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Nutrition Research 24 (2004) 29–43

NUTRITION RESEARCH

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Development and validation of a semi-quantitative food frequency questionnaire for young adult women in the southwestern United States

Goldy Chacko George[a], Tracey J. Milani[a], Henry Hanss-Nuss[a], Minseong Kim[b], Jeanne H. Freeland-Graves[a,*]

[a]Division of Nutritional Sciences, 1 University Station, A2700, The University of Texas at Austin, Austin, TX 78712, USA

[b]Department of Educational Psychology, 1 University Station, D5800, The University of Texas at Austin, Austin, TX 78712, USA

Abstract

The purpose of the study was to develop and validate a multicultural food frequency questionnaire[1] (FFQ) for young women in the southwestern United States. The instrument was validated against 3-day diet records in 95 college women, and cross-validated against the mean of two 24-hour recalls and 4-day food records in 50 low-income postpartal women. Internal consistency reliability was assessed via Cronbach's alpha. Validity was examined via descriptive statistics, Pearson's correlations, and cross-classification by quartile categories. Cronbach's alpha averaged 0.75 for food groups in college women and 0.73 in low-income women. De-attenuated Pearson's correlations centered at 0.42 among college women and at 0.45 among low-income women. Cross-classification of participants into quartiles of nutrient intake resulted in 76% of college women and 79% of low-income women being classified correctly. These results suggest that the FFQ is reliable and valid for dietary assessment among young women in the southwestern United States.

Keywords: Food frequency questionnaire; Validation; Southwestern United States; Multicultural; Women

[1]FFQ may be obtained from the author upon request.

* Corresponding author. Tel.: +1-512-471-0657; fax: +1-512-471-5844

E-mail address: jfg@mail.utexas.edu (J.H. Freeland-Graves).

0271-5317/04/$ – see front matter
doi:10.1016/S0271-5317(03)00220-3

1. Introduction

The southwestern United States comprises a culturally diverse population, with sizeable proportions of Hispanics, African-Americans and non-Hispanic whites [1]. This multicultural society has led to a steady assimilation of ethnic foods into the mainstream diet. Dietary patterns in the region also have been influenced by nationwide changes in the food supply, such as the increased consumption of fat-modified foods [2], restaurant/fast foods [3], functional foods [4], and new types of frozen convenience foods. Consequently, instruments that seek to assess dietary patterns must be revised continually to reflect these changes.

Food frequency questionnaires are widely used for dietary assessments in epidemiologic studies [5] due to their cost- and time-effectiveness [6], and ability to measure "habitual" dietary intake [7]. Unlike diet records that reflect intrinsically the diverse nature of dietary patterns, food frequency questionnaires must be tailored specifically to encompass the diets of the target population.

The purpose of the present study was to develop a multicultural, up-to-date food frequency questionnaire (FFQ) suitable for multiethnic female populations in the southwestern United States. This paper describes the validation of the FFQ against diet records in a sample of college women, and cross-validation against 24-hour recalls and diet records in a group of low-income postpartal women. The two specific populations of college and low-income postpartal women were chosen because future studies using this instrument are planned in both of these target groups. As the FFQ was designed to capture overall diet, a wide range of nutrients was included in the present validation study.

2. Methods

2.1. Study design

In Study 1, a food frequency questionnaire was developed and validated using 3-day diet records from 95 female college students enrolled in an introductory nutrition class at a major University in the southwestern United States. The questionnaire was administered on the first class day prior to any lecture. Methods of recording diets were explained and college women maintained 3-day food intake records in the following week.

In Study 2, the instrument was cross-validated utilizing 24-hour recalls and diet records in a multiethnic sample of 50 low-income women, derived from a longitudinal study on postpartal weight retention [8]. Women were recruited 0-1 days following delivery in a hospital and visited our research site at 1.5-, 3- and 6-months postpartum. The 1.5-month postpartal visit was used to provide training to the low-income postpartal women to complete food records accurately. The FFQ was administered at 6-months postpartum. Twenty-four hour recalls and 2-day diet records were obtained at 3- and 6-months postpartum. These time points were within the "previous six months" reference period of the FFQ.

