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Methods and Tools for Dietary Intake Assessment in Individuals vs. Groups

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Introduction

Dietary intake is an important, modifiable determinant of health and longevity. Comprehensive reviews of the literature have consistently concluded that clear, causal links exist between food intake and major causes of morbidity and mortality, such as coronary heart disease, cancer, diabetes, and obesity.[1-3] In addition, undernutrition continues to be a substantial health problem in many countries.[4]

Given the importance of diet in human health, assessment of dietary intake plays a pivotal role in efforts to improve the health of individuals and populations throughout the world. Dietary intake data are used for three major purposes:

1. At the individual level, assessment of dietary intake is necessary for determining a person's dietary adequacy or risk, assessing adherence to recommended dietary patterns, and tailoring education and counseling efforts.
2. Dietary intake assessment is an integral part of research studies investigating how diet determines the health of individuals and populations. Etiologic studies assess dietary intake as an exposure for association with disease outcomes. Behavioral research assesses dietary intake (or change in intake) as an outcome in studies designed to develop and test strategies that encourage adoption of healthful eating patterns.
3. Finally, at the population level, assessment of dietary intake is necessary to identify national health priorities and develop public health dietary recommendations. These data are used to determine the success of public health interventions in improving dietary patterns and for identification of population subgroups at risk or in need of special assistance. Nutrition monitoring also serves a key role in food assistance programs, fortification initiatives, food safety evaluations, and food labeling programs.

It is clear that dietary assessment is a cornerstone of efforts to improve the health of individuals and groups. However, there are significant concerns about the accuracy and usefulness of self-reported dietary data. The challenges associated with assessing dietary intake are well known and have to do with day-to-day variation in intake, respondent reporting errors and biases, limitations of the assessment instruments, and error in food composition tables.[5] Several different assessment methods and tools have been developed to address these difficulties, and each method has different strengths and weaknesses with regard to the type and quality of data produced. In addition, there are significant differences among these assessment methods in practical matters of respondent burden and cost. Therefore it is necessary to carefully consider the specific objectives of the dietary assessment as a precursor to choosing the best or most appropriate method. Perhaps the first and most important question is whether the data will be used for assessing intake in individuals or groups.

Here we describe the three major types of dietary assessment methods: 1) food records and 24-hour dietary recalls, 2) food frequency questionnaires, and 3) brief assessment instruments. We summarize the scientific and practical advantages and disadvantages of each of these methods. Then we consider the use of these three dietary assessment methods for assessing diet in individuals versus groups; when they are used for determination of an individual's dietary adequacy for purposes of counseling, research studies of dietary intake and disease risk, and nutrition monitoring of populations.

Description of the Three Major Dietary Assessment Methods

Food Records and Dietary Recalls (Records/Recalls)

For many years, food records were considered the "gold standard" of dietary assessment methods. Food records require individuals to record everything consumed over a specified period of time, usually one to seven days. Respondents are typically asked to carry the record with them and to record foods as eaten. Some protocols require participants to weigh and/or measure foods before eating, while less stringent protocols use models and other aids to instruct respondents on estimating serving sizes. The food consumption information is entered into a specialized software program for calculation of nutrient intakes. This data entry step is a time-consuming task and requires trained data technicians or nutritionists.

A dietary recall is a 20 to 30 minute interview in which the respondent is asked to recall all foods and beverages consumed over the past 24 hours. These interviews can be conducted in person or by telephone. In some settings, the information is captured on paper forms and subsequently entered into the software program for nutrient analysis. However, ideally the interview will be conducted simultaneously with direct data entry into the software program. The record/recall analysis program provides specific prompts about foods, preparation methods, and portion sizes; therefore this protocol results in greatly increased standardization of the information received.

Advantages and Disadvantages of Records/Recalls

Both records and recalls provide the same type of data: detailed information on all foods and beverages consumed on specified days. In theory, a food record provides a "perfect" snapshot of intake. In practice, there are significant limitations associated with this method

for assessing food intake. The principal problems are the large respondent burden of recording food intake and the impact on usual food consumption caused by record keeping. Respondents may alter their normal food choices merely to simplify record keeping or because they are sensitized to food choices. The latter reason appears more likely among women,[6] restrained eaters,[7] obese respondents,[8] or participants in a dietary intervention.[9] Other sources of error by respondents include mistakes or omissions in describing foods and assessing portion sizes.

