Food Frequency Questionnaires for Diet Intervention Research

Alan R. Kristal, Ann L. Shattuck, Allan E. Williams
Fred Hutchinson Cancer Research Center

Over the past two decades, food frequency questionnaires (FFQ's) have become a well-accepted method for quantitative assessment of usual nutrient intake. Many questions remain about the accuracy and appropriateness of FFQ's, especially when more precise estimates of actual food intake are desired (Sempos, 1992). There are, however, many practical advantages to FFQ's that motivate their use in a number of specific research applications. Research to improve the validity of FFQ's and modify their characteristics for specific research questions is well warranted.

Here we describe our systematic approach for developing FFQ's that target assessment of dietary intake in large (n>5,000) prospective diet intervention studies. We include developing the questionnaire itself, along with analysis software and a nutrient database. We use as specific examples three FFQ's that have been or are now being used in three large intervention studies.

The first is a minor modification of the FFQ developed by Block and colleagues (1990) at the National Cancer Institute (NCI). This instrument is used throughout the country, and its analysis is based on software and a nutrient database available at no charge from the NCI (National Cancer Institute, 1988). The second FFQ is now being used in the Women's Health Trial-Feasibility Study in Minority Populations (WHT), an evaluation of the intensive Women's Health Trial (Henderson et al, 1990) nutrition intervention to reduce fat intake from 38% to 20% of total energy. The target populations are being recruited from three clinics, one each targeting post-menopausal Black, Hispanic, and lower-socioeconomic status women. The third FFQ is now being used in the NCI-sponsored Working Well study, a multi-center, randomized trial of worksite health promotion, in which a combination of low-intensity individual and environmental nutrition interventions are expected to result in a relatively modest 2 to 3 percentage point decrease in percent of total energy from fat. The later two FFQ's and software for their analysis were developed at the Fred Hutchinson Cancer Research Center and are available from the authors. Much of what follows is generalizable to FFQ's used for other purposes, however we focus on FFQ's for dietary intervention studies to illustrate a broadly applicable approach in concrete terms.

Why Use Food Frequency Questionnaires?

Epidemiologists use FFQ's as a means to characterize the "usual" dietary intake of free living individuals. From a statistical perspective, FFQ's are the only dietary intake measure that minimizes the very high intra-individual, day-to-day variability in nutrient intake without relying on multiple-day assessments of actual foods consumed (e.g., 7-day diet records). The earliest approach to quantifying usual dietary intake was the diet history, developed by Burke (Burke and Stuart, 1938). These were professionally administered, 1-1/2 hour interviews, eliciting descriptions of "usual" meals and snacks, portion sizes, frequency of consuming foods from broad food groups (e.g., meats, fish), and frequency of deviations and variations from usual patterns. These data were combined to generate estimates of usual nutrient intake, based on hand-calculations from food tables. Diet histories are tedious, unstandardized measures, with ample opportunity for interviewer and social desirability biases. As early as 1942 (Donelson and Leichsenring, 1942) there were attempts to formalize this approach by asking study participants about their usual consumption of foods from predefined lists. While perhaps not as flexible as diet histories, they did standardize the nature of data collected and reduced both cost and bias when collecting these data. The 1970's brought the so-called "semi-quantitative" FFQ, in which the standardized list of foods was more comprehensive, the nutrient databases were more carefully constructed, and portion sizes and seasonability were incorporated into software that generated nutrient estimates. There are two instruments developed in this period that remain partially hegemonic in their use: the FFQ developed by Willett and colleagues at Harvard (Willett et al, 1985), and the FFQ developed by Block and colleagues at the NCI (Block et al, 1986). Many other instruments (e.g., at the University of Hawaii (Hankin et al, 1990)) were also developed, but their use tended to remain within those particular research groups. As the use of FFQ's has expanded, so has the number of groups developing them, and modifications to the standard Block and Willett instruments are now commonplace.

For all FFQs, however, the analytic strategy is the same. The frequency of consumption is multiplied by portion size (if asked) and by nutrient density, and these are summed to obtain nutrient totals. Many FFQ's include supplementary questions, for example on types of milk usually consumed and whether chicken is eaten with or without skin. Answers to these questions are incorporated into analysis software to better refine calculation of nutrient intakes. A review of analytic issues when using FFQ's for epidemiological studies is given by Willett (1990) and the reader is referred there for more detail.

