were developed by the Institute of Medicine [444] and then extended by researchers at Iowa State University [445, 446]. Both of these methods work best for estimating usual intakes of nutrients, most of which are consumed nearly every day by most everyone. For foods or food groups that are more episodically consumed (e.g., dark green vegetables), there is a revised version of the modeling by Iowa State University [447]. The NCI recently developed a new usual intake model that is an improvement over previous statistical methods [303]. This method uses two 24-hour recalls to estimate intake of both nutrients and episodically consumed foods. Unlike previous methods, this model allows for covariates such as sex, age, race, or information from an FFQ to supplement the model. The use of frequency information from an FFQ as a covariate in a statistical model is novel. Such data may add important information about an individual's propensity to consume a food—information that is often missing with just a few dietary recalls [328]. A frequency instrument can substantially improve the power to detect relationships between dietary intakes and other variables. The amount of improvement depends on the specific food or nutrient in question and the population under study. Extensive frequency data were collected in 2003–2004 and 2005–2006 for use in estimating usual intakes (see Section III.A).

D. Choice of Nutrient/Food Database

When dietary data are to be converted to nutrient intake data, it is necessary to use a nutrient composition database. Typically, such a database includes the description of the food, a food code, and the nutrient composition per 100 grams of the food. The number of foods and nutrients included varies with the database.

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 [448].

In addition, accepted analytical methods are not yet available for some nutrients of interest [449], analytical quality of the information varies with nutrient [449, 450], and the variances or ranges of nutrient composition of individual foods is in most cases unknown [451]. 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.

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 [452]. USDA produces and maintains the "Nutrient Database for Standard Reference," which includes information on up to 140 food components for 7293 foods. Values for individual carotenoids, selected *trans*-fatty acids, individual sugars, and vitamin K have been incorporated into Release 19 of the Nutrient Database for Standard Reference (NDSR) [453]. In addition, information on about 50 traditional or subsistence foods from the American Indian/Alaska Native Foods Database have been added to this release. Interest in nutrients and food components potentially associated with diseases has led to development of databases for limited numbers of foods. These include databases for flavonoids, proanthocyanidins, choline, and fluoride [454]. Information regarding USDA's nutrient composition databases is available at the USDA's Nutrient Data Laboratory home page [455]. Another database, the USDA Food and Nutrient Database for Dietary Studies, is used for the analysis of survey data in NHANES [63]. It includes information describing each of the approximately 7000 foods, food portions and weights, and nutrient information (derived from the NDSR). The International Network of Food Data Systems (INFOODS) maintains an international directory of nutrient composition data [456]. The recent compilation of some databases throughout the world is found on its website [457].

Research on nutrients (or other dietary constituents) and foods is ongoing. Constant interest in updating current values and providing new values for a variety of dietary constituents remains a priority for researchers. In addition, in the United States, methods that relate dietary intake to dietary guidance have been developed [458, 459]. The 2005 MyPyramid Food Guidance System is based on the 2005 Dietary Guidelines for Americans [307] and produces estimates of servings for 30 components of MyPyramid guidance (e.g., dairy, fruits, vegetables) [460]. Each food not only has a nutrient profile but also has a MyPyramid profile. One limitation in all nutrient databases is the variability in the nutrient content of foods within a food category [461, 462] and the volatility of nutrient composition in the manufactured foods; these limitations are particularly problematic for estimating fatty acids. Depending on the level of detail queried on the dietary assessment instrument, the respondent's knowledge of specific brand names, and the specificity of a particular nutrient database, estimating accurate fatty acid intake can be problematic. For FFQs, collapsing foods into categories that might have highly variable nutrient contents compounds this problem.

Many other databases are available in the United States for use in analyzing records and recalls, but most are based fundamentally on the USDA database, often with added foods and specific brand names. One prominent such database in the United States is the Nutrition Data System for Research (NDS-R) developed by the Nutrition Coordinating Center (NCC) housed at the University of Minnesota [463]. This database includes information on 144 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 NDSR.

Estimates of nutrient intake from dietary recalls and records are often affected by the nutrient composition database that is used to process the data [464–466]. Any differences may be due to the number of food items in the database, the recency of nutrient data, 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. 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. 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. Another key consideration is how the database is maintained and supported.

Developing a nutrient database for an FFQ presents additional challenges as nutrient composition values need to be assigned for a food grouping instead of an individual food item. Various approaches which rely on 24-hour recall data, either from a national population sample or a sample similar to the target population, have been used [88, 112, 467]. Generally, individual food codes from 24-hour recall data are grouped into FFQ food groupings, and a composite nutrient profile for each food grouping is estimated based on the individual foods' relative consumption. Again, for this approach to be effective, the 24-hour data need to be connected to a trustworthy nutrient database.

E. Choice of Dietary Analysis Software

Computerized data processing requires creating a file that includes 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. Many computer 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 was made available in 2006 [457].