Unannounced, interviewer-administered 24-hour dietary recalls are often recommended because respondents cannot change what they ate retrospectively.[10] One major disadvantage of dietary recalls is that they rely on the respondent's memory and ability to estimate portion sizes. In addition, it cannot be verified that social desirability does not influence self-report of the previous day's intake. A noteworthy benefit of recalls is that they are appropriate for low literacy populations.

Both records and recalls are expensive and time-consuming. However, the major scientific issue with records/recalls concerns the issue of day-to-day variability in intake, which means that several days of records/recalls are required to characterize usual intake. Using data on variability in intake from food records completed by 194 participants in the Nurses Health Study, [11] the number of days needed to estimate the mean intakes for individuals within 10% of "true" means would be 57 days for fat, 117 days for vitamin C, and 67 days for calcium. For estimating food consumption for individuals, variability can be even greater. For example, the number of days needed to estimate the following foods within 10% of "true" means would be 55 days for white fish and 217 days for carrots. Unfortunately, research has shown that reported energy intake, nutrient intake, and recorded numbers of foods decreases with as few as four days of recording dietary intake.[12] These changes may reflect reduced accuracy and completeness of recording intake or actual changes in dietary intake to reduce the burden of recording intake. In either case, there are considerable limitations on the usefulness of this methodology for characterizing usual intake in individuals.

Food Frequency Questionnaires (FFQs)

FFQs were developed for conducting research on dietary intake and chronic diseases such as heart disease and cancer. Because these diseases develop over 10 or more years, the biologically relevant exposure is long-term diet consumed many years prior to disease diagnosis. Therefore, instruments that only capture data on short-term or current intake (i.e., food records or recalls) are generally of limited usefulness in nutritional epidemiology research.

FFQs are designed to capture standardized, quantitative data on current or past, long-term diet. Although these questionnaires vary, they usually include three sections: 1) adjustment questions, 2) the food list, and 3) summary questions. Adjustment questions assess the nutrient content of specific food items. For example, participants are asked what type of milk they usually drink and are given several options (e.g., whole, skim, soy), which saves space and reduces participant burden compared to asking for the frequency of consumption and usual portion sizes of many different types of milk. Adjustment questions also permit more refined analyses of fat intake by asking about food preparation practices (e.g., removing skin from chicken) and types of added fats (e.g., use of butter versus margarine on vegetables).

The main section of an FFQ consists of a food or food group list, with questions on usual frequency of intake and portion size. To allow for machine scanning of these forms, frequency responses are typically categorized from "never or less than once per month"

to "2+ per day" for foods and "6+ per day" for beverages. Portion sizes are often assessed by asking respondents to mark "small," "medium," or "large" in comparison to a given medium portion size. However, some questionnaires only ask about the frequency of intake of a "usual" portion size (e.g., 3 ounces of meat).

The food list in an FFQ is chosen to capture data on major sources of energy and nutrients in the population of interest, between-person variability in food intake, and specific scientific hypotheses. The choice of a food list is part data-driven and part scientific judgment. One data-based approach uses record/recall data to determine the major nutrient sources in the diet (i.e., the contribution of specific foods to the total population intake of nutrients). Information on food sources of nutrients in the American population have been published[13,14] but are often unavailable for specific population groups (e.g., Hispanics). However, a food is only informative if intake varies from person to person such that it discriminates between respondents. Therefore, another data-based approach to choosing the food list is to start with a extensive list of foods that is completed by a representative sample of the larger population. Stepwise regression analysis is performed where the dependent variable is the nutrient and the independent variable is frequency of consumption of foods.[15] In this process the computer algorithm ranks foods by the degree to which they explain the most between-person variance in nutrient intake, which is reflected in change in cumulative R^2. In addition to these two data-driven methods, items are often added to a questionnaire because of specific hypotheses (e.g., does consumption of soy foods reduce breast cancer risk).

A particularly challenging issue in FFQ food lists has to do with assessing intake of mixed dishes. For example, many FFQs ask about frequency of pizza consumption. However, from a nutrient perspective there is no accurate way to define "pizza." Depending on whether it is meat or vegetarian, thick or thin crust, tomato or pesto sauce, and so forth, pizza may be either low-fat and high-carbohydrate or extremely high-fat and high-protein. However, it is unreasonable to ask individuals to disaggregate their pizza into servings of breads, vegetables, meats, cheese, and added fats. Therefore FFQs typically strike an uneasy compromise between asking about some mixed dishes (e.g., pizza, hamburgers, tacos) while also asking the respondent to provide information on foods contained in their mixed dishes: "cheese, including cheese added to foods and in cooking." Unfortunately, asking about both "lasagna" and "cheese in cooking" presents the peril of double counting. There are little or no data to guide an investigator in making these judgments.

