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Dietary Intake Assessment: Methods for Adults

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Introduction

There has been longstanding interest in assessing diets of individuals.[1,2] Early in the 20th century, nutritionists studied food and nutrient intakes in order to provide guidance in food selection,[3,4] to interpret clinical and laboratory findings,[5] and to establish dietary requirements.[6,7] Interest in dietary assessment was stimulated in the latter part of the century with the increasing evidence for the role of diet in promoting health and reducing chronic disease risk.[8-11]

Early investigators were concerned with many of the issues that continue to be important for dietary assessment:

1. Selecting appropriate methods for collecting dietary data[5,12-15]
2. Assessing the day-to-day variability of intakes by individuals[12,16,17]
3. Establishing procedures for data analysis[18-20]
4. Estimating food/food group and nutrient intake[5,21]

The following statement appears in the National Research Council's report on diet and chronic disease: "One of the most difficult tasks in nutrition research is documenting the actual or habitual food and nutrient intake of individuals or groups."[8] We should not be surprised that obtaining information about what individuals consume and analyzing for dietary components is a challenging undertaking. Food intake can be a complex behavior.[22] In any day, an individual may consume many different foods, at several eating occasions, both at home and away from home. Willingness and ability to report what is consumed can be influenced by social and environmental events and cognitive abilities.[23-25] Furthermore, food composition databases must continuously be updated to reflect an expanding food marketplace and an increasing number of dietary components associated with health.[26]

This section is organized to review the methods most commonly used to assess intakes by individuals. Attention is given to methodologic validity as well as to the current emphasis on food pattern analysis, dietary supplements, and functional foods.

Methods of Dietary Assessment

The common methods for assessing intakes by individuals are food records, recalls, and food frequencies/diet histories. There have been several reviews of dietary assessment methods, their appropriate uses, modes of administration, and sources of error.[1,27-31] Methods are generally characterized either by the reference period in which respondents are asked to provide information (i.e., retrospective and prospective methods)[31] or by the time frame for which data are collected (i.e., quantitative daily and food frequency methods).[27,28,30]

There is no single optimal dietary assessment method. The objectives of an assessment should be used as a guide in selecting the most appropriate method. Some 30 years ago, Christakis advised that the assessment method selected should be no more detailed, no more cumbersome, and no more expensive than necessary.[32] This advice is still sound.[31] Assessment protocols, regardless of method, may need to provide highly quantitative and detailed data on food consumption. This would be the case for research studies such as clinical trials.[33] More qualitative data is likely to be appropriate when food intake information is used for dietary guidance and counseling.[34]

Food Record

Food records, also known as food diaries, provide a prospective account of foods and beverages consumed in a defined period of time. Generally, records are kept for brief time periods (one to seven days),[28] but they have been kept for up to a month[35] and even a year.[36] To be representative of usual intake, multiple days of records are needed.[27,37]

Food records may be used to meet a variety of objectives. Records are useful for detecting imbalances in food intake and making dietary change recommendations.[38] They are used as self-management tools in weight loss interventions and may be valuable in predicting successful weight loss.[39] Food records have been used extensively to calibrate other dietary assessment methods.[40-45] Records are also useful for documenting compliance of an individual's food intake with a feeding protocol in studies where adherence to a specific diet regimen is important.[46] Intervention studies may use food records to document effectiveness.[47-49]

Food portions may be either weighed or estimated depending on the subjects and the purpose(s) of the assessment.[50] While weighing foods will increase the accuracy of the portion size recorded, it can also increase respondent burden. Sophisticated scales that do not disclose food weights are available, decreasing respondent recording burden[51] but increasing cost. A variety of portion size aids, listed in Table 19.1, are available when portion sizes are to be estimated.

While records are usually kept by respondents, they may also be kept by observers. When food intake is recorded by observation, trained personnel visually estimate dietary intake.[52,53] Observation is particularly useful when circumstances preclude self-reporting of food intake. Thus, observation has been used in assessing intake of nursing home residents. The Omnibus Budget Reconciliation Act[54] requires that all Medicare and Medicaid certified nursing facilities implement a standardized comprehensive assessment, including a measure of nutrient intake, for all residents. Observers visually estimate the portion of served items consumed (i.e., from all to none) by a resident.[55]

When using food records, consideration should be given to the record forms to be used as well as instructions and training for subjects, particularly regarding portion size. Instructions should include guidance on completing the record form as well as directives encouraging subjects to record foods at the time of consumption and not to alter normal eating patterns. Table 19.2 provides sample instructions for the administration of a food record.

TABLE 19.1

Tools for Portion Size Estimation

Type	Examples
Household measures	Measuring cups and spoons[161]
	Rulers[161]
Food models	Food replicas[165]
	Graduated food models[166]
	Thickness sticks[161]
Pictures	2-Dimensional portion shape drawings[124,161]
	Portion photos of popular foods[167]
	Portion drawings of popular foods[161]
Food labels	Nutrition facts label
	Food package weights

TABLE 19.2

Sample Instructions for the Administration of a Food Record

To help us do the best analysis of your food intake, please follow these instructions.

Maintain Your Usual Eating Pattern. Try not to modify your food intake because you are keeping a record.
Record Everything You Eat or Drink. Be sure to include all snacks and drinks. Also include any vitamin or mineral supplements and the dosage for each day.
Write Foods Down As Soon As You Eat Them. Three daily record pages are provided for each day; however, you may not need to use all three. Try to write clearly.

Details are Important!

Completing the food record form

Date. Please record the date at the top of each form.
Name. Please write your name in the space at the top of the form.
Time of Day. Record the time of the day you ate each meal, including AM or PM.
Meal/Where Prepared? Record the name of the meal eaten (i.e., breakfast, lunch, dinner, supper, or snack) and where the meal was prepared (i.e., at home, at a restaurant).
Food Item. Write the name of each food item eaten.
Description/Preparation. Include information on how each food was prepared.
Amount. Record the amount of each food either by using the poster provided or common household measures.

After records have been completed, they should be reviewed to ensure completion. If reviewed with the subject, probing questions may be used to clear up ambiguities and ensure the completeness of the record. This is termed interviewer-assisted food records. When data from food records are compiled and analyzed, records will need to be coded using a standard method.