Table 1
Demographic characteristics of participants

Characteristics	College women (n = 95)	Low-income women (n = 50)
Age (y) (Mean ± SD)	20.1 ± 4.3	23.1 ± 4.3*
Race (%)		
White, non-Hispanic	65	34
Hispanic	16	42
African-American	5	24
Other	14	
Weight (kg) (mean ± SD)	60.9 ± 10.5	72.8 ± 17.6*
Body Mass Index (kg/m^2) (Mean ± SD)	22.0 ± 3.1	28.3 ± 7.3*

* Mean estimates for low-income women are significantly different from corresponding means for college women.

2.2. Subjects

Subject selection criteria for the undergraduate student sample in Study 1 included enrollment in an introductory nutrition course, female gender and accurate completion of the food frequency questionnaire. Parameters established for valid completion of the FFQ were caloric intakes within a pre-defined range of 500 to 3700 kcals. The upper threshold of the range was slightly higher than that used previously by Willett [9] to compensate for the high levels of physical activity that are associated with this population of young, health-conscious college women.

In the spring of 2000, completed food frequency questionnaires and 3-day diet records were obtained from 106 college women. Five subjects were eliminated due to errors detected via a modified DietSys® edit-check system [10] and six subjects were excluded due to unreasonable energy intakes. The modified edit check function was used to identify improbable responses to FFQ questions, such as consuming too many (≥50) foods daily. The final sample of 95 college women belonged to a variety of disciplines and comprised mostly freshmen and sophomores (75.3%). The majority of the sample (75.3%) had normal body weights (BMI 19–24); 12.4% were overweight or obese (BMI ≥ 25) (Table 1).

Inclusion criteria for the cross-validation sample in Study 2 were African-American, Hispanic or non-Hispanic White ethnicity; eligibility for Medicaid (≤185% of the poverty guidelines); ability to speak, read and write English; and absence of pregnancy abnormalities and chronic health conditions. It should be noted that this instrument was designed for those who are literate in English. Populations who reside in the southwestern United States and do not speak English may have food habits that are quite divergent from those of persons who have been acculturated into our society. Nonetheless, the food frequency questionnaire has been translated into Spanish and back-translated into English, and is available upon request. At present, it is unknown what proportion of potential minority participants were eliminated by the English literacy criterion.

Valid completion of food frequency questionnaires was indicated by caloric intakes within a pre-defined range of 500 to 5000 kcals. This range was modified from the 500 to 3500 kcals range proposed by Willett [9] for non-pregnant, non-lactating women. Although 5000 kcals may seem to be a high level of habitual caloric intake, equal or higher cut-off values have been used in studies that included ethnic minority populations [11–13]. A lower cut-off of 4000 kcals would have excluded an additional 17% of the African-Americans, and $\leq$ 6% of Hispanics and non-Hispanic whites. Differential exclusion rates among the ethnic groups would limit interpretation of the ethnic sensitivity of the questionnaire. Also, 58% of the women were overweight or obese by 6-months postpartum, suggesting excessive energy intakes.

Sixty-two women recruited until March 2002 were considered for the cross-validation study. Three women were excluded because they had fewer than 5 days of food record data and four subjects were eliminated due to inaccurate completion of the food frequency questionnaire, as indicated by a modified DietSys® edit-check system [10]. Five women were removed due to unreasonable caloric intakes (kcal$>$5000), resulting in a final sample of 50 subjects. The tri-ethnic sample ranged in age from 18 to 38 years. At 6 months postpartum, 22% of the low-income women were overweight (BMI $\geq$ 25 and $<$ 30) and 36% were obese (BMI $\geq$ 30) (Table 1).

The studies were approved by the Institutional Review Board for Human Subjects of the University of Texas at Austin. Informed consent was obtained from each subject prior to participation.

2.3. Food frequency questionnaire

The semi-quantitative food frequency questionnaire was created as a modification of the Health Habits and History Questionnaire (HHHQ) [14]. The modified questionnaire was based on a reference period of the previous six months. The original food list was revised extensively and updated to include ethnic foods from the southwestern United States, low-fat food choices, a greater selection of fast foods and restaurant food items, functional foods and nutritional supplements (Table 2). The updated food list was based on knowledge of the regional food supply, new products in the market, and previously developed and validated questionnaires [15–17].