Finally, to save space and reduce respondent burden, similar foods are often grouped into a single line item (e.g., white bread, bagels, and pita bread). When grouping foods, important considerations include whether they are nutritionally similar enough to be grouped and whether the group will make cognitive sense to the respondent. For example, a food group composed of rice, macaroni, and cooked breakfast cereal may be nutritionally sensible. However, this question could be difficult to answer because it requires summing food consumption across different meal occasions.

Finally, FFQ summary questions that ask about usual intake of fruits and vegetables are often included in the questionnaire because the long lists of these foods needed to capture micronutrient intake can lead to overreporting of intake.[16]

Assessing the Reliability and Validity of Food Frequency Questionnaires

Because records and recalls are open-ended, they can (in theory) be applied in a standardized manner across populations with markedly different eating patterns. However, as noted above, FFQs are closed-ended forms with limited food lists. Because the food list varies from questionnaire to questionnaire, every FFQ will have different measurement characteristics. In addition, a questionnaire with appropriate foods and portion sizes for

one population group (e.g., older caucasian men) may be wholly inappropriate for another subgroup (e.g., teenage African-American females). Finally, given changes in the food supply over time, such as the introduction of specially manufactured low-fat foods, questionnaires can become obsolete. Therefore the measurement characteristics (i.e., reliability and validity) of an FFQ need to be assessed for each new questionnaire and each new population group assessed.

Reliability generally refers to reproducibility, or whether an instrument will measure an exposure (e.g., nutrient intake) in the same way twice on the same respondents. Validity, which is a higher standard, refers to the accuracy of an instrument. Generally a validity study compares a practical, epidemiologic instrument (e.g., an FFQ) with a more accurate but more burdensome method (e.g., dietary recalls).

Reliability and validity of an FFQ are typically investigated using measures of bias and precision. Bias is the degree to which the FFQ accurately assesses mean intakes in a group. Lack of bias is especially important when the goal is to measure absolute intakes for comparison to dietary recommendations or some other objective criteria. For example, when the aim is to estimate how close Americans are to meeting the dietary recommendation to eat five servings of fruits and vegetables per day, it is critical to know whether the assessment instrument used under- or overestimates fruit and/or vegetable intake. Precision concerns whether an FFQ accurately ranks individuals from low to high nutrient intakes, which is typically the information needed to assess associations of dietary intake with risk of disease. It is important to remember than an instrument can be reliable without being accurate. That is, it can yield the same nutrient estimates two times and be wrong (e.g., biased upward) both times. Alternatively, an instrument can be reliable and consistently yield an accurate group mean (e.g., unbiased), but have poor precision such that it does not accurately rank individuals in the group from low to high in nutrient intake.

A reliability study compares intake estimates from two administrations of the FFQ in the same group of respondents. If an instrument is reliable, the mean intake estimates should not vary substantially between the two administrations. In addition, correlation coefficients between nutrient intakes estimated from two administrations of the FFQ in the same group of respondents should be high, and are generally in the range of 0.6 to 0.7. Reliability is easy to measure and gives an upper bound as to the accuracy of an instrument. While a high reliability coefficient does not imply a high validity coefficient, a low reliability coefficient clearly means poor validity. That is, if an instrument cannot measure a stable phenomenon (such as usual nutrient intake) the same way twice, it clearly cannot be accurate.

In a validity study, bias is assessed by comparing the mean estimates from an FFQ to those from multiple days of records/recalls in the same respondents. This comparison allows us to determine whether nutrient intake estimates from an FFQ appear to be under- or overreported in comparison to the criterion measure. Precision is measured as the correlation coefficients between nutrient intake estimates from the FFQ in comparison to a criterion measure, and typically range from 0.4 to 0.6. However, lower correlation coefficients (<0.4) are not unusual for nutrients that are poorly estimated with an FFQ, such as energy.[17] In addition, inclusion of dietary supplement use will often improve correlation coefficients (>0.8) because supplement use may be more accurately assessed and/or because supplement doses can be extraordinarily high compared to dietary intake, and thereby markedly increase the variability in intake for a nutrient. Some studies also assess precision by ranking nutrient intake estimates, dividing them into categories (e.g., quartiles) and comparing these to similar categories calculated from another instrument. However classifying a continuous exposure into a small number of categories does not reduce the effects of measurement error, and therefore this analysis does not provide additional information above correlation coefficients.[18]

