Validity of a food frequency questionnaire for the determination of individual food intake[1-3]

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ABSTRACT The validity of a food frequency questionnaire for dietary assessment was tested with 31 college students living and dining in a dormitory. A food frequency questionnaire was mailed to participants requesting them to estimate their usual intake of specific food items. Actual food consumption was determined at each meal with self-report forms. These forms required participants to indicate foods chosen at that meal. To test the validity of the frequency questionnaire, regression equations were calculated for each individual using the frequency questionnaire data as the independent variable (X) and actual intake data as the dependent variable (Y). Eighty-four percent of the r values were > 0.50 and 55% were > 0.71. All were significant at the 0.002 level or below. As an alternative test of validity, the percentage of over- and underestimation of each food group was also assessed. Foods which are often major components of a meal (eg, flesh foods) were estimated with greater accuracy than those foods which could be considered accessory (eg, nuts or seeds). While it appears that a large percentage of individuals could accurately estimate their intake with this technique, some individuals were unsuccessful in doing so. Further research is needed to identify individual characteristics which may predict success with this technique. *Am J Clin Nutr* 1984;39:136-143.

KEY WORDS Nutrition surveys, dietary assessment methodology, food frequency questionnaire, validity

Introduction

The relationship between dietary intake and its effect on health is central to the study of nutrition. Paticularly striking examples of this relationship can be seen in the classic symptoms associated with some vitamin deficiencies (1). Despite extensive research in the area of dietary assessment methodology, techniques that are both accurate and feasible for use in "free living" populations are lacking. Several methods have been developed that measure specific food consumption during a given time period, while other techniques have been used to quantify usual or habitual dietary intake. A particularly useful method used to measure usual food consumption is the food frequency questionnaire (2-4). This is a self-administered questionnaire that requires respondents to estimate the frequency of consumption for specified food items. Modified forms have been used to assess consumption of particular

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foods or nutrients (2) or to characterize intake of specific populations (5). Moreover, the frequency method has been used to elucidate associations between dietary habits and disease (6). Widespread use of the technique can be partially attributed to two advantages it has over other "usual" techniques. First, use of the frequency technique may minimize cost and respondent burden since, unlike the diet history method, it does not require a personal interview. Second, it may more accurately measure individual dietary habits than techniques based on household inventory or menu assessment, since the latter provide aggregate information only on foods stored or served, and not on foods consumed by each individual.

Current status of the food frequency method

Despite its widespread use, the validity of the food frequency technique has not been clearly demonstrated. Some data suggest that the food frequency method produces equally accurate estimates of both group and individual intake (4), while other evidence demonstrates that only group consumption can be accurately measured (2, 7). Still other work indicates that this method is a poor estimator on any level (8). These contradictory results can be partially explained by differences in experimental design among these studies. Measuring the validity of this technique requires a substantial sampling of the respondents' actual intake as a basis against which data from the frequency technique can be compared. Such data collection is cumbersome and expensive; however, measuring respondents' actual intake over time has been attempted by various means with limited success. Typically, the actual intake has been determined using another diet assessment method assumed to be more accurate than the frequency technique (2, 4, 5). Hence, the standard for measuring the accuracy of the frequency technique has been different for each study. In addition, the standard itself may have been inaccurate (9–12).

The purpose of the present study was to determine the validity of a food frequency questionnaire using what we consider to be an accurate validity criterion. Actual intake was measured in an indirect, unobtrusive manner. These data were then compared to those obtained with a food frequency questionnaire. We hypothesized that if significant correlations existed between the data sets, the food frequency could be considered a successful estimator of usual dietary intake for individuals.

Methods

Frequency questionnaire

The food frequency questionnaire used in the present study was a listing of 278 commonly consumed foods derived from diets of the principal ethnic groups living in the United States and integrated with standard components of the American diet. It was reviewed against USDA Handbook 8 (13) and Dietary nutrient guide (14) to ensure that commonly consumed food items were not inadvertently omitted. The form had been pretested in the population to ensure that it was representative of the regional food habits. The foods were grouped into categories to facilitate completion of the form by allowing the respondent to judge in relative as well as absolute terms the frequency of food item consumption. Primarily, only single foods were included on the questionnaire; complex entrees were omitted. All items were grouped into 12 food categories on the basis of either physical composition (eg, dairy foods) or cultural use (eg, snacks and desserts). Food intake could be estimated using one of five categories: daily, weekly, monthly, yearly, and rarely/never. Respondents were asked to estimate the number of times per day, wk, month, or yr each item was consumed. The form was mailed at the beginning of the study and returned after completion. Those individuals who had not returned the questionnaire by the end of the study period were telephoned and requested to complete and return it. Individuals failing to do so (n = 12) were not demographically different from those who had (data not shown). Average time reported to complete the questionnaire was 42 min.