The final instrument included 195 items, grouped into eight categories: fruits and juices; breakfast foods; breads, snacks, and spreads; vegetables; meat, fish, poultry and mixed dishes; dairy products; sweets; and beverages. Six nutrition professors, dietitians and nurses, who were familiar with the dietary patterns of the target population, confirmed face and content validity of the final foodlist and reviewed the drafts of the questionnaires. Early versions of the questionnaire were tested for ease of administration and comprehension in 50 college women, and revised.

The format for the frequency response section was identical to the HHHQ and consisted of nine possible categories, ranging from “never or less than once a month” to “2+ times per day.” Options for portion sizes were: small, medium, large and extra-large. The use of an “extra-large” serving size option is consistent with observed trends towards the consumption of large food portions in the United States [18]. Medium serving sizes for newly added foods were derived from Pennington [19], the Food Guide Pyramid [20], and a consensus of a panel of nutrition experts.

Nutrient values for the added foods were derived primarily from the United States

Table 2
Examples of line items in the revised food list

Fruits and juices	
	Mango, papaya
	Pineapple
	Raisins, figs
Breakfast foods	
	Breakfast tacos
	Chorizo
	Eggs, migas
	Egg whites, egg substitutes
	Grits, hominy
	Slim-fast®, breakfast shakes, Ensure®, Boost(2)
	Sports bars, PowerBars, Cereal bars, granola bars
Breads/ Snacks/ Spreads	
	Rice: Spanish, fried rice
	Nachos, potato skins with cheese
	Couscous, kasha, bulgar
	Snacks: low-fat, baked, fat-free chips, popcorn
Meat/fish/poultry/nuts/mixed dishes	
	Cabrito, rabbit
	Chicken fried steak
	Fish, mixed dishes: gumbo, etoufee
	Hamburgers, cheeseburgers, meatloaf, picadillo, meat sandwiches
	Meat empanadas
	Meat substitutes: tofu, veggie burgers
	Egg rolls, taquitos, fried fajita pockets
	Beef/bean burritos, soft tacos, fajitas
	Cheese/beef enchiladas, tamales
	Chili relleno
	Crispy tacos, chalupas
	Menudo, posole soup
	Tripas, tongue; stomach, intestine
	Liver, pate, chicken livers, sweetbreads, brains
	Pork and beef ribs
	Seeds: sunflower/sesame/tahini/pine nuts
Vegetables	
	Asparagus
	Avocado, guacamole
	Beans: pinto, kidney, chili, lentils, black
	Beans: refried, baked, dip
	Beets
	Collard greens
	Eggplant
	Peas, black-eyed
	Peppers: green, red
	Peppers: jalapeno, green chilies
	Mushrooms
	Nopalitos
	Okra
	Radishes
	Sprouts: bean, alfalfa
	Green chili sauce
	Other vegetables: jicama, Jerusalem artichokes, water chestnuts, other
Dairy products	
	Cheese, hard: American, cheddar, Swiss
	Cheese, low-fat/non-fat hard:
	American, cheddar, Swiss
	Ice cream: cones, milkshakes, sundaes
	Ice-cream, low-fat, non-fat
	Yogurt, frozen yogurt: regular fat
	Yogurt, frozen yogurt: low-fat/non-fat
Sweets	
	Candy, with nuts: Pralines, Snickers
	Empanadas, pan dulce, conchas
	Jell-O, sherbet
	Sopapillas
	Pies: pecan
	Pies, other: cobblers, crisps
Beverages	
	Coffee (regular, decaffeinated)
	Soft drinks, other: Gatorade, Snapple
	Fruit drinks, Hi-C, Kool-Aid

Department of Agriculture Nutrient Database for Standard Reference [21]. Missing nutrient values were imputed from values for similar foods; values for multi-ingredient foods that were not available in the USDA database were calculated from the nutrient values of their individual components.