As subject burden can be high for food records, participant willingness and abilities are considerations when using this method. Literacy is required for completion of records; therefore, the method may not be appropriate for all individuals. The act of keeping food records can affect dietary intake,[56,57] which may be critical for estimates of usual intake. Cost is an additional consideration, as reviewing records for completeness, data entry, and data analysis can be expensive.[31]

Recall

Dietary recall provides a retrospective record of intake over a defined time period. While dietary recall may be for any length of time, this method is almost always administered to cover a 24-hour time period and is generally termed the 24-hour recall.[30] Data can be collected either for the previous day or for the 24 hours preceding the interview. To estimate the usual intake of individuals, multiple recalls are needed, preferably on random, nonconsecutive days.[36,58] Typically, an individual is asked to recall all foods eaten during the reference time period, describe the foods, and estimate the quantities consumed.

The 24-hour recall has become a favored way of collecting dietary data,[33,47,59] as recalls can be administered easily and quickly with low respondent burden. Depending on the objectives of the recall, the amount and depth of information collected will vary. This method is becoming the gold standard, particularly as methodological improvements[60-62] and technological capabilities[63,64] increase validity. With the emergence of technological aids in dietary assessment, it is becoming more common for interviewers to collect intake data using interactive software, entering intake data directly into a computer as it is collected.

Recalls may be obtained either in person or by telephone-administered interview. Because recalls by telephone interview have been shown to be practical, valid, and cost-effective,[63-68] they are becoming an increasingly popular mode of data collection, especially for research purposes.

Prior to conducting recalls, training of interviewers is important. This is particularly relevant when more quantitative data are required, increasing the need to use multiple pass and probing techniques. Figure 19.1 provides a sample probing sequence to elicit detailed information regarding one specific food (i.e., macaroni and cheese). The complexity of this probing sequence exemplifies the potentially complex nature of probing questions and the need for good interviewer training. More qualitative food intake data can be achieved with more limited questions.

The 24-hour recall has been criticized because of accuracy related to portion size estimation and subject memory. Portion size estimation aids are available to facilitate quantity estimation (Table 19.1). While 24-hour recalls are not designed to affect the "encoding" of food information, they can incorporate strategies to facilitate memory retrieval. Those strategies include standardized data collection protocols, structured probes to ensure standardized collection, and interactive interview systems.[29,47] The multiple pass technique, which will be discussed later in this section, has also been designed to facilitate memory retrieval.

Food Frequency Questionnaire

Food frequency questionnaires (FFQs) are designed to obtain information about usual food consumption patterns. They provide estimates on intake over a specified time period, ranging from as little as a week[69] to as much as one year.[70] FFQs consist of a list of foods and frequency-of-use response categories. Questionnaires may also include portion size response categories. Food lists may be extensive in order to provide estimates of total intake or they may be focused on foods, groups of foods, or nutrients. Several nutrient specific FFQs have been developed which allow for the examination of selected nutrients such as fat,[71] vitamin A,[72] and vitamin B_6.[73] While not necessarily appropriate for identifying precise nutrient intake, these instruments can provide a rapid, cost-effective way to estimate an individual's usual intake.[74]

Questionnaires may be abbreviated when used to screen for nutritional risk. Screening instruments are typically brief, self-administered, and can be scored quickly, providing an efficient way to monitor eating patterns of individuals. Examples of screening tools include the instruments developed as part of the Nutrition Screening Initiative, which were designed to identify older adults who may need nutrition services and to provide diag-