The theory behind these (so-called) validity studies is that the major sources of error associated with FFQs are independent of those associated with records and recalls, which avoids spuriously high estimates of validity resulting from correlated errors. The errors associated with FFQs are the limitations imposed by a fixed list of foods and the respondents' ability to report usual frequency of food consumption (and usual portion sizes) over a broad time frame. In contrast, diet records are open-ended, do not depend on memory, and permit measurement of portion sizes. Errors in food records result from coding errors and changes in eating habits while keeping the records. Error in recalls results from estimation of portion sizes, participant memory, and coding errors.

Nonetheless, it is apparent that there are correlated errors between FFQs and records or recalls. Social desirability could influence how participants record or recall food intake across all types of dietary assessment instruments.[6,9] Participant error in estimating portion sizes could bias recall and FFQ estimates of intake in similar ways. There are also correlated errors in nutrient databases. Finally, research using doubly-labeled water to determine energy requirements have demonstrated significant underreporting of energy intakes from food records that may vary by participant characteristics.[8] It is important to be aware of the limitations of records and recalls as criterion measures of dietary intake, and cautiously interpret results based on these measures.

A final note is that an FFQ cannot, in and of itself, be validated. Only individual nutrient intake estimates can be validated by comparison of a nutrient estimate from the FFQ to a more accurate measure.

Advantages and Disadvantages of Food Frequency Questionnaires

The major advantage of FFQs is that they attempt to assess usual, long-term diet; either current or in the past. In addition, they have relatively low respondent burden and are simple and inexpensive to analyze because they can be self-administered and are machine scannable. A disadvantage of these questionnaires is that respondents must estimate usual frequency of consumption of approximately 100 foods and the associated usual portion sizes. These types of questions (i.e., this cognitive task) can be exceedingly difficult for many respondents, as evidenced by the prevalence of energy estimates from FFQs well outside the realm of what is plausible.[19] For example, it is not unusual for respondents to report usual energy intakes that are less than 500 kcals per day or greater than 5000 kcals per day. In addition, the format of the questionnaire is not user-friendly. Because FFQs are machine scannable, respondents must indicate their responses by filling in circles in a food-by-frequency matrix similar to that used in standardized testing. Some population groups may be unfamiliar or uncomfortable with such data collection methods. As might be hypothesized, validity studies of FFQs suggest that these forms may be less valid in less educated respondents.[20]

Another major disadvantage of these questionnaires is related to the close-ended nature of the form. The limited food list will not be appropriate for all individuals in a population and as noted above, different forms have different measurement characteristics in different populations. Therefore data from different FFQs are not directly comparable, nor are data from the same FFQ used in different populations, or data from the same FFQ used at different points in time (because of changes in the food supply). Finally, dependent upon the food list chosen by the investigator, the validity of nutrient intake estimates will vary from nutrient to nutrient.

Brief Dietary Assessment Instruments

Comprehensive dietary assessments (records/recalls and FFQs) are not always necessary or practical, which has led to the development of a diverse collection of brief assessment

instruments. These include three general types: 1) ecologic-level measures such as food disappearance data or household food inventories, 2) short instruments that target a limited number of foods and/or nutrients, and 3) questionnaires that assess dietary behavior.

Ecologic-Level Measures

One well-known ecologic assessment of dietary intake is per capita food consumption estimated using national data on the total food supply. Publications from the Food and Agricultural Organization provide data on a country's total food supply from which non-consumption uses (such as exports and livestock feed) are subtracted, after which the total remaining food available can be divided by the population to obtain the per capita estimate of intake. These population intakes have been correlated with disease incidence across countries in provocative hypothesis-generating studies.[21-24]

Other ecologic measures, such as supermarket sale receipts,[25] have been developed and evaluated. Household food inventories are another example. In one study, the presence (in the house) of 15 high-fat foods was found to correlate with household members' dietary fat intake at 0.42 ($p<0.001$).[26] Individuals with ≤ 4 high-fat foods in their house had a mean of 32% energy from fat compared to 37% for those with ≥ 8 high-fat foods. Poor household food availability has also been shown to be significantly associated with greater individual-level measures of food insecurity.[27]