Dietary data from the food frequency questionnaire were analyzed using DietSys®, a software program developed by Block et al. [10]. This program was updated with the nutrient values and portion size information for newly added foods. Analysis options provided refinement of nutrient calculations based on participant responses to summary questions. For example, Fruit Adjust checks a summary question on frequency of consumption of fruits with the total of individual fruit items selected. Options that were retained were Fruit Adjust, Vegetable Adjust, Eat Skin (on chicken), and Meat Fat (fat on meat). Those that were turned off were Dark question (dark meat) and Recalc (modification of portion size of energy intake outliers) [22,23]. The analysis options used in the present study are consistent with those used by others [23,24].

2.4. Reference data

The reference data for the measurement of nutrient intakes consisted of 3-day food records in college women, and 6-day diets (two 24-hour recalls and four food intake records) in the postpartal women. All college women provided three days of dietary data. In the 50 low-income postpartal women, 6-day diet records were collected from 46 women and 5-day diet records were obtained from four women. In general, dietary data were obtained in the ratio of two weekdays and one weekend day.

Stringent quality control procedures were applied during all phases of dietary data collection. Professors with expertise in nutrition instructed the college women on how to complete diet records accurately. The young women were encouraged to include details on foods, such as methods of preparation, brand names, and fat contents of meats and milk. Plastic cups, food models and beverage containers were used to facilitate estimation of portion sizes. On receipt, diet records were checked for accuracy and completeness.

Dietary data collection in the low-income postpartal women was carried out by individuals with post-baccalaureate training in nutrition or health sciences. Approximately 1.5 months following recruitment in the study, participating women visited the clinic site and received detailed written and oral instructions for accurate completion of food records. With the help of food models and measuring cups and spoons, participants were trained to estimate portion sizes correctly for the diet records. Subjects were given a set of plastic measuring cups and spoons to take home for use.

Prior to the 3- and 6-month visits, diet record forms and detailed written instructions for accurate food record completion were mailed to participants. Subjects were requested to complete the diet records and bring them in to the research site. At the 3- and 6-month postpartum visits, well-trained project staff reviewed food records for accuracy and completeness, and then conducted 24-hour dietary recalls. A dietitian created a standardized interview protocol, which is available upon request. This interview protocol, food models and memory prompts (measuring cups and spoons, and activities) were used in the administration of the diet recalls. Careful examination of the data revealed that the quality of the recalls and records did not decline between the 3- and 6-month postpartal visits.

Nutrient intakes from the 24-hour recalls in low-income women and the food records from both populations were calculated using Food Processor, version 7.4 (ESHA, OR, 1999). This nutrient database contains information on over 18,000 foods [25]. Graduate students majoring in human nutrition coded the dietary records and recalls. A standardized list of food codes was compiled and this list guided the substitution of food codes for any missing brands in the nutrient database. All data were checked methodically and errors corrected.

In college women, the mean of the three diet records was used in all analyses. In low-income women, paired samples t-test showed that there were no significant differences between nutrient means of the two 24-hour recalls and the mean of the 4-day diet records

($p>0.05$). Nutrient means from the recalls and diet records also were correlated significantly with each other ($p<0.01$); correlations exceeded 0.5 for total calories, protein, dietary fiber, vitamin C, calcium, iron and magnesium. Thus, the diet record and recall values of low-income women were combined and are referred collectively to as diet records in the remainder of this paper. Others have used this combination method [14,26].

2.5. Statistical analyses

Data were analyzed using the Statistical Program for Social Sciences (SPSS) for Windows (SPSS 9.0, Chicago, Ill, 1998). Reliability of the FFQ was tested using Cronbach's alpha, a measure of internal consistency reliability. The method of Cronbach's alpha was an appropriate reliability measure for this study as the FFQ is composed of distinct food groups or domains, each with a number of related items [27]. Foods were categorized on the basis of the Food Guide Pyramid [20], and internal consistency reliability was assessed within food groups. Cronbach's alpha has been used previously to estimate internal consistency reliability of dietary questionnaires [28].