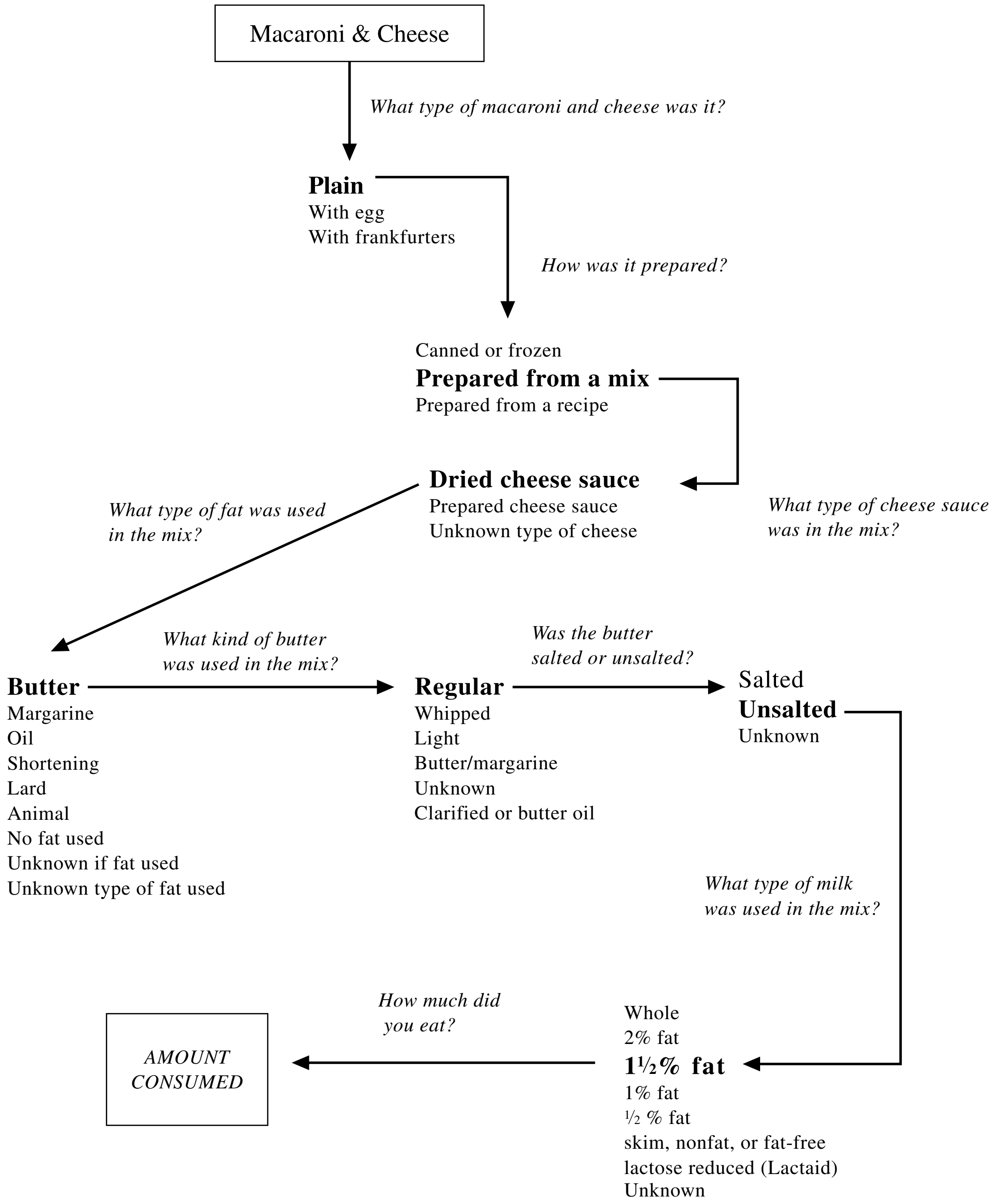

FIGURE 19.1
A sample probing scheme. This scheme could be used with recalls to elicit more information from a respondent who consumed macaroni and cheese. Bold print indicates respondent's reply. Probing questions, which are specific for each response, are italicized. (Adapted from Nutrition Data System for Research [NDS-R] software, developed by the Nutrition Coordinating Center [NCC], University of Minnesota, Minneapolis, MN.)

nostic information on nutrition status.[75,76] Very abbreviated instruments may not be valid representations of true intake.[77]

Creating a food frequency questionnaire is an intensive process,[78] thus, there is heavy reliance on instruments that have already been developed. Validity is a critical issue and is generally determined by calibration with other assessment methods.[73,79-84] When using an FFQ, it is important to ensure that the questionnaire is valid for use in the population of interest, as the performance of an instrument may vary between subgroups. Questionnaires have been validated in specific populations such as adolescents,[85] pregnant women,[42] and low-income black women.[86]

Several cognitive issues could compromise the validity of an FFQ. Subjects may have difficulty recalling foods consumed over a lengthy time period. Additionally, participants may need to perform arithmetic computations to average usual consumption of foods to fit into the response categories for consumption frequency. The cognitive demands of the FFQ may be reduced by a new variation in questionnaire administration, termed the picture sort approach, in which participants sort food cards into categories.[87,88]

While FFQs generally provide qualitative data, if portion size estimation is included on the questionnaire, semi-quantitative information can be deduced from these instruments. In some cases, inclusion of portion size may yield only small differences in data as compared to FFQs analyzed using only medium portions.[89]

Diet History

Food frequency questionnaires are sometimes referred to as diet histories. The classic diet history method was designed to estimate an individual's usual intake over a relatively long period of time. Originally developed by Burke,[90] the method consists of several components, including a 24-hour recall and questions about usual eating patterns, a cross-check questionnaire with a list of foods and questions about likes, dislikes, and usages, and a three-day food record. This method is not used commonly today. Administration requires a highly trained dietitian and can be time consuming.

Summary

Several methods have been listed which can be used to assess the usual dietary intake of adults. Well-designed quality control procedures are particularly important in research studies to ensure consistency of data across time and subjects.[33] Additionally, the advantages and disadvantages of data collection modes (i.e., self- or interviewer-completed) should be considered (See Table 19.3). The success of any assessment method is based upon a partnership between the individual respondent and the assessment staff. Care should be taken to ensure the appropriateness of the method and the level of detail collected. Respecting participants' abilities and ensuring that their dignity is not compromised is salient in establishing a successful partnership.

Issues Affecting Validity

In his address at the First International Conference on Dietary Assessment Methods, Beaton stated, "In the past decade there has been a great deal published about the errors

TABLE 19.3

Self-Completed and Interviewer-Completed Data Collection

Collection Mode	Advantages	Disadvantages
Self	Interviewer training not needed Sense of privacy Data collection time may be reduced	Response rate may be low Respondent burden may be high Tasks may be misinterpreted Respondent training needed for more complete data Data preparation and entry time may be high
Interviewer by phone	Good Response rate Opportunities for probing Low respondent burden Relatively quick Interviewer anonymity	Contact times may be inconvenient Hearing problems for some subjects Availability of portion aids Data collection may be more expensive for toll calls Potential for interviewer bias
Interviewer in person	Good response rate Opportunities for probing Low respondent burden Respondent interviewer rapport	Contact times may be inconvenient Potential for interviewer bias

in dietary data…this is understandable, but unfortunate because it can easily leave the impression that dietary data are worthless."[91] He reminded his audience that, while dietary intake data cannot and never will be estimated without error, a serious limitation is not the errors themselves, but failure to understand the nature of the errors and the consequent impact on data analysis and interpretation. Several recent reviews have delineated potential sources of error for different assessment methods.[28,31,51] Consideration of strategies to minimize error is pertinent in yielding accurate intake data, regardless of assessment method (see Table 19.4).

Recent attention to the accuracy of dietary intake data has focused on the underreporting of energy by 10 to almost 40%.[59,92-97] These findings are based on an extensive literature comparing intakes to energy needs estimated using doubly-labeled water,[98] weight maintenance data,[59] and applying age- and sex-specific equations to estimate energy requirements.[99] Underreporting has been found to be more common among women[99-101] and older persons[99,100,102] as well as overweight,[99-101] post-obese,[92] and weight-conscious individuals.[99,100] Literacy[103] and depression[104] have been associated with underreporting. Selective underreporting has also been associated with certain food types such as fats[95,99,105] and sweets.[105]

While underreporting of energy is common in groups of individuals,[59,94,95,99,100,106-108] both underreporting and overreporting can occur.[44,59,100] Individuals who possess characteristics

TABLE 19.4

Benefits Derived from Minimizing Assessment Error

Clinical Setting	Research Setting
Improve ability to detect inadequate, imbalanced, or excessive dietary intake	Improve accuracy of nutrient intake estimations
Provide a better basis for nutrition counseling and interventions	Decrease attenuation between intake data and biomarkers
Improve ability to monitor dietary changes	Provide a better basis for nutrition education program Provide a better basis for elucidation of diet-disease relationships

associated with underreporting may actually report intake accurately or overreport intake. However, the magnitude of underreporting may be even greater for individuals as error due to overestimation can reduce underestimation bias in groups.[102]

Due to the complex nature of intake data and the variability of under and over reporting, it is unlikely that a single correction factor will be derived that could be applied to self-reported energy intake.[109] The purpose of this section is to review components of assessment that may be modified to reduce sources of error.