There are three epidemiological study types for which FFQs are necessary:

1. In case-control studies, where usual diet (often in the distant past) must be ascertained retrospectively, FFQs are the only feasible approach;

2. In very large longitudinal studies (e.g. Iowa Women's Health Study (Kushi et al, 1992) or the Nurses Health Study (London et al, 1989)), where dietary intake assessment must be self-administered, distributed by mail, and analyzed without extensive hand-coding of foods to a nutrient data base; and

3. Large intervention studies, when repeated administration of multiple-day diet records or 24-hour recalls would be overwhelming in cost.

Table 1 illustrates this last point on costs. We contrasted cost estimates for using FFQ's compared to 4-day diet records for participant screening at recruitment and nine years of dietary intake monitoring in the dietary intervention arm of the proposed Women's Health Initiative (WHI). The estimates are conservative for 4-day records, for which others estimate over $100 per record for training, review, and analysis. Estimates for the FFQ assume that a machine-readable form, and hardware and software are all available. Were 4-day records to be used to monitor diet intake in the WHI, it would increase the study cost by at least 60 million dollars.

Food Frequencies for Intervention Studies

Though probably less valid than random-day, unannounced 24-hour recall interviews for monitoring study compliance, FFQs are the only cost-effective means of monitoring individual dietary intake in large intervention studies. We therefore consider the optimal characteristics of an FFQ for this purpose. These include:

1. Sensitivity to the behavior changes targeted by the intervention. This is especially important if the intervention will result in relatively small changes (e.g., from community-wide, health promotion programs).

2. Ease of modifying the FFQ to include new food items or changes in food nutrient composition. In a long-term study (e.g., 10 years), the food supply in the United States will change markedly, especially in the number of fat-modified formulations of commonly consumed foods.

3. Ease of processing. The only feasible approach is to use mark-sense (machine readable) forms. In addition, the analysis software and associated nutrient database must be easy to use, to allow processing many thousands of forms at low cost.

Structure of Intervention FFQ's: There are three sections to the FFQ's we have designed specially for intervention research. The first section consists of questions on types of foods and preparation techniques that can be used to alter how analysis software interprets specific food items. The second contains a list of foods and food groups, and for each the respondent indicates the usual portion size and frequency of consumption. The third section consists of summary questions on usual use of a broad groups of foods (e.g., vegetables) that are used to further adjust nutrient calculations. We discuss these section below.

*Adjustment Questions:*Adjustment questions can be used for two purposes. First, they can capture information on use of foods from a potentially very long list and reduce the number of food items needed in the body of the questionnaire. The example shown in Figure 1 contrasts the approach used in the Block/NCI FFQ to that used in the WHT FFQ. The Block/NCI FFQ uses three food items for coffee creamer compared to one on the WHT FFQ. The Block/NCI approach allows for a mix of different types of creamers, while the WHT FFQ allows more specificity on type of creamer and is easier to answer. Adjustment questions can also be used to ascertain more complete food use behavior than can be captured with food items alone. The example given in Figure 2 shows how popcorn (eaten at least once a week by over 40% of participants in the Working Well Intervention Study) can be captured as either a high-fat or low-fat snack.

Food Items: There is some controversy in the literature and among nutritional epidemiologists on the appropriate means to select food items. There are three approaches, described simply as nutrient disappearance (Block et al, 1986; also described in Kristal et al, 1990a), explained variance (Byers et al, 1985; also described in Kristal et al, 1990a) and a combination of the two based on expert judgment and a familiarity with food consumption patterns in the population under study (Willett, 1990). The later approach is most appropriate for an intervention FFQ, because it must include foods and food groups that can distinguish persons who do and do not adopt the intervention goals.

To increase the number of foods that can be considered in an FFQ of reasonable length, most foods must be combined into groups. We suggest three important points to consider when grouping foods:

1. Food groups must be cognitively coherent. It makes no sense to ask people to estimate their usual consumption of "cakes, cookies, granola, waffles, and French toast," even though they may be similar in nutrient content per serving. Much research is needed on how people classify foods, but clearly to group foods used in different amounts for different purposes makes little sense.

2. Food should be grouped to produce less confusion in self-report. The example given in Table 2 gives a comparison of pasta and other grains on the Block/NCI FFQ and their corresponding groups on the WHT FFQ. The WHT FFQ is designed to capture how food use should change due to the intervention, and foods are grouped to be sensitive to fat used in their preparation.