Estimates of absolute nutrient intake in both populations were obtained using descriptive statistics. Paired samples t-tests were used to analyze differences in nutrient means produced by the FFQ and the reference methods in both samples. Nutrients were natural-log or square-root transformed as needed, to increase the normality of their skewed distributions and Pearson's correlation co-efficients were calculated. Correlation co-efficients were de-attenuated to correct for within-person variation in diet records. The formula used was: where r_t is the true correlation between the food frequency questionnaire and the diet records, r_o is the observed correlation between methods, λ (lambda) is the ratio of the within-person variance to the between-person variance, and n is the number of replicate measures of dietary data [29]. The within- and between-person variance components necessary for the above equation were calculated using analysis of variance. Correlation coefficients were not adjusted for energy intake in this study as the instrument is intended primarily for use in community health settings, where absolute intakes are of greater interest than energy-adjusted nutrient values. This is consistent with recent recommendations [23,30] that the use of calorie adjustment be governed by the intended application of the food frequency questionnaire. There are also concerns that energy adjustment might result in inflated correlation coefficients [30].

The ability of the FFQ to assign individuals correctly by quartiles of nutrient intake was evaluated using contingency tables. For this, nutrient intakes from the FFQ and the diet records were classified into quartiles, and percent agreement between the classifications produced by the two methods was determined. Individuals were deemed classified correctly if they were categorized into the same quartile or within one quartile by both methods. Cross-classification by quartiles was used as a criterion for evaluation since food frequency questionnaires are used frequently to study relationships between specific dietary variables and the incidence of disease. In these studies, inappropriate classification of subjects might be of greater consequence than over- or under-estimation of nutrient means [31].

Table 3
Internal consistency as determined via Cronbach's alpha within homogenous food groups of the food frequency questionnaire in college women and low-income women

Food group	Number of items	Cronbach's alpha	
		College women (n = 95)	Low-Income women (n = 50)
Fruits	23	0.73	0.70
Vegetables	42	0.86	0.85
Dairy products	12	0.64	0.58
Meat, fish and poultry	49	0.80	0.84
Grains	19	0.66	0.66
Foods with added fats and sugars	22	0.82	0.74

3. Results

The internal consistency of the FFQ as determined via Cronbach's alpha coefficients for each food group is illustrated in Table 3. The median Cronbach's alpha estimate for food groups was 0.77 in college women and 0.72 in low-income women.

The means and standard deviations of the various nutrients estimated from the diet records and the food frequency questionnaire in the two populations are shown in Table 4. In college women, nutrients that were significantly overestimated by the FFQ relative to diet records were protein, monounsaturated fat, vitamin B1, vitamin B2, vitamin B6, folate, vitamin C, calcium, magnesium, phosphorus, potassium, sodium, zinc and alcohol. Nutrients that were significantly overestimated in low-income women were saturated fat, monounsaturated fat, dietary fiber, vitamin A, beta-carotene, vitamin B1, vitamin B2, vitamin B6, folate, vitamin C, vitamin E, calcium, magnesium, phosphorus, potassium, and zinc. Only dietary fiber was underestimated with statistical significance in college women; none of the nutrients were significantly underestimated in low-income women ($p>0.05$). For energy and the major energy-yielding nutrients, the average overestimation bias was +5.1% for college women and +6.6% for low-income women.

Pearson's correlation coefficients for the nutrients assessed by the FFQ and the diet records also are shown in Table 4. In college women, deattenuated Pearson correlations ranged from 0.24 for sodium to 0.65 for vitamin A, with a mean of 0.42. De-attenuated correlation coefficients in the sample of low-income women ranged from 0.28 for sodium to 0.59 for vitamin E, with a mean of 0.45.

Cross-classification of nutrient intakes into quartiles by the FFQ and the diet records are illustrated in Table 5. This method resulted in 34% of college women being ranked into exactly the same quartile by both dietary methodologies. When considering all nutrients, 76% of college women were classified into the same or adjacent quartile. Individuals who were misclassified greatly, i.e., ranked in the first quartile with either the FFQ or the diet record, and in the fourth quartile with the other instrument, ranged from zero to 10%. The smallest degree of misclassification (0%) was seen for alcohol; the greatest degree of misclassification (10%) was for protein, iron and sodium. Among low-income women, exact concordance (agreement) between the rankings produced by the two methods averaged 39%.