Memory

Food recall is a cognitively demanding task. Understanding of dietary recall accuracy is derived from advances in cognitive psychology.[23] Classic work in this area described memory processes: encoding or learning information, transmission to long-term memory, and retrieval.[110-112] Early studies described strategies for encoding information as well as strategies for retrieving memories, such as free recall, recognition, and cued recall.

The memory model of cognitive psychology is applicable to dietary recall.[25] To accurately report intake, people must be able to remember what foods were consumed, how the foods were prepared, and the quantities of foods eaten. This requires the acquisition of specific food memories and the ability to retrieve these memories. Individuals who pay little attention to foods consumed, people who have difficulty storing information in memory, and those who lack the cognitive ability to retrieve food memories may not be able to accurately recall dietary intake.

Several techniques have been developed to reduce memory-related error in dietary data. For the 24-hour recall, techniques such as probing (See Figure 19.1),[113] encoding strategies,[25] memory retrieval cues,[25] and a multiple pass system[59,62] have been employed to improve memory. Campbell and Dodd's[113] classic paper showed that probing elicited additional information with significant impact on total caloric intake. Ervin and Smiciklas-Wright found that older adults were able to remember more foods when a deeper processing strategy was used during encoding and a recognition task was used for memory retrieval.[25] Record-assisted recalls may be used to help reduce memory-related error in food records.[114,115]

Recent work suggests that 24-hour recalls which incorporate a multiple pass technique into a standardized interview protocol with structured probes can reduce the commonly observed underestimation of intake for groups of individuals.[62] A multiple pass technique provides respondents several opportunities (i.e., passes) to recall foods eaten using both free recall and cued (probed recall) strategies.[59,62,116,117] As generally administered, the strategy involves three recall passes: an introductory opening sequence in which a respondent is asked to recall all items eaten, an interactive, structural probe sequence to elicit food descriptions and amounts, and a final review of the recall. The multiple pass technique is theoretically sound,[117] and when incorporated into a well-structured interactive interview process may decrease underreporting for groups of individuals.[59,62] While these studies are encouraging for the presentation of group data, there is room for improvement in assessing individuals' intakes.[59] Little data exists, however, on alternative modes of administering a multiple pass strategy and the "gains" at each pass.

A multiple pass technique can be facilitated by the use of interactive software.[118] This allows for a greater level of detail and facilitates data collection, but the technology is generally expensive and is not used commonly in clinical settings. However, written tools, such as probing guides, may be used to mimic this process when quantitative analysis is critical.

Portion Sizes

It is well documented that individuals have difficulty estimating amounts of foods and beverages.[61,119-121] There is a tendency toward overestimation of smaller portion sizes and underestimation of larger portion sizes which can lead to the "flat slope syndrome."[121,122] Portion size estimation aids (Table 19.1) have been shown to reduce portion size estimation error.[123] Estimation aids vary in sophistication and cost. Choice of tools is dictated partially by feasibility. In a clinical setting, aids such as food replicas, real foods, and food picture books may be appropriate. For interviews conducted by phone, tools that are compact for mailing, such as a chart with two-dimensional portions,[124] would be more appropriate.

A number of investigators have investigated whether training subjects to "judge" portion sizes improves quantity estimates.[61,125-130] These studies suggest that training effects may be retained for some days after training and may have significant impact on some, but not all foods. For example, amorphous foods (e.g., salads) are more resistant to training effects.

Variability of Intake

Day-to-day variation of food intake has been well documented in the literature.[36,131,132] Accordingly, assessment of an individual's total dietary intake, particularly by quantitative daily methods, at any one time may not yield an accurate measure of usual intake.[36] Basiotis et al. found that over 100 days of dietary data may be needed to accurately estimate an individual's typical intake for certain nutrients, such as vitamin A.[133] To lessen the effect of day-to-day dietary variation when using 24-hour recalls, assessment should be done on multiple, random, nonconsecutive days[36,58,134] that include both weekend and weekdays. For food records and 24-hour recalls, increasing the number of assessment days will decrease error related to variation in food intake; however, this must be balanced with subject tolerability and assessment objectives.

Consumption Frequency

Accurate estimation of how often foods are consumed is particularly important for retrospective assessment methods. For food frequency questionnaires, frequency of consumption estimates may contribute more error than portion size estimates.[135] The cognitive demands required to mathematically calculate consumption frequency contribute to the error involved with this measure. It has been suggested that the precision of food frequency questionnaires can be increased by not using predefined consumption frequency categories, such as three to four times per week, instead allowing participants to simply enter a number to reflect intake.[135] Ability to accurately recall the frequency of consumption of foods deteriorates as the amount of time between intake and assessment increases, yet longer reference time periods yield more accurate results than questionnaires with shorter reference periods.[136]

Response Bias

All assessment methods are subject to response bias. Social desirability may lead some individuals to selectively omit foods that may be regarded as unacceptable (e.g., alcohol, high fat foods),[23] while others may report eating a healthier diet than that which was actually consumed.[137,138] Self-reported assessment data may also be biased by participation in a dietary intervention.[139]

For both interviewer-assisted and self-completed assessment, questions should be reviewed for face validity to help ensure that participant comprehension of the questions is appropriate. When using interviewers to collect data, training to avoid leading questions and verbal and nonverbal cues that may appear to be judgmental can decrease response bias. Quality control procedures can ensure that interviewer questioning is consistent and nonbiasing.[140,141] Conducting interviews by telephone may reduce bias compared to face-to-face interviews.[63]

In regard to particular assessment methods, food frequency questionnaires may be subject to response bias, as current diet may influence recall of dietary intake in the past,[142] especially for individuals with diet-related illnesses.[143] Response bias can also be induced by methods with a high participant burden. For example, the burden of keeping food records may lead subjects to submit incomplete records, introducing a response bias.[144] Techniques that reduce respondent burden, such as interviewer-assisted food records, can reduce this effect and may improve the quality of data collected.

Data Entry

Data entry is the link between the information provided by a respondent and analysis of the data. Data entry often requires decisions by coders to adjust information provided to meet the demands of a specific data analysis program.[145] If the respondent provides incomplete data or the database does not include all diet items, coders must decide on reasonable substitutions for portion size or food items. Thus, the quality of the data provided by respondents, the quality of the database, and the default assumptions by coders can all contribute to variability in the final food and nutrient data descriptions.[145]

Decisions about amounts of foods eaten may be guided by U.S. Department of Agriculture (USDA) publications on portions commonly consumed in the United States. The USDA has published several reports on foods commonly eaten and the quantities consumed at an eating occasion.[146,147] These reports provide data on amounts eaten by participants in nationwide food consumption surveys.

