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Relative Validity of a Food Frequency Questionnaire Used to Assess Food Intake During a Dietary Intervention Study

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To develop a cost-effective alternative for evaluating dietary intake in large-scale intervention trials of cancer and cardiovascular disease outcomes, we designed and validated a semiquantitative food frequency questionnaire (FFQ). We collected 6 to 8 of the 24-hr dietary recalls from 87 adults (ages 30–72 yr) who were randomly assigned to a walnut-supplemented diet or a control diet in a 6-mo dietary intervention trial. Relative validity of a 171-item FFQ in assessing intake of selected foods and the prescribed intervention (intake ≥25 g/day or intake <2 g of walnuts) was determined using 24-h dietary recalls as the reference. De-attenuated correlations between FFQ and dietary recalls were .82 for walnuts, .80 for fruits, .79 for grains, .77 for vegetables, .63 for water, .44 for sweets, and .36 for dairy/eggs. High within-person variation did not allow de-attenuation for the remaining foods, but uncorrected correlations were high (>.7) for the beverage variables. The FFQ correctly classified 86 out of 87 subjects in the 2 prescribed intervention groups. The FFQ can provide an accurate measure of a food-based intervention (i.e., walnut supplementation) in a trial setting and can also accurately estimate a number of other food groups consumed during the trial.

INTRODUCTION

Compelling scientific evidence points to the protective effects of a healthy diet (1–4) and the benefits of dietary modification in preventing and treating cancer, cardiovascular, and other chronic disease conditions (5–10). Because dietary interventions are increasingly being utilized in the treatment and/or management of chronic disease, a determination of the efficacy of a dietary intervention necessitates valid measures of diet and diet change in large samples. Valid measurement of compliance with dietary intervention presents an additional challenge not faced in observational investigations of diet and disease. Tendency toward reporting socially desirable dietary habits, training effect from repeat dietary measures, as well as complexities associated with intervening lifestyle and behavioral factors also introduce errors in the assessment of dietary intervention. Recently, a food frequency questionnaire (FFQ) has been used to assess dietary change in a number of large clinical intervention trials where the 24-h recall or diet record would not have been practical or cost effective. A few of these large clinical trials have validated the ability of the FFQ to assess nutrient intake using diet records, diet recalls, or biomarkers as the reference (11–14,38,39).

Thus, when considering the prohibitive cost of direct dietary assessment in large samples, developing and utilizing an FFQ becomes a cost-effective alternative to evaluating dietary intake during intervention trials. We designed a semiquantitative FFQ to assess intake of foods and food groups for a dietary intervention trial that investigated the effects of regular walnut consumption on several health parameters (15). Our report has two aims: 1) to validate the food and food group consumption estimates of this FFQ relative to multiple 24-h dietary recalls and 2) to determine how well the questionnaire is able to assess

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the prescribed intervention measures—intake or nonintake of walnuts. We note that none of the existing validated questionnaires for intervention trials (11–14,38,39) have an item for walnuts or other specific nuts. Moreover, the validity of an FFQ to measure a specific food that is part of a dietary intervention has, to date, been done in 1 trial of cruciferous vegetables and breast cancer (38,39). We are especially interested in validation of a questionnaire to assess compliance with future dietary interventions for the prevention and/or management of chronic diseases (cancer, cardiovascular disease) and associated biomarkers.