Thus our frequency form had a unique feature that facilitated its completion. Participants were allowed to select the frequency category they preferred for each food. Although "once daily" and "seven times per week" represent an equal number of occasions, different categories may be preferred for different foods. This is in contrast to other frequency techniques which require respondents to use researchers' predetermined categories.

Sample

A student dormitory/dining complex at the University of California, Davis, CA was used as a test population. For an extensive description of the population see Krantzler et al (15). This population was sampled using a systematic restricted random sampling technique to ensure approximately the same number of males and females. The advantage of using this sample were: *1*)

foods available to the students were limited, *2*) all ingredients of foods served were known, *3*) participants were centrally located and could be contacted easily, and *4*) unobtrusive observation of the respondents' intake was possible.

Questionnaires were mailed to 48 individuals and 36 were completed and returned. Of these 36 questionnaires five were not usable, thus the final n was 31.

Validity criterion

To determine respondents' actual intake, an indirect observation technique was developed. At each meal, forms listing the total menu along with a nine-point preference rating scale next to each food were distributed (see Appendix for sample form). Participants were instructed to mark food items and number of servings they had *selected* for each meal and to identify how well they liked (preference) each food *selected* using the nine-point scale. Their selections and preferences were recorded during or immediately after each meal. The "preference forms" were then returned with trays to the dishroom where, hidden from view, staff persons visually evaluated them for accuracy. Food items that remained on the trays but were absent from the form, could be identified thus reducing the possibility of losing dietary information. The focus on preferences of foods chosen rather than on food selection itself functioned to deemphasize the monitoring of selection, since individuals may alter their intake if they are aware that their food choices are being observed. Data were collected daily for every meal over 28 consecutive days during the months of May and June. Three meals were served each weekday and two meals each weekend day. Data collected for one meal were not usable, hence the final n (number of meals) was 75. The procedures followed were approved by and in accordance with the Committee on Human Experimentation at the University of California, Davis, CA.

The frequency technique was validated by comparing observed (preference form) data with frequency questionnaire estimates. The data were compared using foods as the unit of comparison. The frequency data were transformed into monthly frequencies, eg, milk reportedly consumed three times per week was converted to 12 times per month (1 month was defined as 28 days). Although preference forms were available for 73 meals, fewer were actually obtained for each individual, and thus observed data were weighted to estimate intake over the entire study period. For example, if 75% of the preference forms were collected from an individual, the observed intake was multiplied by a factor of $1/0.75$. Those participants who consumed fewer than 50% of their meals within the experimental setting were excluded from analysis ($n = 5$). In addition, any foods on the questionnaire never served in the dining commons during the study period were deleted. As a result, while the questionnaire listed 278 foods, only 169 were served and thus used in analyses.

Instead of listing all possible combination dishes individuals might consume, the components of combination dishes were listed singly (eg, tomato sauce) and respondents were directed to estimate intake of these components. The purpose of this was 2-fold. First listing components avoids the use of lengthy lists of complex dishes which would have been tedious to the respondents. Second, it avoided a possible underreporting bias. Because it was virtually impossible to include all dishes, an individual's favorite dish might have been omitted and thus his or her intake would have been underreported.

To test individuals' ability to estimate their intake, Pearson's product moment correlations were calculated for each questionnaire comparing the 169 pairs of foods. Regression equations predicting actual intake (dependent variable, Y) from frequency estimates (independent variable, X) were also computed for each individual. A regression with a slope close to 1 and a Y intercept close to 0 would indicate that the frequency technique has strong predictive value (given $\sigma^2X = \sigma^2Y$).

To determine respondents' ability to estimate their consumption of each food category, the frequency and degree of over- and underestimation of intake for each food category was calculated. This was computed by subtracting the frequency of actual consumption from the questionnaire estimate for that food. If this difference was positive, food consumption was overestimated. Conversely, if it was negative, consumption was underestimated. The degree to which a food group was incorrectly estimated was measured in units of five. That is, individuals are grouped according to whether or not they misestimated their consumption by a factor of 1 to 5 times, 6 to 10 times, etc. Food categories included varying numbers of foods. Hence, the 31 respondents estimating intake of 20 foods in the beverage category generated more frequencies (31×20) than those same individuals estimating consumption of 3 foods in the sugar sweeteners group (31×3). To facilitate comparison between groups, percentages are calculated for the over- and underestimates for a given category by dividing by the number of foods and individuals ($n \times 31$) within that category.