Food Composition Tables

Food composition databases provide values for the nutritional content of foods. Errors in these databases will introduce systematic biases during data analysis. Further research to improve the validity of the nutrient values within food composition databases will further increase the accuracy of any dietary assessment methodology. This topic will be covered in more detail in Section 23.

Summary

Dietary assessment is a dynamic field, with novel approaches being developed, such as computer-assisted self-interviews.[148] Various techniques to improve validity have been developed (See Table 19.5), but much work still needs to be done to decrease both systematic and random errors. Refinement of current methods and the development of new techniques will improve confidence in the accuracy of dietary data.

TABLE 19.5

Considerations to Reduce Error when Collecting Assessment Data

Potential Error Sources	24-Hour Recalls	Food Records	Food Frequency Questionnaire
Memory	Multiple pass technique Probing questions Encoding strategies	Interviewer assisted records Encouraging adherence to appropriate instructions	Memory retrieval techniques
Portion size	Portion size estimation aids Subject training Interviewer training	Portion size estimation aids Weighing scale Subject training	Portion size estimation aids Subject training
Day-to-day variability	Multiple recall days Nonconsecutive days of data Include weekdays & weekends Collect data in different seasons	Multiple days of records Include weekdays & weekends Collect data in different seasons	N/A
Response bias	Interviewer training Clearly worded, open-ended questions Objective interviewer responses Recalls on unannounced, random days	Objective instructions Reduce respondent burden Limit days of data collection	Objective responses for interviewer mode
Data entry	Documentation of decisions Interactive software with detailed probes and automatic coding	Strict coding and data entry rules Interviewer assisted records Detailed probing guides and instructions	Strict coding and data entry rules Computer scannable forms for automatic coding

Current Issues in Assessment and Analysis

Dietary Quality Scores and Food Pattern Analysis

Historically, dietary quality scores have been a method of interpreting nutrient intakes of an individual by comparison with a dietary standard such as the Recommended Dietary Allowances[149] or, more recently, the Daily Reference Intakes.[150] The nutrient adequacy ratio (NAR), the amount of a particular nutrient in the diet divided by the dietary standard, has been commonly used for a number of years.[30,151] A mean adequacy ratio (MAR) can also be calculated and represents the mean of the NAR for several nutrients of interest.[30] Another way to examine the quality of an individual's diet is to calculate the number of servings from each food group and compare this with food grouping standards such as the USDA Food Guide Pyramid.[152] However, depending on the food group scheme used, serving sizes and placement of foods into groups may vary considerably. Approaches to food group analyses also differ.[153] For individuals, a behavioral approach, in which food group changes are based on nutrition education strategies, is more appropriate. This approach usually defines specific nutritional education programs for health promotion, such as the National Cancer Institute's 5 A Day Program.

With the introduction of the USDA Food Guide Pyramid,[152] other dietary quality scores have been developed which take into account not just nutrients or food group servings alone, but an aggregation of these two assessments into one score. The Healthy Eating

Index score, created by the USDA, takes into account servings from the major food groups of the Food Guide Pyramid as well as a dietary variety and health risk-related nutrient intakes.[154] This more comprehensive approach, as well as others that have been developed,[155] is becoming an increasingly popular approach to interpretation of the dietary intakes of groups or individuals. According to a recent article, identifying food patterns in groups and in individuals might be a better determinant of risk for disease as well as mortality.[156] This is based on the premise that diets are not comprised of single nutrients or foods but combinations of nutrients and nonnutrient components. The interactions of all these dietary components make it difficult to determine the effects of single dietary components. Additionally, dietary behaviors are complex and many different patterns of intake may be occurring simultaneously, such as decreasing fat intake while increasing fruits and vegetables.

Any method of assessing an individual's dietary intake is dependent on the methods of interpretation. More comprehensive methods of interpretation may facilitate the identification of more specific patterns of intake and their relationship to disease.

Dietary Supplements

Increased nutrient intakes from supplements have been related to certain disease risk such as cardiovascular disease (vitamin E), neural tube defects (folate), osteoporosis (calcium), and cancer (antioxidants such as vitamin C and beta-carotene). Approximately 40 to 50% of the general population over the age of two years in the U.S. takes a dietary supplement (see Table 19.6).[157,158] These numbers continue to rise especially for more non-traditional or complementary therapies such as herbal or botanical supplements. Supplement use is higher in non-Hispanic white females, and increases with age in some segments of the population.[157,159] The supplement intake of special populations such as individuals with cancer diagnosis are much higher, up to 80% in some studies.[159,160] Knowledge of dietary supplements as well as an understanding of assessment methods is critical to the overall assessment of nutrient and other dietary components.

Supplement intake data can be assessed in a variety of ways and is usually collected by questionnaire, including food frequency questionnaires, or as part of intake data such

TABLE 19.6

Categories of Supplements

Category	Examples
Vitamins (single or multiple formulations)	Vitamin C, E, D, B_6
Minerals (single or multiple formulations)	Iron, calcium, chromium, zinc
Vitamin(s) with mineral(s)	Calcium with vitamin D; vitamin E with selenium
Herbs and other botanicals	St. John's Wort, ginkgo biloba, ginseng, saw palmetto
Flavonoids	Quercetin, rutin, hesperidin, diadzin
Carotenoids	Lycopene, zeaxanthin, lutein, dried carrot extract, other vegetable extracts
Fatty acids/fish oils, other oils	Linoleic acid, omega 3 fatty acids, DHA EPA
Amino acids/nucleic acids/proteins including co-enzymes, enzymes & hormones	L-glutamine, coenzyme Q-10, bromelain, tryptophan
Microbial prepartions/probiotics	*Lactobacillus acidophilus, B. bifidus, L. bulgaris*
Glandular and other organ preparations	Dessicated glands such thyroid and adrenal
Miscellaneous	Shark cartilage, pycogenol, chrondoitin sulfate

as by 24-hour dietary recall or by food records. When collected by the latter methods it is important to recognize that the intake of supplements for the day of data collection may not reflect the pattern of intake over an extended period of time. Detailed questionnaires, which are better for capturing long-term intake and frequency of intake, are used frequently in research studies, clinical practice, and nutrition monitoring and surveys.[161,162]

Quantifying supplement intake is a difficult and tedious process. When collecting supplement information, it is important to identify what level of detail is needed to describe or quantify dietary intakes with dietary supplements. Strategies may include having those individuals bring in their supplement labels, or photocopy the labels. Other strategies include having the participants respond to questionnaires that provide lists of single vitamins and minerals as well as common brand names for multiple formulations. For herbal and botanical ingredients and other components not typically found in common formulations, it might be necessary to identify the active components and, above all else, to obtain brand name and label information.