METHODS

Study Design and Participants

We conducted a dietary intervention trial on free-living adults to investigate the effects of long-term intake of walnuts on body weight (15) and other health parameters. Participants in the intervention study were selected from various Southeast California communities based on their response to recruitment advertisements for a dietary intervention trial. Respondents underwent a selection process that included 2 telephone screenings, an informational meeting, and a personal interview. The previously described selection criteria (15) included weight change <1 kg during the previous 6 mo, body mass index (BMI) <35 kg/m^2, and habitual diet including nuts less than once a week. A weight-related metabolic disorder (e.g., diabetes, hypothyroidism) or aversion or known allergy to nuts excluded an individual from the study. Of the 94 participants who were eligible for the study, 2 dropped out due to compliance difficulty, 2 were withdrawn when diagnosed with metabolic disorder at the time of the study, and 3 completed less than 6 dietary recalls. Thus, dietary assessment data for this validation study is based on 87 participants who completed at least 6 dietary recalls and a self-administered FFQ. The final sample for analysis was composed of 48 females and 39 males, aged 30 to 72 yr (mean = 54.7 yr).

At baseline, we randomly assigned participants to either the control (defined as walnut intake <2 g/day) or walnut-supplemented diet (defined as walnut intake ≥25 g/day). This yielded diet groups that did not significantly differ in age, gender, and BMI (see Table 1). We provided participants in the walnut-supplemented diet prepackaged and premeasured walnuts, which account for about 12% of their daily caloric intake (range = 28–56 g/day), and instructed those in the control diet to eat their usual diet but refrain from eating walnuts and other nuts. In this instance, caloric intake was assessed by 24-h recall. Aside from asking the walnut-supplemented group to eat their daily allotment of walnuts, no other dietary guidance was given to keep the study as free-living as possible.

During the dietary intervention of 6 mo, we collected multiple unannounced, 24-h dietary recalls through telephone interviews. The participants self-administered the FFQ at the end of the 6-mo intervention period.

TABLE 1
Selected Baseline Characteristics of Study Participants in the Dietary Intervention Trial for All Participants and by Diet Groups[a]

	Mean (SD)		
		By Diet Groups	
Characteristic	All Participants[b]	Walnut[c]	Control[d]
Age (yr)	54.7 (10.3)	55.3 (9.9)	54.0 (10.7)
BMI (kg/m^2)	26.4 (3.4)	26.0 (3.5)	26.9 (3.2)
Females (%)	55	58	51

[a]Abbreviation is as follows: BMI, body mass index.
[b]$N = 87$.
[c]$n = 48$, walnut intake ≥25 g/day.
[d]$n = 39$, walnut intake <2 g/day.

Dietary Assessment Methods

Reference method: 24-h dietary recalls. Considering the context in which dietary data were collected and the degree of respondent burden, we chose unannounced, 24-h dietary recall by telephone interview as the reference method for the validation of the FFQ. Furthermore, unannounced, unscheduled dietary recalls may prevent the respondent from planning a favorable intake or the tendency to deviate from one's usual intake. It has also been shown that multiple, unannounced, 24-h dietary recalls may be the preferred method in dietary intervention studies (16).

We collected 6 to 8 of the 24-h dietary recalls (mean ± SD = 6.9 ± 0.4 recalls per participant) through telephone interviews from each participant at intervals of 2 to 5 wk between recalls. To account for day-to-day variation, recalls covered all days of the week. On the average, recall interviews lasted 30 min. For walnut intake in the intervention group, we were able to estimate absolute amount of intake (g/day) using data on whether a subject consumed their specific allotment of walnuts (computed as approximately 12% of daily energy intake) as part of the intervention (15).

Research nutritionists who collected the dietary recalls were trained on the use of the Nutrition Data Systems for Research, an interactive software developed by the Nutrition Coordinating Center, University of Minnesota (17). The nutritionists used a script for the recall interviews and followed protocols to avoid interinterviewer bias and for orderly flow, prompt recording, and precision in the data collection process.