Targeted Instruments

Dietary assessment instruments that measure a limited number of foods and/or nutrients are most useful when the target food/nutrient is not distributed throughout the food supply. For example, dietary fat is widely distributed in dairy foods, meats, added fats, desserts, prepared foods, etc. Therefore, short instruments that attempt to estimate fat intake tend to be biased and imprecise.[28,29] Alternatively, intake of the isoflavones genestein and daidzain, which are largely limited to soy foods, can be captured with a relatively short instrument (15 foods).[30]

Behavioral Instruments

The development of diet behavioral instruments was motivated by problems with assessing dietary intervention effectiveness, particularly low-fat interventions. Traditional comprehensive instruments, such as records and FFQs, yield fairly imprecise estimates of fat intake that may not be sensitive to an intervention focused on changing participants' dietary behavior. One of the best known instruments of this type is the fat-related diet habits questionnaire.[31] This instrument was based on an anthropologic model that described low-fat dietary change as four types:

1. Avoiding high-fat foods (exclusion)
2. Altering available foods to make them lower in fat (modification)
3. Using new, specially formulated or processed, lower-fat foods instead of their higher-fat forms (substitution)
4. Using preparation techniques or food ingredients that replace the common higher-fat alternative (replacement)

Although originally developed for intervention assessment, the diet-habits questionnaire has since been used as a short assessment instrument in other research settings.[32,33]

Advantages and Disadvantage of Brief Assessment Instruments

The principal advantage of ecologic measures is that they are simple, inexpensive, nonintrusive, and objective measures of nutritional status. However these environmental indicators do not provide precise measures of individual intake.

Targeted questionnaires also tend to yield rather imprecise food and/or nutrient estimates. For example, short questionnaires for assessing fruit and vegetable intake have been extensively used in surveillance and intervention research. The typical approach uses two summary questions to capture consumption of most fruits and vegetables: "How often did you eat a serving of fruit (not including juices)?" and "How often did you eat a serving of vegetables (not including salad and potatoes)?," to which are added usual consumption of juice, salad, and potatoes.[34] Comparison of this brief measure with food records, food frequency estimates, and serum carotenoids indicates that this method yields particularly biased (underestimated) and imprecise measures of vegetable intake, likely because vegetables in mixed foods such as casseroles or sandwiches may be forgotten and unreported.[16]

The major advantage of the behavioral questionnaires is that they are short and simple (i.e., low respondent burden) and can be easily data-entered and scored. The disadvantage is that the diet "score" derived from these measures can be difficult to interpret because it is not comparable to nutrient or food intake measures. In addition, because these questionnaires have typically been "validated" in relation to records or recalls, which have many sources of error and bias, the degree to which they accurately reflect dietary intake is unknown.

Use of Dietary Assessment Methods in Individuals vs. Groups

Determination of an Individual's Dietary Adequacy for Purposes of Counseling

Records/Recalls

Records and recalls are used in clinical and counseling settings to assess dietary intake and are often used in a qualitative fashion. That is, respondents are asked to describe a usual day's intake and the nutritionist simply "eyeballs" the eating pattern for estimating dietary adequacy or risk, adherence to a prescribed diet, and/or areas for improving eating habits. The individualized nature of the interview can allow for probing and personalization of the feedback.

Whether these methods are used in a quantitative or qualitative manner, records and recalls can provide useful and understandable information to a respondent. The respondent can observe that the dietary recommendations are based directly on the food intake information provided and can use the advice to alter future food choices, food preparation techniques, or portion sizes. Therefore, on an individual level, records and recalls can serve an important teaching function. In addition, there is considerable literature indicating that the act of keeping records (i.e., self-monitoring) is a significant predictor of success in achieving weight loss or making other dietary changes.[29]

Food Frequency Questionnaires

FFQs tend to produce imprecise dietary intake estimates because of respondent error and inappropriate food lists. In addition, the data input (usual frequency of intake and portion sizes) and nutrient calculation algorithms are a black box to the respondent. Therefore the respondent cannot easily use this information to make more healthful food choices. For

these reasons, FFQs are not generally useful for assessing an individual's nutrient intake for purposes of counseling.