Functional Foods

According to the Institute of Medicine of the National Academy of Sciences (1994) the definition of functional foods is "any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains."[163] Currently, there is a major research emphasis to identify physiologically active components, or phytochemicals, and their potential for decreasing disease risk. Functional foods can consist of foods or food ingredients, including fruits and vegetables to more specialized products such as those containing soy or phytostanols (i.e., margarines with claims of reducing blood cholesterol levels).

Since many of the phytochemicals in foods are still under investigation, it is premature to emphasize quantification of single functional food components in dietary assessment. However, improvements in individual assessment methods will make it possible to quantify and link these components in functional foods with their potential health benefits. Examples of where individual assessment plays a significant role in providing this linkage can be found in the literature examining fruit and vegetable intakes. There are now databases that can accurately quantify the carotenoid content of foods.[118,164] As cooking methods, storage, and exposure to air and water are known to affect the carotenoid content of fruits and vegetables, the development of these databases has been a challenge. In the case of assessing carotenoids, for example, it is important to distinguish between pink and white grapefruit (i.e., pink grapefruit has 3740 mg lycopene, whereas white grapefruit has 0 mg). This one simple observation in assessing an individual's intake can have a significant impact on determining the relationship between dietary carotenoids and blood carotenoids and the potential role they may have in cancer risk in groups of individuals.

In assessing diets for research purposes it is important to consider the level of detail required for other components in foods as well. The assessment issues outlined in this section are the same for assessing functional foods. As more components are identified and quantification is possible, databases need to be developed that make analysis of functional foods and their components possible. The knowledge gained in the study of functional foods will drive the type and level of detail in methodology and database development.

References

1. Bingham S. *Nutr Abstr Rev (Series A)* 57: 705; 1987.
2. Medlin C, Skinner JD. *JADA* 88: 1250; 1988.
3. Mudge GG. *J Home Ec* 15: 181; 1923.
4. Mudge GG. *JADA* 1: 166; 1926.
5. Turner D. *JADA* 16: 875; 1940.
6. Widdowson EM. *J Hygiene* 36: 269; 1936.
7. Widdowson, EM. *J Hygiene* 36: 293; 1936.
8. National Research Council, *Diet and Health: Implications for Reducing Chronic Disease Risk,* National Academy Press 46; 1989.
9. Public Health Service, *Healthy people: Surgeon General's Report on Health Promotion and Disease Prevention,* US Department of Health and Human Services, Washington DC; 1979.
10. Public Health Service, *Promoting Health/Preventing Disease: Objectives for the Nation,* US Department of Health and Human Services, Washington DC; 1980.
11. US Department of Health and Human Services, *Healthy People 2010 (Conference Edition),* US Department of Health and Human Services, Washington DC; 2000.
12. Leverton RM, Marsh AG. *J Home Ec* 31: 111; 1939.
13. Huenemann RL, Turner D. *JADA* 18: 562; 1942.
14. Young C, et al. *JADA* 28: 124; 1952.
15. Young C, et al. *JADA* 28: 218; 1952.
16. Wait B, Roberts LJ. *JADA* 8: 323; 1932.
17. Yudkin J. *Brit J Nutr* 5: 177; 1951.
18. Hunt CL. *J Home Ec* 5: 212; 1918.
19. Burke BS, Stuart HC. *J Pediatr* 12: 493; 1938.
20. Donelson EG, Leichsenring JM. *JADA* 18: 429; 1942.
21. Tigerstedt R. *Skand Arch Physiol* 24: 97; 1910.
22. Blundell JE. *Am J Clin Nutr* 71: 3; 2000.
23. Dwyer JT, Krall EA, Coleman KA. *JADA* 87: 1509; 1987.
24. Smith AF. *Eur J Clin Nutr* 47: S6; 1993.
25. Ervin RB, Smiciklas-Wright H. *JADA* 98: 989; 1998.
26. Roberfroid MB. *J Nutr* 129: 1398S; 1999.
27. Life Sciences Research Office, *Guidelines for Use of Dietary Intake Data,* Federation of American Societies for Experimental Biology, Bethesda, MD; 1996.
28. Gibson RS. *Principles of Nutritional Assessment,* Oxford University Press, New York; 1990.
29. Thompson FE, Byers T. Dietary assessment resource manual, *J Nutr* 124: 2245S; 1994.
30. Smiciklas-Wright H, Guthrie HA. *Nutrition Assessment: A Comprehensive Guide for Planning Intervention,* 2nd ed, Simko MD, Cowell C, Gilbride, JA Eds, Aspen Publishers, Gaithersburg, MD: 165; 1995.
31. Dwyer J. *Modern Nutrition in Health and Disease,* 9th ed, Shils ME, Olson JA, Shike M, Ross AC, Eds, Williams & Wilkins, Philadelphia: 937; 1999.
32. Christakis G. *Am J Public Health* 63: 1S; 1973.
33. Copeland T, et al. *JADA* in press.
34. Olendzki B, et al. *JADA* 99: 1433; 1999.
35. St. Jeor ST, Guthrie HA, Jones MB. *JADA* 83: 155; 1983.
36. Tarasuk V, Beaton GH. *Am J Clin Nutr* 54: 464; 1991.
37. Craig MR, et al. *JADA* 100: 421; 2000.
38. Tian HG, et al. *Eur J Clin Nutr* 49: 26; 1995.
39. Streit KJ, et al. *JADA* 91: 213; 1991.
40. Achterberg C, et al. *J Can Diet Assoc* 52: 226; 1991.
41. Block G, Hartman AM, Naughton D. *Epidemiology* 1: 58; 1990.
42. Brown JE, et al. *JADA* 96: 262; 1996.
43. Cummings SR, et al. *Am J Epidemiol* 126: 796; 1987.