Questionnaire. We designed a 171-item, semiquantitative FFQ to assess food intake in the context of the intervention study that lasted for 6 mo. The questionnaire was administered at the end of the intervention to assess intake during the previous 6 mo, at which time period the dietary recalls were collected. Thus, the time frame covered by the FFQ coincided with that of the dietary recalls. The FFQ was sent to the participants 2 wk before the last clinic. While attending the clinic visit, the

TABLE 2
Food and Food Group Intake Estimates (Servings/Day) of Food Frequency Questionnaire (FFQ) and Multiple 24-h Dietary Recalls (DR) for All Participants[a]

Food and/or Food Group[b]	Description/Items[b]	Mean (SD) Servings/Day	
		FFQ	24-h DR
Grains	Grains and flour; nonsweet and sweet breads; cold and cooked cereals; chips; potato chips; tortilla; crackers; granola and cereal bars; pretzels	3.0 (1.3)[c]	3.5 (1.6)
Vegetables	Raw, cooked, frozen, and canned vegetables; beans and peas; vegetarian meat substitutes; vegetable recipes	4.1 (2.6)[c]	3.2 (1.5)
Fruits	Fresh, frozen, canned, dried fruits; fruit juices and drinks	2.8 (1.8)[d]	1.8 (1.1)
Meats	Red meats; poultry; game; cold cuts and sausages; organ meats; fish and fish roe; shellfish	1.2 (1.2)	1.4 (1.0)
Dairy & eggs	Milk; cream; cheese; ice cream and related products; yogurt; imitation milk, cream, and related products; real and imitation eggs	2.7 (2.3)	3.3 (2.3)
Walnuts	English walnuts	0.5 (0.6)[c]	*0.7 (0.6)*
Other nuts	Nuts and nut butters other than walnuts; seeds	0.3 (0.4)[c]	0.1 (0.2)
Fats & oils	Animal fat; margarines; table spreads; oil; shortening; salad dressing	2.0 (1.2)	1.8 (1.0)
Desserts	Cookies, cakes, pies, puddings, frostings, miscellaneous desserts	0.3 (0.3)	0.4 (0.4)
Sweets	Candy (chocolate and nonchocolate); sugar, syrup, preserves, and jelly	1.3 (2.4)[c]	2.8 (2.4)
Water	Water (bottled, tap)	4.6 (3.3)	4.3 (2.5)
Alcoholic beverages	Liquor, wines, and other alcohol-containing beverages	0.3 (0.6)	0.2 (0.5)
Non-alcoholic beverages	Soda, coffee, tea	2.6 (2.2)	2.8 (2.1)

[a]$n = 87$.
[b]Food grouping adapted from the Nutrition Coordinating Center Food Grouping Scheme.
[c]Significantly different from dietary recall estimates at $P < 0.005$, paired t-test.
[d]Significantly different from dietary recall estimates at $P < 0.0001$, paired t-test.

returned questionnaires were carefully inspected and reviewed with the respondent to ensure no items were missed.

The semiquantitative FFQ used in this intervention study was adapted from a previously validated quantitative FFQ developed at our institution for a longitudinal study (18,19) of a cohort with a high prevalence of vegetarianism. For example, items on whether portion size was small, medium, or large were removed. Because the trial subjects follow a diet pattern more similar to U.S. norms, we modified the original FFQ by removing sections on meat substitutes and adding more sections on animal products and foods consumed in Southern California (e.g., yogurt, food common to the Hispanic diet such as beans, cheese, and tortillas). After these modifications, the questionnaire was pilot-tested for clarity, interpretation, and improvement in format among 10 individuals with similar demographic characteristics but who were not participants in the study.

The FFQ is composed of 171 hard-coded foods that were used in this analysis. Food items are grouped under the following categories: breads, grains and starches; vegetables; legumes and nuts; eggs, dairy products, oils; fish and meats; fruits; beverages; sweets and baked goods; and condiments and dressings. Food portion sizes specified for each item in the questionnaire are based on average serving sizes using familiar measuring devices, for example, cups, tablespoons, glass, can, and others. The frequency section consists of 8 categories: never or rarely, 1 to 3 per mo, 1 per wk, 2 to 4 per wk, 5 to 6 per wk, 1 per day, 2 to 3 per day, and 4+ per day.