However, data on *food consumption* from FFQs has been used for individual feedback. For example, Kristal et al. developed computer programs for tailored feedback to participants in a self-help dietary intervention that used FFQ data to provide food-specific recommendations to reach nutritional goals (e.g., "if you use low-fat mayonnaise instead of regular mayonnaise you will cut your fat by 28 g per week").[35] Because the feedback provided to the participants is food based and taken directly from their responses (e.g., type of mayonnaise used and frequency consumed), this approach avoids the black box problems associated with using FFQs to estimate nutrient intake.

Brief Assessment Instruments

These instruments are diverse, and therefore it is difficult to generalize regarding their use. Ecologic measures are intended to be environmental indicators and therefore are generally not appropriate for individuals. However, it is clear that some simple targeted instruments can be very useful for individual counseling. For example, a rather short set of questions can likely assess usual fruit and vegetable consumption sufficiently for purposes of advising a respondent whether his/her intake appears to be adequate or inadequate.

Research Studies of Dietary Intake and Disease Risk

Records/Recalls

Records and recalls have limited usefulness in research studies of diet and disease risk for both scientific and practical reasons. Scientifically, records/recalls only assess current, short-term diet, and in most etiologic studies usual long-term (and often past) diet is the exposure of biologic significance. Practically, records and recalls are infeasible because of costs and respondent burden. However, records and recalls are often used in subsamples of the parent study for the following purposes:

1. FFQ reliability and validity substudies
2. Evaluating dietary interventions where the goal is to compare mean intakes in the intervention versus the control group
3. As a check of the main study assessment instrument (such as an FFQ)

Food Frequency Questionnaires

As noted above, the major advantage of an FFQ is that it attempts to assess the exposure of interest in most applications: usual dietary intake in an individual. The main use of these instruments is to rank study participants from low to high intake of many foods and nutrients for comparison (on the individual level) with disease risk. However, these questionnaires produce food and nutrient estimates containing considerable random error resulting from inadvertently marking the wrong frequency column, skipping questions, and failures in judgment. These errors introduce noise into nutrient estimates such that our ability to find the "signal," such as an association of dietary fat and breast cancer, is masked or attenuated (i.e., biased toward no association).

However, a more important concern in research studies is systematic error. Systematic error refers to under- or overreporting of intake across the population, and person-specific sources of bias. For example, studies indicate that obese women are more likely to underestimate dietary intake than normal-weight women.[8] Systematic error may result in either

null or spurious associations. Prentice used data from FFQs collected in a low-fat dietary intervention trial to simulate the effects of random and systematic error on an association of dietary fat and breast cancer, where the true relative risk (RR) was assumed to be 4.0.[36] Assuming only random error exists in the estimate of fat intake, the projected (i.e., observed) RR for fat and breast cancer would be 1.4. Assuming both random error and systematic error exists, the projected RR would be 1.1, similar to that reported in a recent meta-analysis on dietary fat and breast cancer.[37] Data on systematic error from biomarker studies, combined with these types of statistical simulations, clearly suggest that measures of self-reported dietary intake may not be adequate to detect many associations of diet with disease, even when a strong relationship exists. It is important to note that records/recalls are not exempt from these biases.

Finally, FFQs cannot provide detailed information on specific foods (e.g., brand names) or eating patterns (e.g., meals per day or consumption of breakfast) that may be important in some research studies.

Brief Assessment Instruments

Most brief instruments were developed for very specific research applications. The biggest concern when using a brief instrument is that it is often impossible to anticipate all the questions regarding diet that may become important by the end of a study. Therefore, the choice of a brief instrument limits future questions that can be addressed. Nonetheless, data collection for research purposes is a compromise between what is ideal and what is practical, and a comprehensive dietary assessment may not always be possible.

Nutrition Monitoring of Populations

Records/Recalls

Records and recalls have proven very useful for nutrition monitoring. A single day's intake can provide estimates of the average intake of large groups that are comparable to those obtained with more burdensome techniques.[38] Because these methods are open-ended, they are especially useful for assessing mean intake across population groups with markedly different eating patterns.