Results

The ability of individuals to estimate their usual intake of 169 foods is presented in **Table 1**. Correlation coefficients ranged from 0.23 to 0.91 with 85% of the values > 0.50 and 55% > 0.71. All correlations were highly significant ($p < 0.002$). The slopes of the regression lines ranged from 0.46 to 2.06 with 32% of the slopes between 0.90 and 1.10 and y intercepts between -0.5 and 3.0. The regression equation for all individuals had a slope of 1.10 and y intercept of 1.78.

The ability of 31 individuals to estimate intake of particular food groups is shown in **Table 2**. In general, most of the food groups were accurately estimated as demonstrated by the large clusters of values around the zero point. However, there was variation in accuracy of estimation among the groups. The dairy category had a high frequency in

TABLE 1
Individual regression equations—regression equations predicting actual intake from frequency questionnaire estimates of all food items for each individual

Regression equation	Correlation coefficient Pearsons r	Level of significance of r
1. y = 0.51x + 1.51	0.52	0.001
2. y = 0.96x + 2.55	0.61	0.001
3. y = 1.08x + 3.11	0.63	0.001
4. y = 0.58x + 3.32	0.50	0.001
5. y = 2.06x + 0.29	0.83	0.001
6. y = 0.91x − 0.29	0.88	0.001
7. y = 1.29x + 1.10	0.71	0.001
8. y = 0.46x × 4.04	0.23	0.002
9. y = 1.14x + 0.63	0.91	0.001
10. y = 1.05x + 0.98	0.72	0.001
11. y = 1.19x + 1.27	0.74	0.001
12. y = 1.09x + 2.69	0.67	0.001
13. y = 1.26x + 2.69	0.77	0.001
14. y = 0.65x + 0.87	0.67	0.001
15. y = 0.92x + 0.92	0.55	0.001
16. y = 1.99x + 1.04	0.78	0.001
17. y = 0.69x + 2.81	0.58	0.001
18. y = 1.51x + 0.62	0.75	0.001
19. y = 0.69x + 1.70	0.54	0.001
20. y = 0.94x + 1.22	0.77	0.001
21. y = 1.63x + 4.27	0.48	0.001
22. y = 0.97x + 4.29	0.47	0.001
23. y = 1.77x + 0.12	0.89	0.001
24. y = 1.00x + 2.48	0.49	0.001
25. y = 1.29x + 0.81	0.84	0.001
26. y = 1.08x + 0.24	0.88	0.001
27. y = 1.65x − 0.14	0.80	0.001
28. y = 0.96x + 4.04	0.48	0.001
29. y = 1.02x + 0.68	0.82	0.001
30. y = 1.25x + 2.35	0.80	0.001
31. y = 0.98x + 1.09	0.76	0.001
Regression for all individuals combined		
y = 1.10x + 1.78	0.66	0.001

the > 30 column; this was primarily due to extreme overestimation of milk consumption. The fats/oils groups also had more overestimations than the other groups, although these errors were divided equally among foods in this category. There were no underestimations in the nuts/seeds group, although two foods, peanuts and sunflower seeds, were each highly overestimated once.

The food group data adjusted to percentages indicate that consumption of flesh foods, grains/starches, and snacks/desserts were more accurately estimated than other categories. The converse was true of fats and oils whose intake was more poorly estimated (Table 2).

Discussion

The range of β values for individuals indicates a moderate variation in individuals' ability to estimate their food intake (Table 1). However, a large percentage of regression equations possessed slopes close to 1 and y intercepts less than 3, demonstrating that many individuals successfully estimated their intake using this frequency technique. The regression line for all individuals demonstrates that this technique was successful in accurately estimating intake of the group.

The distribution of estimation errors for each food group indicates that the frequency technique was highly successful at eliciting accurate estimates of some foods, but less accurate for others (Table 2). Foods that are often major components of a meal and eaten in large quantities, such as flesh foods and grains or starches, were better estimated than foods used in smaller quantities (eg, fats or oils and nuts or seeds). Snacks and desserts were also estimated well. These foods were also consumed in large quantities in this sample; perhaps this large consumption enabled them to be estimated more accurately. In the beverage category, milk was poorly estimated by 12 individuals. This may be a reflection of our inability to measure food consumption outside the dining commons. Several students reported that they ate a bag lunch provided by the food service instead of returning to the dining commons at noon. Buying a beverage such as milk to accompany their lunch was probably not uncommon.