Statistical Methods

Validity. We analyzed food intake estimates, expressed in number of servings per day, of 13 food and food groups (see Table 2). Foods were grouped based on the Food Grouping Scheme of the Nutrition Coordinating Center (17). We used the U.S. Food and Drug Administration (FDA) (20) serving sizes to compute intake in terms of amount of servings per day, that is, gram amount of a specific food eaten was divided by the gram amount per FDA serving size. All statistical analyses were performed with Statistical Analysis System (SAS Institute, Cary, NC) software version 8.0 and S-Plus (Insightful Corp, New York, NY).

We determined the performance of the FFQ in estimating food and food group intake estimates at the group level by a paired t-test. Validity of the individual level of intake was assessed with correlation analyses (Pearson's), with correction for measurement errors. Because our intent was to determine the amount of variation explained by the test method on the reference method (i.e., R^2), the use of parametric (Pearson's) correlation analyses does not assume any particular underlying distribution of the variables (21). To correct for attenuation due to within-subjects variation in multiple dietary intake measurements with the reference method (dietary recalls), the following formula was used (22):

$$r_c = r_o\sqrt{1 + \left(S_w^2/S_b^2\right)n}$$

where r_c = corrected/de-attenuated correlation coefficient; r_o = uncorrected/attenuated correlation between FFQ and 24-h recalls; S_w^2 = within-subjects variance of the multiple, 24-h recalls; S_b^2 = between-subject estimate of variance in the reference method (24-h recalls); and n = number of repeated measures of the 24-h recalls.

Correction of the correlation coefficients using the method described above creates conditions in which we could not assume normally distributed errors for r_c. Thus, instead of the traditional asymptotic methods to determine confidence intervals about r_c, we computed "distribution-free," nonparametric 95% confidence intervals using the BC_α bootstrap re-sampling method (23), with each confidence interval determined from the distribution of r_cs from 2,000 samples.

Prescribed intervention measure. To determine if the FFQ was able to capture the prescribed intervention measure on both the control and walnut-supplemented diets, we compared mean intake estimates of the FFQ and the 24-h dietary recalls using a paired *t*-test. The intervention measure was defined as average intake of ≥25 g of walnuts per day among those in the walnut-supplemented diet and nonintake (<2 g) of walnuts among those in the control diet. Serving size for most nuts is approximately 1/4 cup, which is equivalent to 25 g of walnut halves. Thus, we used 25 g as our basis for the prescribed intervention measure for the walnut-supplemented diet group. Conversely, in a free-living situation, it is possible that one would unknowingly consume a walnut-containing food especially if bought commercially or prepared by other people (e.g., cookies). Walnut intake in such a situation becomes unintentional. A teaspoon of walnuts weighs approximately 2 g, and such amount will be unnoticeably present in food. Thus, we defined nonintake of walnuts to be intake <2 g walnuts. For both prescribed intervention measures, we evaluated the degree of agreement between the test and reference methods by cross-classification and graphical means.

RESULTS

Validity

As previously stated, Table 1 shows that the treatment groups are similar in age, gender distribution, and BMI. Food grouping and description of each food and/or food group and the corresponding reported mean (SD) intakes in servings per day are tabulated in Table 2 for all participants. Reported mean intake of walnuts on the FFQ was slightly lower (by about 0.2 servings, $P < 0.005$), and other nuts was slightly higher (by about 0.2 servings, $P < 0.005$). We expected the difference in walnuts because the serving size on the FFQ was based on a familiar unit (i.e., 1/4 cup), whereas that on the dietary recalls was based on the exact weight of the allotted walnuts (which ranged between 28 and 56 g) provided to the participants.

Other trends in Table 2 include an overestimate by the FFQ of vegetables and fruits (by one serving) and an underestimate of sweets (by 1.5 servings) and grains .5 serving). Figure 1 is a graphical summary of how the absolute intake estimates differed between the two methods. Bars on the left side of the "0" value indicate underestimated values on the FFQ, whereas bars on the right indicate overestimation on the FFQ.