44. Domel SB, et al. *J Am Coll Nutr* 13: 33; 1994.
45. Kristal AR, et al. *Am J Epidemiol* 146: 856; 1997.
46. Jackson B, et al. *JADA* 86: 1531; 1986.
47. Buzzard IM, et al. *JADA* 96: 574; 1996.
48. Gorbach SL, et al. *JADA* 90: 802; 1990.
49. Kuehl KS, et al. *Prev Med* 22: 154; 1993.
50. Moulin CC, et al. *Am J Clin Nutr* 67: 853; 1998.
51. Bingham SA, *Ann Nutr Metab* 35: 117; 1991.
52. Gittelsohn J, et al. *JADA* 94: 1273; 1994.
53. Dubois S. *JADA* 90: 382; 1990.
54. Omnibus Budget Reconciliation Act of 1990, P. L. 101-508; 1990.
55. Morris JN, et al. *The Gerontologist* 30: 293; 1990.
56. Rebro SM, et al. *JADA* 98: 1163; 1998.
57. Pekkarinen M. *World Rev Nutr Diet* 12: 145; 1970.
58. Larkin FA, Metzner HL, Guire KE. *JADA* 91: 1538; 1991.
59. Jonnalagadda SS, et al. *JADA* 100: 303; 2000.
60. Lyons GK, et al. *JADA* 96: 1276; 1996.
61. Howat PM, et al. *JADA* 94: 169; 1994.
62. Johnson RK, Driscoll P, Goran, MI. *JADA* 96: 1140; 1996.
63. Fox TA, Heimendinger, J, Block G. *JADA* 92: 729; 1992.
64. Derr JA, et al. *Am J Epidemiol* 136: 1386; 1992.
65. Casey PH, et al. *JADA,* 99: 1406; 1999.
66. Krantzler NJ, et al. *Am J Clin Nutr* 36: 1234; 1982.
67. Pao EM, Sykes KE, Cypel VS. *USDA Methodological Research for Large Scale Dietary Intake Surveys, 1975-88,* Home Economics Research Report no. 49, US Department of Agriculture, Human Nutrition Information Service, US Government Printing Office, Washington, DC: 181; 1989.
68. Morgan KJ, et al. *JADA* 87: 888; 1987.
69. Cullen KW, et al. *J Am Coll Nutr* 18: 442; 1999.
70. Hartman AM, et al. *Nutr Cancer* 25: 305; 1996.
71. Retzlaff BM, et al. *Am J Public Health* 87: 181; 1997.
72. Sloan NL, et al. *Am J Public Health* 87: 186; 1997.
73. Brants HA, et al. *Eur J Clin Nutr* 51: S12; 1997.
74. Briefel RR, et al. *JADA* 92: 959; 1992.
75. White JV, Dwyer JT, Posner BM, et al. *JADA* 92: 163; 1992.
76. The Nutrition Screening Initiative, *Incorporating Nutrition Screening and Interventions into Medical Practice,* The Nutrition Screening Initiative, Washington, DC; 1994.
77. Posner BM, et al. *Am J Public Health* 83: 972; 1993.
78. Subar AF, et al. *FASEB J* 14: A559; 2000.
79. Block G, et al. *J Clin Epidemiol* 43: 1327; 1990.
80. Longnecker MP, et al. *Epidemiology* 4: 356; 1993.
81. Musgrave KO, et al. *JADA* 89: 1484; 1989.
82. Willett WC, et al. *JADA* 87: 43; 1987.
83. Potischman N, et al. *Nutr Cancer* 34: 70; 1999.
84. Lund SM, Brown J, Harnack L. *Eur J Clin Nutr* 52: 53S; 1998.
85. Rockett HR, Wolf AM, Colditz GA. *JADA* 95: 336; 1995.
86. Coates RJ, et al. *Am J Epidemiol* 134: 658; 1991.
87. Kumanyika SK, et al. *Am J Clin Nutr* 65: 1123S; 1997.
88. Kumanyika S, et al. *JADA* 96: 137; 1996.
89. Laus MJ, et al. *J Nutr Elder* 18: 1; 1999.
90. Burke BS. *JADA* 23: 1041; 1947.
91. Beaton GH. *Am J Clin Nutr* 59: 253S; 1994.
92. Black AE, et al. *Eur J Clin Nutr* 51: 405; 1997.
93. Bandini LG, et al. *Am J Clin Nutr* 65: 1138S; 1997.
94. Champagne CM, et al. *JADA* 98: 426; 1998.
95. Goris AH, Westerterp-Plantenga MS, Westerterp KR. *Am J Clin Nutr* 71: 130; 2000.