3. Foods need to be grouped considering their nutrient similarities. Here, it will often be necessary to prioritize precisely what nutrients are of most interest. Again, the example in Table 3 contrasts the grouping of soups in the Block/NCI FFQ to the WHT FFQ. The Block/NCI FFQ emphasizes beta-carotene, while the WHT FFQ emphasizes fat and total energy.

Summary Questions: Summary questions ask about the usual consumption of vegetables, fruits, cereal, and fats used in cooking. Summary questions are useful when there are long lists of items, for example on the WHT FFQ there are 22 vegetables and 10 fruits. The more items given, the greater will be the tendency to overestimate consumption within these broad groups. Answers to summary questions are used to adjust individual item frequencies so that the sum of all items in a food group are the same as the reported usual frequency of consumption.

Nutrient Database for FFQ's

Generating a nutrient database for a new FFQ requires considerable care and expert judgment. Questions that must be addressed in developing a nutrient database are: 1) what specific foods, and what amounts, will comprise each FFQ item; 2) what weights will be used for calculating the relative contributions of specific foods to an FFQ item; and 3) what portion size will be used on the questionnaire as the average serving? One approach to all three of these issues is described by Block et al (1986) and implemented in the NCI diet analysis software (National Cancer Institute, 1988). This approach was based on the 11,658 24-hour diet recalls collected in the HANES II. One hundred twenty-seven food categories were created by grouping the 2,244 foods reported in the survey. The median portion sizes and nutrient content from each food category were used to generate the nutrient database, while the portion sizes listed on the questionnaire were commonly consumed amounts in household measures. This approach is only feasible when extensive population-based data exist, and it still requires considerable expert judgment in creating food categories and selecting portion sizes. On the surface this approach seems most appropriate for studies of the general population, but it may not obtain in intervention studies when dietary change results in patterns of intake not at all common in the general population. The alternative, and far more common, approach to database generation is to use expert committees to define the mix of foods and their portion sizes that comprise each FFQ food item, and to similarly use expert committees to define a general serving size in common household units.

Our approach to generating a FFQ nutrient database is based on a structured, self-documenting spreadsheet. Figure 3 shows an example of the spreadsheet used for the Working Well FFQ. By working through this spreadsheet, we make and document all the decisions needed to create the FFQ database. The first four columns of the spreadsheet identify the item number on the FFQ form (e.g. FF10a is the first question in section 10 of the FFQ), the database number for the FFQ item, the database number for each subcomponent within a FFQ food item, and the FFQ item text. The next 2 columns give weights for each food item subcomponent. Note that a single component food item has weights of 1.0, while the complex mix of canned and fresh peaches, plums and apricots has weights for canned vs fresh and the relative amounts of each fruit within each. The next column lists the food code that links the spreadsheet to the output from the University of Minnesota's Nutrient Data System

(NDS), described below. The last two columns give serving size in household units and the corresponding gram weights. Additional columns, not shown, are used for notation and further documentation. Once this spreadsheet is generated, we use it to link to the NDS nutrient database, calculate summary nutrients from the weighted nutrients in each subcomponent, and structure the database used by the FFQ analysis software.

Extracting the nutrient vector for each food subcomponent item can be tedious and error-prone if nutrients are key-entered from published tables. Further, modification of the database when there are updates of reference nutrient databases require continuing database maintenance. Our approach is to link the spreadsheet to an output record generated from a commercially available nutrient software system developed by the University of Minnesota (Nutrition Coding Center, 1992). This software is designed to analyze food records or collect 24-hour recalls. However, because it stores nutrient analyses of diets in a separate subfile for each record, we simple assign the NDS record identification number to correspond to the NDS number on the spreadsheet. Thus, the nutrient string can be linked and manipulated using standard statistical software to generate the nutrient database for FFQ analysis.

This approach is enormously flexible. It allows us to routinely update our FFQ databases when there are revisions to the reference nutrient database due to manufacturing changes or improved analytic methods. It also lends itself to modifications, such as new foods or new food mixes for a given FFQ item, with relatively modest programming effort.