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 [468]. If precise nutrient information is required, it is important that the system is able to expand to incorporate information about newer foods in the marketplace and to integrate detailed information about food preparation (e.g., homemade stew) by processing recipe information. 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 automated food coding system used for the NHANES is the USDA's AMPM [56]. The AMPM is a network dietary coding system that provides online coding, recipe modification and development, data editing and management, and nutrient analysis of dietary data with multiple user access to manage the survey activities. It is available to government agencies and the general public only through special arrangement with USDA. A similar program is available in a commercial software program called the Food Intake Analysis System [469] available from the University of Texas.

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.

F. 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. Several investigators have discussed the need for and importance of such considerations in the assessment of diet [332, 379, 416, 470–472], and research using cognitive testing methods in dietary assessment has been reported [110, 218, 263, 279, 416, 473–478]. A thorough description of cognitive interviewing methods is found in Willis [479].

There is an important distinction between specific and generic memories of diet. Specific memory relies on particular memories about episodes of eating and drinking, whereas generic memory relies on general knowledge about the respondent's 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 over 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 [471].

What can the investigator do 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 dietary recall, foods that the respondent did not initially report 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 dietary 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 [332, 472]. 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 impact the social desirability of particular responses for foods seen as "good" or "bad." For example, the presence of other family members during the dietary interview may enhance social desirability bias, especially for certain foods like alcoholic beverages. An interview in a health setting such as a clinic may also enhance biases related to the social desirability of foods tied to compliance with dietary recommendations previously made for health reasons. 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.

G. Validation/Calibration Studies

It is important and desirable that any new dietary assessment method be validated or calibrated against other more established methods [176, 177, 179, 480]. Furthermore, even if an instrument has been evaluated, its proposed use in a different population may warrant additional validation research in that population. The purpose of such studies is to better understand how the method works in the particular research setting and to use that information to better interpret results from the overall study. Before a new FFQ or brief assessment questionnaire is used in the main study, for example, it should be evaluated in a validation/calibration study that compares the questionnaire to another dietary assessment method, for example, 24-hour dietary recalls or a more detailed FFQ, obtained from the same individuals, and, preferably, to biological markers such as DLW or UN. The NCI maintains a register of validation/calibration studies and publications on the Web [481].

Validation studies yield information about how well the new method is measuring what it is intended to measure, and calibration studies use the same information to relate (calibrate) the new method to a reference method using a regression model. Validation/calibration studies are challenging because of the difficulty and expense in collecting independent dietary information. Some researchers have used observational techniques to establish true dietary intake [83, 392, 482, 483]. Others have used laboratory measures, such as the 24-hour urine collection to measure protein, sodium, and potassium intakes and the DLW technique to measure energy expenditure [24–30, 70, 75, 126, 165, 166, 168, 484]. However, the high cost of this latter technique can make it impractical for most studies. The overall validity of energy intake estimates from the dietary assessment can be roughly checked by comparing weight data to reported energy intakes, in conjunction with use of equations to estimate basal energy expenditure [27, 36, 38, 39, 43, 46, 81, 82, 484–486] (also discussed in Chapter 4).

Because they are relatively expensive to conduct, validation/calibration studies are done on subsamples of the total study sample. However, the sample 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., two nonconsecutive 24-hour recalls on 100 people rather than four recalls on 50 people) can often help to increase precision without extra cost [487]. To the extent possible, the sample should be chosen randomly.

The resulting statistics, which quantify the relationship between the new method and the reference method, can be used for a variety of purposes. Because, in most cases, the reference method (usually records or recalls) is itself imperfect and subject to within-person error (day-to-day variability), measures such as correlation coefficients may underestimate the level of agreement with the actual usual intake. This phenomenon, referred to as "attenuation bias," can be corrected for using 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 [341, 344]. The corrected correlation coefficients also give guidance as to the sample size required in a study, as the less precise the diet measure, the more individuals will be needed to attain the desired statistical power [341]. The estimated regression relationship between the new method and the reference method can also be used to adjust the relationships between diet and outcome as assessed in the larger study [160]. For example, the mean amounts of foods or nutrients, and their distributions, as estimated by a brief method, can be adjusted according to the calibration study results [488]. In addition, methods to adjust estimates of relationships measured in studies (e.g., relative risk of disease for subjects with high nutrient intake compared to those with low intake) have been described [172, 173, 344, 489, 490]. Many of these adjustments require the assumption that the reference method is unbiased [172, 342]. There is much evidence, however, that, at least for some nutrients, the reported intakes from recalls and records are also biased in a manner correlated with the tool of interest (such as an FFQ) [109], violating this assumption. Violation of this assumption would lead to overestimates of validity. For these reasons, researchers have sometimes used as reference measures biomarkers such as UN that have been shown in feeding studies to be unbiased measures of intake. Currently, however, only a few such biomarkers are known. Another area in need of further study is the effect of measurement error in a multivariate context, as most research thus far has been limited to the effect on univariate relationships [175, 179, 491, 492].

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