Potential sources of error

In studies involving human subjects, there are many variables that are difficult to control. In our study, aspects of the experimental design and analyses reduced the probability of errors common to other studies. However, we were unable to measure consumption outside the study site, and this inability may have contributed to error in our measurements. We did estimate the percentage of meals eaten within the study site by asking respondents, at the beginning of the study, to estimate on a meal-by-meal and day-by-day basis the number of meals eaten in the dining commons. The average

TABLE 2
Frequency distribution of errors of over and underestimation estimates of food intake by 31 individuals for n foods in each food category*

	Underestimation							Overestimation							
	>30	26 to 30	21 to 25	16 to 20	11 to 15	6 to 10	1 to 5	0	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	>30
Flesh foods				2	3	14	85	162	137	19	1	3	3		
(n = 14 foods)				†	(1)‡	(3)	(20)	(38)	(32)	(4)	†	(1)	(1)		
														(12 from milk)	
Dairy foods	1			1	4	11	55	127	77	12	17	7	7	6	14
(n = 11 foods)	†			†	(1)	(3)	(16)	(37)	(23)	(6)	(5)	(2)	(2)	(2)	(4)
Fats/oils					1	4	5	24	14	10	10	9	4	3	6
(n = 3 foods)					(1)	(4)	(6)	(27)	(16)	(11)	11	(10)	(4)	(3)	(7)
Grains/starches		2	1	5	13	34	132	229	196	27	13	4	4	2	6
(n = 22 foods)		†	†	(1)	(2)	(5)	(20)	(34)	(29)	(4)	(2)	(1)	(1)	†	(1)
Vegetables				1	2	3	55	191	111	18	19	17	3	13	6
(n = 25 foods)				†	†	(1)	(13)	(44)	(25)	(4)	(4)	(4)	(1)	(3)	(1)
Legumes						3	37	127	58	13	2			2	1
(n = 8 foods)						(1)	(15)	(52)	(24)	(5)	(1)			(1)	†
Nuts/seeds								31	58	1	1				2
(n = 3 foods)								(33)	(62)	(1)	(1)				(2)
Berries/fruits		1		1	4	6	44	217	260	39	13	4	7	8	8
(n = 20 foods)		†		†	(1)	(1)	(7)	(35)	(42)	(6)	(2)	(1)	(1)	(1)	(1)
Beverages		1	4	2	3	8	45	299	184	22	7	9	5	15	5
(n = 20 foods)		†	(1)	†	†	(1)	(7)	(49)	(30)	(4)	(1)	(1)	(1)	(2)	(1)
Snacks/desserts				1	1	5	54	275	200	11	3		1		1
(n = 18 foods)				†	†	(1)	(10)	(50)	(36)	(2)	(1)		†		†
Condiments		1			4	6	64	315	214	24	13	11	4	16	3
(n = 22 foods)		†			(1)	(1)	(9)	(47)	(32)	(4)	(8)	(2)	(1)	(2)	†
Sugar/sweeteners						3	9	50	19	5			2		4
(n = 3 foods)						(3)	(11)	(54)	(21)	(5)			(2)		(4)
Total errors of each frequency	1	5	5	13	34	97	585	2047	1528	201	99	64	41	65	56

* Row totals = 31 × N foods in a given category. Because of occasional missing values, row totals may be slightly less than 31 × n.
† Less than 1%.
‡ Percentage errors in parentheses.

number of meals reportedly eaten in the study site was 92.5%. Thus, although we have not measured *total* actual consumption, we believe our measurements are large enough to reflect accurately true food intake. Our validity criterion compares favorably to what typically is used in studies of this type. As noted previously, other researchers have utilized a different self-report method such as dietary recall (16), record (4, 5), dietary history (2, 4, 8), or weighed intake (2). Occasionally, national averages of nutrient intakes such as were collected in the Hanes survey (Health and Nutrition Examination Survey) are used as the validity criterion (17). The data collected by these methods were assumed to represent actual or typical consumption and were used to measure the accuracy of the frequency methods. Yet, the accuracy of these techniques, themselves, is questionable (9–11,18–20).