Table 3 shows the de-attenuated (corrected) correlation values between the reported intakes on the FFQ and the 24-h dietary recalls. De-attenuated correlations ranged between.36 for dairy and eggs and.82 for walnuts. We also found a de-attenuated correlation of.67 for meats (uncorrected correlation = .20), but because of high within-subjects variance could not get a stable estimate of the confidence interval. Uncorrected correlation values ranged from low ($r = .13$, $P > 0.05$ for sweets) to high ($r = .82$, $P < 0.0001$ for alcoholic beverages). It was impossible to de-attenuate the correlations for other nuts, fats and oils, desserts, alcoholic beverages, and nonalcoholic beverages. This could be due to high within-subjects variance or high within-subjects to between-subject ratios that caused the de-attenuated correlations to go beyond unity. Energy adjustment did not substantially alter these correlations.

Assessment of the Prescribed Intervention Measure

We wanted to determine if compliance with the prescribed intervention measure, that is, intake of ≥25 g walnuts for those who are in the walnut-supplemented diet or nonintake (intake <2 g) of walnuts for those in the control diet, can be assessed accurately by the FFQ. Table 4 shows that mean walnut intake as reported by the control diet group did not significantly differ between the two methods. However, the walnut diet group reported a significantly lower mean intake on the FFQ compared to the dietary recall. As pointed out earlier, this was due to the different serving size units used in the 2 methods. We checked for agreement by categorizing the reported intake according to the definition of the prescribed intervention measure. As shown in Table 5, there is excellent agreement between the two methods on nonintake of walnuts among the subjects in the control diet. In the walnut diet group, one subject reported a higher walnut intake on the FFQ compared to what was actually eaten (dietary recall). Overall, the FFQ was able to assess compliance to the intervention measure reasonably well.

Walnuts allotted to the participants varied according to their energy intake; thus, there is a greater spread in intake among those in the walnut diet compared to those in the control diet as seen in Fig. 2. The Bland–Altman plot (Fig. 3) shows more clearly the agreement between the 2 methods in assessing the