Preliminary Evaluation:

We have completed preliminary evaluation of the validity of this database approach, compared to the analysis resulting from the NCI Health History Questionnaire software. In these analysis we used the modified Block/NCI questionnaire that can be analyzed using either our system or the NCI system. Table 4 gives the correlations and differences between nutrients estimated using the two systems. Correlations were above .90 for most nutrients. Exceptions were where we expected them: in percent energy from fat, where our software makes different assumptions about portion sizes and the interpretation of adjustment and summary questions; and for fiber, where the NDS system uses more recent data based on improved analytic techniques. In another analysis, (Table 5) we compared results based on correlations between each analysis approach and the mean of two-4 day records (Kristal et al, 1990b). Again, correlations were similar, with the exceptions of fiber and vitamin C (higher for the FHCRC) and vitamin A (higher for the NCI). These preliminary results suggest that our approach based on using the NDS database are similarly valid as the approach used in the NCI software. Advantages of our software are that it can analyze the more complex FFQ's used in intervention studies (the NCI software is limited in adjustment and summary questions) and our software is far more simple to modify.

In summary, we have developed a system for developing and analyzing FFQs that appears similarly valid to those reported by others. The system is easily modifiable, employs a mark-sense readable form, and is optimized for use in large clinical trials. This approach is now in use in several large trials. Researchers interested in further details of the system or in any of the FFQ's used in these intervention studies may contact the authors.

Figure 1

Comparison of Coffee Creamer Assessment in the Block/Nation Cancer Institute and Women's Health Trial Food Frequency Questionnaires

Block/National Cancer Institute

Adjustment Items

None

Food Items

Milk in coffee or tea
Cream (real) or half-and-half in coffee or tea
Non-dairy creamer in coffee or tea

Women's Health Trial

Adjustment Items

Did you use milk or cream in coffee or tea during the last three months?

No, go to question 6

Yes

When you used milk or cream in coffee or tea, was it usually…

- Cream or half-and-half
- Whole milk
- 2% milk
- 1% milk
- Nonfat/Skim milk
- Non-dairy Creamer
- Milk, do not know kind

Food Items

Cream, milk or non-dairy creamer in tea or coffee

Figure 2

Example of Women's Health Trial Food Frequency Questionnaire Adjustment Questions on Popcorn

Adjustment Items

Did you eat popcorn during the last three months?

No, go to question 7

Yes

What type of popcorn did you usually eat?
- Popped in oil, pre-popped, or at movies
- Regular microwave
- Air-popped or special "light" microwave

When you ate popcorn, how often did you add butter or margarine?
- Almost Always
- Often
- Sometimes
- Rarely
- Never

Food Items

Popcorn

Figure 3

Example of Spreadsheet for Generating the Working Well Food Frequency Questionnaire Nutrient Database

FFQ Var Name	D.B. #	D.B. Sub. #	Item Name	%1	%2	Food Mix	NDS #	Serv Size Household Units	Ave. Item Serv Size (GMS)
FRUITS									
FF10a	1	1	Apples, Pears, etc.	1.00	0.50	apple w/skin	0001	1 med.	138.0
	1	2		1.00	0.30	pear, raw	0002	1 med.	166.0
	1	3		1.00	0.20	applesauce, sweet	0003	1/2 cup	128.0
FF10b	2	1	Bananas	1.00	1.00	bananas	0010	1 each	114.0
FF10c	3	1	Peaches, etc.	0.43	0.76	peaches, canned	0020	1/2 cup	126.0
	3	2		0.43	0.12	apricots, canned	0021	1/2 cup	126.0
	3	3		0.43	0.00	nectarines, canned	—	1/2 cup	126.0
	3	4		0.43	0.12	plums, canned	0022	1/2 cup	126.0
	3	5		0.57	0.66	peaches, fresh	0023	1 med.	87.0
	3	6		0.57	0.12	apricots, fresh	0024	3 each	106.0
	3	7		0.57	0.11	nectarines, fresh	0025	1 med.	136.0
	3	8		0.57	0.11	plums, fresh	0026	2 med.	132.0

Table 1

Comparison of Costs using Four-Day Diet Records or Food Frequency Questionnaires to Monitor Diet in the Women's Health Initiative

Purpose	Number of Measures	Cost: 4-Day Diet Record	Cost: Food Frequency Questionnaire
Screen Women for Eligibility (<38% fat [%En])	540,000	$26,983,800	$1,177,200
Monitor Fat Intake in Intervention Arm	864,000	$43,174,080	$1,883,520
Estimated Cost per Measure[1]		$49.97	$2.18

[1] 1992 Costs for Processing and Quality Control. Does not include participant training, documentation review, or institutional overhead.