96. Martin LJ, et al. *Am J Clin Nutr* 63: 483; 1996.
97. Kroke A, et al. *Am J Clin Nutr* 70: 439; 1999.
98. Schoeller DA, Fjeld CR. *Annu Rev Nutr* 11: 355; 1991.
99. Briefel RR, et al. *Am J Clin Nutr* 65: 1203S; 1997.
100. Johansson L, et al. *Am J Clin Nutr* 68: 266; 1998.
101. Stallone DD, et al. *Eur J Clin Nutr* 51: 815; 1997.
102. Black AE, et al. *Eur J Clin Nutr* 45: 583; 1991.
103. Johnson RK, Soultanakis RP, Matthews DE. *J Am Diet Assoc* 98: 1136; 1998.
104. Smiciklas-Wright H, et al. *FASEB J* 13: A263; 1999.
105. Bingham S. *Am J Clin Nutr* 59: 227S; 1994.
106. Champagne CM, et al. *JADA* 96: 707; 1996.
107. Kortzinger I, et al. *Ann Nutr Metab* 41: 37; 1997.
108. Mertz W, et al. *Am J Clin Nutr* 54: 291; 1991.
109. Schoeller DA. *Metabolism* 44: 18; 1995.
110. Wessells MG. *Cognitive Psychology,* Harper & Row, New York; 1982.
111. Craik FIM. *Philos Trans R Soc Lond B Biol Sci* 302: 341; 1993.
112. Schaie KW, Willis SL. *Adult Development and Aging,* 2nd ed, Schaie KW, Willis SL, Eds, Little, Brown and Company, Boston; 324; 1986.
113. Campbell VA, Dodds ML. *JADA* 51: 29; 1967.
114. Eldridge AL, et al. *JADA* 98: 777; 1998.
115. Lytle LA, et al. *JADA* 93: 1431; 1993.
116. De Maio TJ, Ciochetto T, Davis W. *American Statistical Association: Survey Methods:* 1021; 1993.
117. Wright JD, Ervin RB, Briefel RR, Eds. *Consensus Workshop on Dietary Assessment: Nutrition Monitoring and Tracking the Year 2000 Objectives,* Department of Health and Human Services, National Center for Health Statistics, Hyattsville, MD, 1993.
118. Nutrition Coordinating Center, *Nutrient Data System for Research (NDS-R) software,* University of Minnesota, Minneapolis, MN.
119. Blake AJ, Guthrie HA, Smiciklas-Wright H. *JADA* 89: 962; 1989.
120. Smiciklas-Wright H, et al. *Progress Report 390,* Northeastern Cooperative Regional Research Publication, Pennsylvania State University, Agriculture Experiment Station: 1; 1988.
121. Young LRN. *Nutr Rev* 53: 149; 1995.
122. Faggiano F, et al. *Epidemiology* 3: 379; 1992.
123. Cypel YS, Guenther PM, Petot GJ. *JADA* 97: 289; 1997.
124. Nutrition Consulting Enterprises, *Food Portion Visual,* Nutrition Consulting Enterprises, Framingham, MA, 1981.
125. Rapp SR, et al. *JADA* 86: 249; 1986.
126. Bolland JE, Yuhas JA, Bolland TW. *JADA* 88: 817; 1988.
127. Yuhas JA, Bolland JE, Bolland TW. *JADA* 89: 1473; 1989.
128. Bolland JE, Ward JY, Bolland TW. *JADA* 90: 1402; 1990.
129. Weber JL, et al. *JADA* 97: 176; 1997.
130. Slawson DL, Eck LH. *JADA* 97: 295; 1997.
131. Guthrie HA, Crocetti AF. *JADA* 85: 325; 1985.
132. McAvay G, Rodin J. *Appetite* 11: 97; 1988.
133. Basiotis PP, et al. *J Nutr* 117: 1638; 1987.
134. Hartman AM, et al. *Am J Epidemiol* 132: 999; 1990.
135. Flegal KM, et al. *Am J Epidemiol* 128: 749; 1988.
136. Smith A. *Cognitive Processes in Long-Term Dietary Recall, DHHS Publication No. 92-1079,* Series 6, No. 44, Department of Health and Human Services, National Center for Health Statistics, Hyattsville, MD; 1991.
137. Hebert JR, et al. *Int J Epidemiol* 24: 389; 1995.
138. Hebert JR, et al. *Am J Epidemiol* 146: 1046; 1997.
139. Kristal AR, et al. *J Am Diet Assoc* 98: 40; 1998.
140. Edwards S, et al. *Am J Epidemiol* 140: 1020; 1994.
141. Smiciklas-Wright H, et al. *JADA* 81: 28S; 1991.
142. Dwyer JT, Coleman KA. *Am J Clin Nutr* 65: 1153S; 1997.

143. Malila N, et al. *Nutr Cancer* 32: 146; 1998.
144. Gersovitz M, Madden JP, Smiciklas-Wright H. *JADA* 73: 48; 1978.
145. Lacey JM, et al. *Coder Variability in Computerized Dietary Analysis,* Research Bulletin Number 729, Massachusetts Agricultural Experiment Station, Massachusetts; 1990.
146. Pao EM, et al. *Foods Commonly Eaten by Individuals: Amounts Per Day and Per Eating Occasion,* Home Economics Research Report Number 44, Consumer Nutrition Center, Human Information Service, Hyattsville, MD; 1982.
147. Krebs-Smith SM, et al. *Foods Commonly Eaten in the United States: Quantities Consumed Per Eating Occasion and in a Day, 1989-91,* NFS Report No. 91-3, US Department of Agriculture, Agriculture Research Service, Washington, DC; 1997.
148. Kohlmeier L, et al. *Am J Clin Nutr* 65: 1275S; 1997.
149. Food and Nutrition Board, *Recommended Dietary Allowances,* 10th ed, National Academy Press, Washington, DC; 1989.
150. Food and Nutrition Board, *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin* B_6*, Folate, Vitamin* B_{12}*, Pantothenic Acid, Biotin, and Choline,* National Academy Press, Washington, DC; 1998.
151. Guthrie HA, Scheer JC. *JADA* 78: 240; 1981.
152. US Department of Agriculture, *The Food Guide Pyramid: A Guide to Daily Food Choices,* US Department of Agriculture, Nutrition Information Service; 1992.
153. Cullen KW, et al. *JADA* 99: 849; 1999.
154. Bowman SA, et al. *The Healthy Eating Index: 1994-96, CNPP-5,* US Department of Agriculture, Center for Nutrition Policy and Promotion; 1998.
155. Haines PS, Siega-Riz AM, Popkin BM. *JADA* 99: 697; 1999.
156. Kant AK, et al. *JAMA* 283: 2109, 2000.
157. Ervin RB, Wright JD, Kennedy-Stephenson J. *Use of Dietary Supplements in the United States, 1988-94,* Series 11, No. 244, Department of Health and Human Services, National Center for Health Statistics, Hyattsville, MD; 1999.
158. Slesinski MJ, Subar AF, Kahle LL. *J Nutr* 126: 3001; 1996.
159. Newman V, et al. *JADA* 98: 285; 1998.
160. Winters BL, et al. *FASEB J* 13: A253; 1999.
161. Tippett KS, Cypel YS, Eds. *Design and Operation: the Continuing Survey of Food Intakes by Individuals and the Diet and Health Knowledge Survey, 1994-96,* Nationwide Food Survey Report No. 91-1, US Department of Agriculture, Agricultural Research Service; 1998.
162. Rock CL, et al. *Nutr Cancer* 29: 133; 1997.
163. Milner JA. *J Nutr* 129: 1395S; 1999.
164. US Department of Agriculture, *USDA-NCC Carotenoid Database for U.S. foods,* 1998-1999.
165. NASCO, *Nasco nutrition teaching aids, 1999-2000 catalog* Fort Atkinson, WI: 437; 1999.
166. National Center for Health Statistics, *Dietary Intake Source Data: United States, 1976-80. (DHHS publication no. PHS 83-1681),* Series 11, no. 231, US Department of Health and Human Services, Washington, DC; 1983.
167. Hess MA, Ed. *Portion Photos of Popular Foods,* American Dietetic Association: 128; 1997.