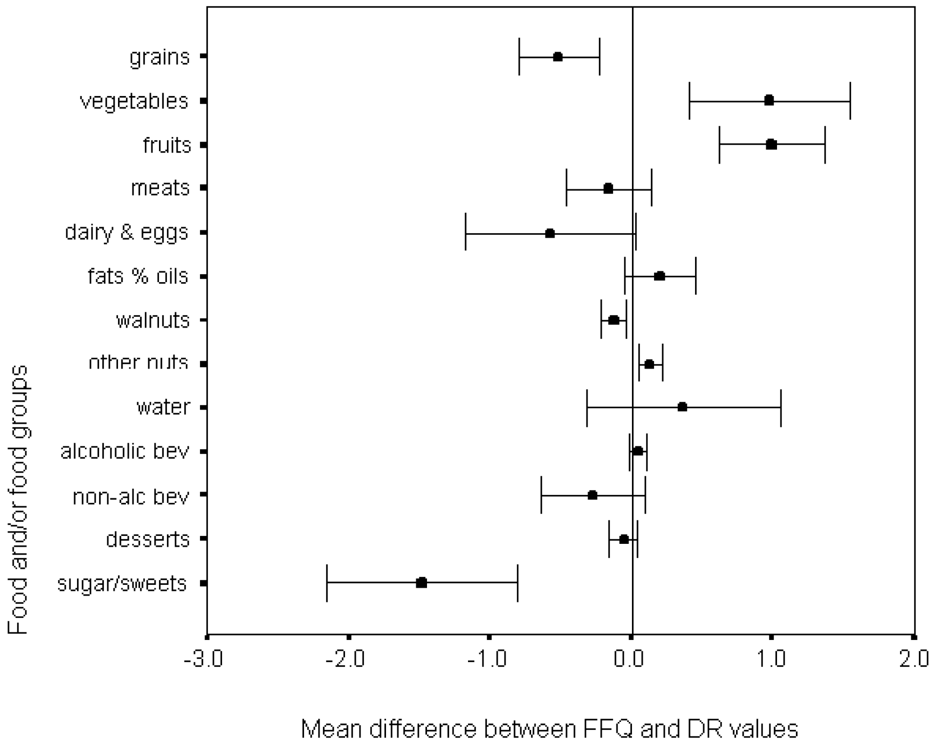

FIG. 1. Mean and 95% confidence intervals of differences between the reported food frequency questionnaire (FFQ) and multiple, 24-h dietary recall (DR) values for the food and food groups. Mean difference is calculated as FFQ – DR. Bars to the right of the vertical line through point 0.0 indicate overestimation by FFQ relative to DR, whereas bars to the left of the vertical line indicate underestimation by FFQ relative to DR.

TABLE 3
Corrected Correlations Between Food Frequency Questionnaire Estimates of Food and/or Food Group Intake and Multiple 24-h Dietary Recalls as Reference Method for All Participants[a]

Food and/or Food Group	Uncorrected r	Corrected r (95% Confidence Interval)
Grains	.47[b]	.79 (.49–1.00)
Vegetables	.25[b]	.77 (−.17 to 1.00)
Fruits	.32[b]	.80 (.09–1.00)
Meats, fish, poultry	.20	[c]
Dairy and eggs	.30	.36 (−.22 to .88)
Fats and oils	.40[b]	[c]
Walnuts	.79[b]	.82 (.63–.97)
Other nuts and seeds	.40[b]	
Water	.44[b]	.63 (.34–.88)
Alcoholic beverages	.85[b]	[c]
Nonalcoholic beverages	.68[b]	[c]
Desserts	.18	[c]
Sweets	.13	.44 (−.40 to 1.00)

[a] $n = 87$.
[b] $P < 0.05$ for the correlation.
[c] Corrected (de-attenuated) correlation could not be computed due to high within-subjects variance for this food.

prescribed intervention measure. There is greater agreement between the two methods for those in the control diet, as shown by the single cluster of points, compared to those who were in the walnut-supplemented diet, which presents clusters of points and a definite overreporter on the FFQ. The same outlier can be clearly seen in Fig. 3.

DISCUSSION

We validated a 171-item, semiquantitative FFQ designed to assess food intake and the prescribed intervention during a dietary intervention trial using multiple, 24-h, telephone dietary recalls as the reference method. To date, we are aware of only one study that has validated an FFQ for the measurement of a specific food in an intervention trial (38,39). In this study in which cruciferous vegetables were part of an intervention diet (38), Thomson et al. found that cruciferous vegetable intake on repeat FFQs showed good reliability ($r = .58$) and was significantly correlated ($r = .26$, $P < 0.01$) with a putative urinary biomarker of crucifer intake. To the best of our knowledge, only 4 dietary intervention studies have validated nutrient indexes derived from their FFQ (11–14).

Our major findings from the FFQ include 1) a high correlation ($r = .82$) with intake of walnuts measured by dietary recalls and a 99% agreement with the classification (by diet recall) of subjects into the two prescribed intervention groups (intake

TABLE 4
Comparison (Paired *t*-test) of Intake Estimates of the Intervention Food (Walnut) in Servings/Day on the Food Frequency Questionnaire (FFQ) and on Multiple, 24-h, Dietary Recalls (DR)

	Mean (SD) Intake, Servings/Day		Mean Difference	
	FFQ	24-h DR	FFQ – DR	*P* Value
Walnut diet group ($n = 48$)	0.98 (0.56)	1.21 (0.25)	−0.223 (0.534)	0.005
Control diet group ($n = 39$)	0.01 (0.03)	0.02 (0.04)	−0.003 (0.035)	0.650

≥25 g/day or intake <2 g of walnuts); and 2) high correlations (>.6, de-attenuated and attenuated) with diet recall measures of fruits, grains, vegetables, meats, water, and beverages. The test food, walnuts, had the highest correlation coefficient among the foods and food groups that were validated in this study. This is expected because, as the test food, intake would be highly variable. On the other hand, the high degree of correlation between the two methods on walnut intake could have been due to compliance bias because the participants were completely aware of the intervention measure and may have reported their walnut intake according to what was expected.