Table 2

Comparison of Pasta and Other Grains Items in the Block/National Cancer Institute and Women's Health Trial Food Frequency Questionnaires

Block/National Cancer Institute

Spaghetti, lasagna, or other pasta with tomato sauce

Mixed dishes with cheese (such as macaroni and cheese)

Rice

Women's Health Trial

Macaroni and cheese, lasagna

Spaghetti or other pasta with meat sauce

Spaghetti or other pasta with tomato sauce (no meat)

Rice, noodles or other grains (as a side dish)

Table 3

Comparison of Soup Items in the Block/National Cancer Institute and Women's Health Trial Food Frequency Questionnaires

Block/National Cancer Institute

Vegetable and tomato soups, including vegetable beef, minestrone

Other soups

Women's Health Trial

Creamy and meat soups (chowders, potato, ajiaco, etc.)

Bean soups (pea, lentil, black bean, minestrone, potages, etc.)

Other soups (chicken noodle, vegetable, etc.)

Table 4

Correlations between Nutrients calculated using the Nutrient Data System/Fred Hutchinson Cancer Research Center and National Cancer Institute Analysis Systems, N = 486

Nutrient	Correlation	Difference[1]
Energy (Kcal)	.97	45.3
Fat (%En)	.90	1.7
Fat (g)	.96	4.4
Protein (g)	.98	0.2
Fiber (g)	.80	0.9
Alcohol (g)	.99	0.5

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[1] (NDS/FHCRC - NCI)

Table 5

Correlations of Nutrients Calculated using the Nutrient Data System/Fred Hutchinson Cancer Research Center and National Cancer Institute Analysis Systems with the Mean of Two, Four-Day Diet Records, N=97

	Energy	Fat (%En)	Fat	Calcium	Fiber	Vitamin A	Vitamin C
FHCRC	.31	.64	.46	.61	.44	.37	.33
NCI	.33	.65	.48	.60	.36	.44	.26

References

Block G, Hartman AM, Dresser CM, Carrol MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. Am J Epidemiol 1986; 124: 453-469.

Block G, Woods SM, Potosky A, Clifford C. Validation of a self-administered diet history questionnaire using multiple diet records. J Clin Epidemiol 1990; 43:1327-1335.

Burke BS, Stuart HC. A method of dietary analysis. J Ped 1938; 12: 493-503.

Byers T, Marshall J, Fiedler R, Zielezny M, Graham S. Assessing nutrient intake with an abbreviated dietary interview. Am J Epidemiol 1985; 122: 41-50.

Donelson EG, Leichsenring JM. A short method for dietary analysis. J Am Diet Assoc 1942; 18: 429-434.

Hankin JH, Yoshizawa CN, Kolonel LN. Reproducibility of a diet history in older men in Hawaii. Nutr Cancer 1990; 13: 129-140.

Henderson MM, Kushi LH, Thompson DJ, Gorbach SJ, Clifford CK, Insull W, Moskowitz M, Thompson RS. Feasibility of a randomized trial of a low-fat diet for the prevention of breast cancer: dietary compliance in the Women's Health Trial Vanguard Study. Prev Med 1990; 19:115-133.

Kristal AR, Shattuck AC, Henry HJ. Patterns of dietary behavior associated with selecting diets low in fat: Reliability and validity of a behavioral approach to dietary assessment. J Am Diet Assoc 1990b; 90: 214-220.

Kristal AR, Shattuck AL, Henry HJ, Fowler A. Rapid assessment of dietary intake of fat, fiber and saturated fat: validity of an instrument suitable for community intervention research and nutritional surveillance. Am J Health Prom 1990a; 4: 288-295.

Kushi LH, Sellers PA, Potter JD, Nelson CL, Munger RA, Kaye SA, Folsom AR. Dietary fat and post-menopausal breast cancer. J Natl Cancer Inst 1992; 84: 1092-1099.

London SJ, Colditz GA, Stampfer MJ, Willett WC, Rosner B, Speizer FE. Prospective study of relative weight, height and risk of breast cancer. J Am Med Assoc 1989; 262: 2853-2858.

National Cancer Institute, Division of Cancer Prevention and Control Health Habits and History Questionnaire. Personal Computer System Packet, NCI, 1988.

Nutrition Coordinating Center, University of Minnesota. Nutrient Data System, Release 2.4, 1992.

Sempos CT. Some limitations of semiquantitative food frequency questionnaires. Am J Epidemiol 1992; 135: 1127-1132.

Willett WC. Nutritional Epidemiology. Oxford University Press, New York; 1990.

Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witchi J, Hennekins CH, Speizer FE. Reproducibility and validity of a semi-quantitative food frequency questionnaire. Am J Epidemiol 1985; 122: 51-65.