However, a single day's intake cannot be used to study distributions of dietary intake because on any one day, an individual's diet can be unusually high (e.g., a celebratory meal) or low (e.g., a sick day). These days are not representative of an individual's intake even though they may be perfectly recorded. This day-to-day variation in intake is random and does not bias the mean intake for a group, although this variability does result in an increased distribution of observed intake (i.e., a wide standard deviation). However, if multiple measures (per person) are collected on a subsample of the population, it is possible to obtain an estimate of the within- vs. between-person variance and calculate the "true" standard deviation around the mean for the population. This procedure allows the investigator to determine the percent of individuals above (or below) a specified cut-point.[15]

Although the use of records/recalls in nutrition monitoring appears straightforward, there is actual considerable subtlety about the data needed to address public health dietary objectives. For example, assume that a public health objective is to reduce total fat intake to less than or equal to 30% energy from fat. A critical clarification of this objective is whether:

1. The population mean intake should be 30% energy from fat, in which case approximately half of the group will have intakes exceeding that level, or

2. The entire population should have intakes less than or equal to 30% energy from fat, in which case the group mean will be several percentage points below 30%.

If the public health objective is the first goal listed, then nutrition monitoring can be appropriately performed with a single 24-hour record/recall for determination of mean intake in the population. Alternatively, if the public health objective is the second, then multiple records/recalls (per person) will need to be collected for assessment of intake distribution in the population to determine the proportion of individuals consuming more than 30% energy from fat.

Food Frequency Questionnaires

FFQs have proven most useful in nutritional epidemiologic studies when the objective is to rank individuals from low to high intake for a food or nutrient. However, as described above, FFQs are close-ended forms with limited food lists, and the accuracy of FFQs will vary considerably across groups with different eating patterns. Therefore when the goal is to assess mean intakes in population subgroups with markedly different dietary patterns, or to track changes in intake over long periods of time, the FFQ is not the instrument of choice.

Brief Assessment Instruments

The accuracy of several of these instruments is particularly sensitive to differences in dietary patterns across population groups. For example, the validity of a fat-related behavioral questionnaire depends entirely on knowledge of those dietary behaviors that influence fat intake. In populations with different dietary patterns, the instrument would be useless for assessment of fat intake. Overall, it is useful to remember that brief dietary assessment instruments are developed for very specific objectives and caution needs to be taken when applying them to other populations or using them for other purposes.

Summary

Much of what has been presented here is summarized in Tables 21.1 through 21.3. Specifically, Table 21.1 summarizes the major scientific and practical advantages and disadvantages of the major dietary assessment methods. Table 21.2 provides an overview of the issues regarding use of data from dietary intake assessment methods. Table 21.3 gives a summary of consideration regarding use of dietary intake assessment in individuals versus groups.

The use of sophisticated computerized technologies and internet accessibility has the potential to address many of the practical and logistic limitations of the major dietary intake assessment methods. For example, a computer screen could provide life-size pictures of foods to help respondents more accurately estimate serving sizes. A user-friendly computer-administered dietary recall could eliminate the costs associated with this method of collecting data. A touch-screen FFQ program, with algorithms for limiting questions to foods eaten with some minimal frequency, could eliminate the unfriendly format of the questionnaire and tailor the food list. Nonetheless, these practical advances will not eliminate the scientific problems inherent in dietary self-report. In particular, the

issues of systematic and person-specific biases in self-report can likely only by addressed by use of objective biomarkers for identification, quantification, and correction of random and systematic error.[39]

It is clear from this brief overview that choosing the appropriate dietary assessment method is a complex decision based on the specific objective, with an eye toward the competing demands of accuracy and practicality. There is no right or wrong approach, only the best possible measure given the specific objectives of the assessment. In spite of all the challenges and limitations of dietary assessment methods, these data will continue to serve an essential role in efforts to improve the health and longevity of individuals and groups.