Table 4
Comparison of nutrient values estimated via diet records and semi-quantitative food frequency questionnaire in college women and low-income women

	Nutrient Intakes (Mean ± SD)				De-attenuated Pearson's r[a,b]	
	College women (n = 95)		Low-Income Women (n = 50)		College women (n = 95)	Low-Income (n = 50)
	Diet Record	Food Frequency Questionnaire	Diet Record	Food Frequency Questionnaire		
Energy (keal)	1811 ± 563	1872 ± 649	1983 ± 458	2092 ± 1032	0.53**	0.58**
Carbohydrate (g)	242 ± 82.2	233 ± 89.2	249 ± 64.6	241 ± 120	0.49**	0.54**
Protein (g)	71.3 ± 27.8	79.3 ± 31.9*	77.2 ± 24.8	83.4 ± 44.5	0.38**	0.42**
Fat (g)	61.8 ± 31.2	67.6 ± 29.5	77.3 ± 21.4	89.7 ± 48.5	0.52**	0.46**
Saturated fat (g)	20.4 ± 11.2	23.1 ± 10.6	26.8 ± 7.5	31.6 ± 17.1†	0.53**	0.48**
Monounsaturated fat (mg)	13.4 ± 9.3	25.5 ± 11.9‡	14.4 ± 7.5	34.5 ± 19.4†	0.39**	0.36*
Cholesterol (mg)	210 ± 160	232 ± 132	299 ± 151	305 ± 192	0.34**	0.45**
Dietary Fiber (g)	15.6 ± 6.4	13.7 ± 6.6†	11.7 ± 4.8	13.8 ± 8.6†	0.35**	0.50**
Vitamin A (μg RE)	1050 ± 799	949 ± 608	587 ± 411	861 ± 626‡	0.65	0.42**
Beta carotene (mg)	2703 ± 3829	2266 ± 1935	962 ± 1704	1886 ± 1963†	0.56**	0.38**
Vitamin B1 (mg)	1.2 ± 0.6	1.7 ± 0.7‡	1.1 ± 0.45	1.7 ± 0.9‡	0.34**	0.42**
Vitamin B2 (mg)	1.5 ± 0.56	2.2 ± 0.91‡	1.3 ± 0.53	2.0 ± 1.1‡	0.40**	0.48**
Niacin (mg)	19.6 ± 9.7	21.7 ± 8.5	17.2 ± 6.5	20.2 ± 11.0	0.35**	0.40**
Vitamin B_5 (mg)	1.5 ± 0.6	1.9 ± 0.79‡	1.2 ± 0.51	1.7 ± 0.93‡	0.34**	0.37*
Folate (mg)	260 ± 124	354 ± 172‡	182 ± 97.5	334 ± 201‡	0.38**	0.41**
Vitamin C (mg)	101 ± 65.1	138 ± 84.7‡	71 ± 55.3	118 ± 81.5‡	0.55**	0.51**
Vitamin E (mg)	8.3 ± 7.3	9.4 ± 4.7	6.2 ± 4.9	10.1 ± 7.3‡	0.28*	0.59**
Calcium (mg)	774 ± 317	964 ± 439‡	632 ± 299	882 ± 599‡	0.58**	0.57**
Iron (mg)	13 ± 4.4	13.6 ± 5.3	12.0 ± 4.4	13.6 ± 7.2	0.32**	0.41**
Magnesium (mg)	213 ± 86.4	276 ± 112‡	159 ± 63.6	270 ± 160‡	0.32**	0.50**
Phosphorus (mg)	971 ± 392	1326 ± 519‡	868 ± 327	1277 ± 735‡	0.38**	0.52**
Potassium (mg)	2241 ± 767	2712 ± 1080‡	1747 ± 313	2669 ± 1451‡	0.45**	0.52**
Sodium (mg)	2913 ± 949	3446 ± 1435‡	2964 ± 1009	3480 ± 1998	0.24*	0.28
Zinc (mg)	7.9 ± 3.2	12.0 ± 5.5‡	8.9 ± 3.6	11.8 ± 6.4‡	0.25*	0.44*
Alcohol (g)	3.2 ± 8.6	6.8 ± 8.5‡	0.75 ± 3.4	1.06 ± 2.2	0.47	0.36