While our results indicate that the frequency method can accurately measure usual intake of a large percentage of individuals, other research has reported contradictory results regarding its validity (2, 4, 5, 7, 8). Because of the aforementioned weaknesses in their validity criterion, the assessment of the validity of the frequency methods may not be accurate.

Conclusions

This is the first study to test the accuracy of a food frequency checklist using long-term, indirect observation. The accuracy of our assessment method was enhanced by having participants record their preferences (and intake) during or immediately after each meal. In addition, we decreased the potential reactivity by deemphasizing the monitoring of food intake in two ways. First, food preferences were emphasized over food selection, and second, plate waste was examined unobtrusively. Thus, we believe a minimally biased representation of participants' intake was obtained and the validity of the frequency method was evaluated with acceptable accuracy.

For estimating usual intake of a group, this technique appears to be highly successful. Due to its accuracy for groups, ease of administration and low cost, this method may be most appropriate when comparing intake of groups, such as in studies of an epidemiological nature.

We do not, however, recommend the frequency technique as a tool to precisely estimate usual intake of all individuals. The student sample used in our study may have unique characteristics making it unrepresentative of other populations. In addition, while there is a cohort with whom this method is highly successful, there are also some individuals apparently unable to use this technique. A goal of further research in this area is to identify characteristics of individuals such as age, economic status, and educational background which may predict success with this technique.

In addition, the food frequency method does not possess the same level of accuracy for all food categories. Food categories that are major components of a meal were estimated with great accuracy while foods used in small quantities were reported with lower validity. Perhaps other methods, such as repeated dietary recall or records may be more successful in determining usual intake of these less frequently consumed foods.

In previous studies, lack of proper observation techniques may have introduced error and confounded validity assessment of the frequency technique. Establishing accurate validity assessment techniques has been a major problem. While it is very difficult to obtain accurate, long-term representative dietary data from large samples, efforts must be made in this area to clearly determine the validity of dietary assessment techniques.

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Appendix

Form used to collect actual intake data

Meal Card no. _____
Date: 5/19/80
Meal: Breakfast

FOOD PREFERENCE SURVEY

Part I. Please circle the number next to each food item on your tray. In the next column, put the number of servings of the food taken. In column 3, we'd like you to rate the food on a 9-point scale as shown below, to indicate how much you like or dislike each food.

1	2	3	4	5	6	7	8	9
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Food item	No of servings	Rating (circle appropriate no)
1. Fresh apple	_____	1 2 3 4 5 6 7 8 9
2. Fruit cocktail	_____	1 2 3 4 5 6 7 8 9
3. Pear halves	_____	1 2 3 4 5 6 7 8 9
4. Cream of wheat	_____	1 2 3 4 5 6 7 8 9
5. Strawberry crepe	_____	1 2 3 4 5 6 7 8 9
6. Cheese omelette	_____	1 2 3 4 5 6 7 8 9
7. Diced potatoes	_____	1 2 3 4 5 6 7 8 9
8. Hard-boiled egg	_____	1 2 3 4 5 6 7 8 9
9. Cold cereal (specify): _____	_____	1 2 3 4 5 6 7 8 9
10. Milk with cereal	_____	1 2 3 4 5 6 7 8 9
11. Donut	_____	1 2 3 4 5 6 7 8 9
12. Cinnamon rolls	_____	1 2 3 4 5 6 7 8 9
13. Fruit (specify): _____	_____	1 2 3 4 5 6 7 8 9
14. Bread (specify): _____	_____	1 2 3 4 5 6 7 8 9
15. Beverage (specify): _____	_____	1 2 3 4 5 6 7 8 9
_____	_____	1 2 3 4 5 6 7 8 9
_____	_____	1 2 3 4 5 6 7 8 9
16. Other (specify): _____	_____	1 2 3 4 5 6 7 8 9
_____	_____	1 2 3 4 5 6 7 8 9
_____	_____	1 2 3 4 5 6 7 8 9

Part II. Please put a check next to those additional items you ate at this meal:

_____ Salt
_____ Pepper
_____ Ketchup
_____ Mustard
_____ Mayonnaise
_____ Salad dressing
_____ Jam/jelly
_____ Peanut butter
_____ Honey
_____ Ice cream
_____ Sugar
_____ Pickles
_____ Lemon
_____ Oil
_____ Vinegar
_____ Applesauce
_____ Yogurt
_____ Cottage cheese
_____ Soy sauce
_____ Tabasco
_____ Butter
_____ Margarine
_____ other (specify):
_____
_____
_____

Did you take a sack lunch today?

_____ yes _____ no