TABLE 21.1

Summary of the Major Advantages and Disadvantages of Dietary Assessment Methods

Characteristics	Single Record/Recall	Multiple Record/Recalls per Person	Food Frequency Questionnaire (FFQ)	Brief Assessment Instruments
Brief Description	Detailed recording of everything consumed in one day	Multiple days (per person) of recording of everything consumed	Measure of usual intake determined from frequencies of consumption of about 100 foods (or food groups)	Diverse group of short tools developed to target limited number of foods, nutrients, and/or dietary behavior
Scientific Features				
Advantages	Open-ended format appropriate for all types of eating patterns Provides detailed information on foods consumed Provides data that are comparable across populations and time Recalls can't affect (past) food choices	(Same as single records/recalls) 3-4 days of records/recalls have been used to characterize usual intake in individuals	Captures data on usual, long-term intake Can be used retrospectively	Ideal for studies where comprehensive assessment is not needed Some are non-intrusive and therefore relatively objective Behavioral assessments may be more sensitive to dietary interventions than nutrient estimates
Disadvantages*	Can only capture information on current intake, and one day's intake does not characterize usual intake Records can change eating behavior Recalls depend on respondent memory	(Same as single records/recalls) Because of day to day variability in intake, even 3-4 days of intake only roughly approximates usual intake	Accurate reporting of usual intake of foods is very difficult for some respondents Limited food list will not be appropriate for all respondents Different questionnaires are needed for different populations and therefore do not produce comparable nutrient estimates	Typically provide fairly imprecise estimates of nutrient intakes Because of targeted nature of these instruments, future scientific questions on other foods or nutrients cannot be addressed
Practical Features				
Advantages	Recalls do not require literate respondents Because recalls are interviewer administered, data can be collected in a standardized way	(Same as single records/recalls)	Fairly low respondent burden Once developed, scannable FFQs are inexpensive and easy to analyze	Low respondent burden Usually simple and inexpensive to code and analyze
Disadvantages	Expensive to collect, code, and analyze	(Same as single records/recalls) Multiple records or recalls are extremely burdensome for participants	FFQ development costs are extremely high	

* All types of dietary self-report are subjective and are subject to under-reporting and person-specific biases associated with sex, obesity, social desirability, etc.

TABLE 21.2

Summary of the Issues Regarding Use of Data from Dietary Intake Assessment Methods

Data	Single Record/Recall	Multiple Record/Recalls per Person	Food Frequency Questionnaire (FFQ)	Brief Assessment Instruments
Appropriate use of data	To estimate absolute mean values for intakes of foods and nutrients Group means and standard deviations for comparison to other groups	As an approximation of usual intake in an individual if used with caution and recognition that there will be considerable attenuation of associations with other variables	Ranking individuals from low to high intakes for foods or nutrients	Ranking individuals from low to high intakes for the specific food or nutrient being targeted
Inappropriate use of data*	Ranking respondents from low to high intakes For determination of the percent of population above (or below) some cut-point		Estimation of absolute nutrient intakes for comparison to other questionnaires or populations Just because an FFQ has been "validated" does not mean that it assesses all nutrients with good, or equal, accuracy	Estimation of absolute intakes for nutrients
Data not available	These methods cannot be used to assess dietary intake in the past	(Same as single record/recall)	Eating pattern information (e.g., meals per day). Detailed information on foods consumed, such as brand names	(Same as FFQ)

* Because of considerable random and systematic error, no forms of dietary self-report data should be regarded as "truth."

TABLE 21.3

Summary of Considerations Regarding Use of Dietary Intake Assessment in Individuals vs. Groups

	Single Record/Recall	Multiple Record/Recalls per Person	Food Frequency Questionnaire (FFQ)	Brief Assessment Instruments
Individual Assessment				
Appropriate Use	Qualitative use in clinical setting Teaching tool regarding food composition For self-monitoring	(Same as single record/recall) 3-4 days can be used as an approximation of usual intake	To provide feedback regarding respondent consumption of a food vs. recommended intake	Targeted instrument may be appropriate for individual counseling for the food or nutrient being assessed
Inappropriate Use	As estimate of usual intake		Nutrient intake estimates too imprecise for individual counseling	Reliable estimate of absolute intakes
Research Studies				
Appropriate Use	For comparing mean intakes in control vs. intervention group As a check of FFQ mean intake estimates for a group	(Same as single record/recall) Validity substudies for comparison of nutrient intake estimates to FFQ	For ranking individuals from low to high intakes for determination of associations with disease risk	Where costs or logistic realities prohibit use of a comprehensive assessment instrument
Inappropriate Use	When characterization of usual, long-term diet is the exposure of interest	(Same as single record/recall) In study population where respondent burden will result in poor quality data	For estimation of absolute intakes When comparable data needed across markedly different populations	In cases where there is the potential for important, new research questions to emerge
Nutrition Monitoring of Populations				
Appropriate Use	Nutrition monitoring of group means, including trends analyses Descriptive data on population eating patterns For international comparisons of food and nutrient intake	(Same as single record/recall) 3-4 days can approximate usual intake in individuals		
Inappropriate Use	To determine percentage of population meeting a dietary recommendation or at risk		For estimation of absolute intakes For time trends analyses because changing food supply cam make questionnaires obsolete	To estimate absolute intakes

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