[a] Energy and nutrient values were square-root or log-transformed as needed to increase normality prior to calculation of correlation coefficients.
[b] All correlation coefficients were de-attenuated to adjust for within-person variance in diet records.
† Significantly different from diet records within each population, i.e. within college women and within postpartal women: $p < 0.05$
‡ Significantly different from diet records within each population, i.e. within college women and within postpartal women: $p < 0.01$.
* Correlations within each population were significant: $p < 0.05$.
**Correlations within each population were significant: $p < 0.01$.

The mean percentage of low-income women classified into the same or adjacent quartile by the two methods was 79%. In low-income women, gross misclassification by the two methods ranged from 0% for dietary fiber, vitamin C, vitamin E and alcohol to 6% for total fat, vitamin A, iron, sodium and zinc.

Table 5
Cross-classification of college women and low-income women by quartiles of energy and nutrient intakes based on diet records and the newly developed food frequency questionnaire

Nutrient	College women (n = 95)			Low-income women (n = 50)		
	Same quartile (%)	Within one quartile (%)	Opposite quartile (%)	Same quartile (%)	Within one quartile (%)	Opposite quartile (%)
Energy	44	71	4	42	84	2
Carbohydrate	34	79	3	40	82	2
Protein	26	78	10	40	80	4
Fat	37	81	3	38	80	6
Saturated fat	42	80	4	30	82	4
Monounsaturated fat	33	78	7	26	77	4
Cholesterol	38	72	6	42	74	4
Dietary fiber	37	70	7	30	80	0
Vitamin A	41	81	4	40	78	6
Beta-carotene	41	84	1	30	82	4
Vitamin B1	25	76	7	34	70	2
Vitamin B2	36	73	5	40	88	4
Niacin	25	70	8	30	84	2
Vitamin B_6	31	76	7	32	72	4
Folate	33	66	7	40	82	2
Vitamin C	40	81	5	50	74	0
Vitamin E	31	73	6	36	80	0
Calcium	41	74	7	44	82	2
Iron	36	73	10	32	78	6
Magnesium	33	76	6	44	78	2
Phosphorus	31	79	8	42	84	2
Potassium	37	78	5	48	92	4
Sodium	21	69	10	30	72	6
Zinc	34	70	9	38	64	6
Alcohol	33	82	0	70	84	0

4. Discussion

The results of this study suggest that the newly developed food frequency questionnaire is valid for its intended purpose. Mean estimates of internal consistency reliability (Cronbach's alpha) obtained in college women (0.75) and low-income women (0.73) were higher than those reported by Shannon et al. [32] for a fat and fiber-related dietary questionnaire (0.53). The mean value obtained in this study also compares favorably with that reported previously by Murphy et al. [28] (0.64) for a food behavior questionnaire in a convenience sample of 100 low-income women.

The ensuing sections on the validity of the food frequency questionnaire should be prefaced with the caveat that validation studies differ in terms of the demographic characteristics of their study populations, types of reference data used, sample sizes, lengths of questionnaires, and study designs [33]. Hence, meaningful comparison of outcomes from multiple validation studies requires the examination of broad ranges, rather than specific values of validity coefficients and over/under estimation bias [14]. It is in this context that results from the present study are discussed.

Compared to the diet records in this study, the food frequency questionnaire overestimated energy intake by 3.4% in college women and 5.5% in low-income postpartal women. Recent validation studies comparing food frequency questionnaires against diet records and recalls in U.S. women have reported biases in energy intake ranging from –3.4% [33] to +25% [34]. The apparent differences among validation studies in the direction (over- or under-estimation of nutrient means) and degree of bias may be explained partly by variations in the number and specificity of items on the questionnaire [35].

Research suggests that diet records and multiple 24-hour recalls may underestimate energy and nutrient intakes in females by as much as 10–46% [7,36,37]. This may be particularly true for obese subjects [38,39], and may explain the greater difference obtained between food frequency questionnaire and diet record estimates in the low-income postpartal women, 58% of whom were either overweight or obese (BMI $\geq$ 25). It may be plausible that the estimates obtained from the food frequency questionnaire are closer to the true intakes of the participants than those suggested by the diet records and recalls.

The majority of studies validating food frequency questionnaires against diet records and recalls have reported correlation coefficients ranging between 0.4 and 0.7 for nutrients [9]. Pearson's validity coefficients obtained in the present study lie within this range. The mean de-attenuated correlation coefficient obtained in this study (0.42 among college women; 0.45 among low-income women) compares favorably with those reported by Subar et al. [33] for the 126-item Willett food frequency questionnaire (0.33), and are slightly lower than mean coefficients obtained for the 106-item Block food frequency questionnaire (0.50) and the 124-item Diet History Questionnaire (0.54). The correlation coefficients between diet records and recalls in this study are similar to those obtained in other studies by Baumgartner et al. [40] (0.47), Patterson et al. [26] (0.47), Taren et al. [41] (0.48) that evaluate multiple nutrients in southwestern populations. For certain nutrients (eg. riboflavin and potassium), FFQ estimates in the present study were significantly different from those of diet records, even though estimates from the two methods were correlated significantly. It is plausible that although the food frequency questionnaire overestimated means for certain nutrients, it did so in a consistent manner. Although the FFQ demonstrated strong correlations for energy, carbohydrate, saturated fat, vitamin C, and calcium, the psychometric properties of the instrument may be less robust for certain nutrients such as monounsaturated fat, alcohol, vitamin B6 and sodium.

The average correlation obtained in the tri-ethnic sample of low-income postpartal women in this study (0.45) parallels that obtained in a validation study of a food frequency questionnaire vs. diet recalls in low-income pregnant women (0.47) [42]. The mean correlation in the low-income women in the present study (0.45) compares favorably with that seen in the multi-ethnic sample by Kristal et al. [12] (0.4) and the African-American sample by Yanek et al. [13] (0.45), both of which included low-income women.

The mean percentage of subjects correctly classified in the same quartile by both the food frequency questionnaire and the diet records in this study (34% in college women; 39% in low-income women) was comparable to the 35% and 39% reported by Robinson et al. [43] and Andersen et al. [44], respectively, in evaluations of 100-item and 190-item food frequency questionnaires. The favorable correlations and quartile classifications that were obtained suggest that our instrument is suitable for ranking individuals according to their nutrient intakes.

The number of well-designed food frequency questionnaires developed for populations in the United States has increased in the past few years. Populations targeted were the general U.S. population [24,45–48] and specific sub-groups including Asians and Hawaiians [11], African-Americans [13,35,49,50], Korean-Americans [51], Hispanics and non-Hispanic Whites [40,52], tri-ethnic samples of non-Hispanic Whites, African-Americans, and Hispanics [12,53], and minority/multiethnic populations in the southwest [16,17,26,34,40,54,55]. The present instrument builds upon previous food frequency questionnaires for the southwestern U.S. population by incorporating new foods available such as fat-modified foods and a wide variety of ethnic foods. It is essential to continually update food frequency questionnaires because of changing demographics and rapidly evolving food supplies.

Recent evidence suggests that food frequency questionnaires and other self-reported dietary measures, including diet records, may share certain person-specific biases or errors [56] such as misreporting of portion sizes. It is preferable that biases in the reference instrument are independent of those in food frequency questionnaires. One way to overcome this shared bias is to utilize biomarkers such as urinary nitrogen, serum nutrient levels or doubly labeled water [56,57]. Although biomarkers may serve as useful reference instruments for food frequency validation, the cost involved and associated subject burden were outside the scope of this study.

In conclusion, this food frequency questionnaire may be used to identify areas of dietary concern in young adult women in order to better target nutrition interventions, and to examine relationships between dietary patterns and health outcomes.

Acknowledgments

This research was supported by grant RO1 NR04679 from the National Institutes of Health. We are grateful to Dr. Helen Hazuda, Ph.D. and to Ms. Patricia Pillow, M.S., R.D. for sharing their food frequency questionnaires with us, and for offering valuable suggestions regarding the manuscript.

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