Results for the intervention measure assessment indicate that the FFQ was able to assess nonintake of walnuts in the control diet group better than intake of walnuts in the walnut-supplemented group. The only dietary instruction given to the participants was to eat or not eat walnuts depending on their assigned diet. Such advice should be easy to follow. Compliance would have been harder if the control diet participants were regular walnut eaters, but because we selected study participants who were not regular nut eaters, we did not expect compliance difficulty in this group. Walnut-supplemented diet participants were provided their individual premeasured, prepackaged, ready-to-eat walnuts to make compliance even easier. Average walnut intake in grams as reported on the dietary recalls ranged from 16.5 g to 50.3 g. As seen in Table 5, one of the participants in the walnut-supplemented group had an actual intake lower than that prescribed, and this participant was the reason for the minimum intake value (16.5 g).

Because it is likely that participants in the walnut-supplemented diet may develop an aversion for walnuts over time, we asked the participants to assess their own degree of compliance at the end of 6 mo. In a separate questionnaire, we asked "As best as you can recall, how conscientious were you in taking your allotted walnuts during the past six months?" In this group, 2 indicated they remembered to eat their allotted walnuts 27 to 28 days in a month, 23 remembered to eat their walnuts 29 to 30 days in a month, and 22 ate their walnuts every day; One subject did not answer the question. There was no indication that anyone in the group developed an aversion to walnuts; thus, their reported intake on the dietary recall can be considered their actual intake.

Correlation values for most of the food/food groups in this study are similar to what have been reported in other food-based validation studies (24–29) except for sweets in which reported uncorrected values are higher than $r = .13$. Compared to reported values in other works (30–32), results of this study showed higher correlation values for grains, vegetables, and fruits. None of the food-based validation studies specifically reported validity of intake estimates of water by a FFQ, which was found in this study to be reasonably accurate compared to the dietary recalls. Water intake was found to be associated with fatal coronary heart disease (33); thus, we wanted to validate the ability of this FFQ in assessing water intake.

We found that on our FFQ, there was a tendency toward overestimation of foods considered to be healthy, such as fruits and vegetables, and underestimation of foods that are considered less healthy or unhealthful, such as sweets, on the FFQ. Overestimation of fruits and vegetables in the FFQ was reported in a calibration study conducted among a group of women (34). Conversely, underreporting of foods that are considered unhealthful

TABLE 5
Agreement Between the 2 Methods, Food Frequency Questionnaire (FFQ) and Multiple, 24-h, Dietary Recall (DR), on the Prescribed Intervention Measures by Diet Groups

FFQ	Dietary Recall	
	Walnut-Supplemented Diet Group[a]	
Prescribed Intervention[b]	<25 g of Walnuts, *n*[c]	≥25 g of Walnuts, *n*
<25 g of walnuts, *n*	0	0
≥25 g of walnuts, *n*	1	47
	Control Diet Group[d]	
Prescribed Intervention[b]	<2 g Walnuts, *n*	≥2 g Walnuts, *n*
<2 g walnuts, *n*	39	0
≥2 g walnuts, *n*	0	0

[a] $n = 48$, kappa = .99.
[b] Prescribed intervention is ≥25 g of walnuts for those in the walnut-supplemented diet group and <2 g of walnuts in the control diet group.
[c] n = number of participants.
[d] $n = 39$, kappa = 1.

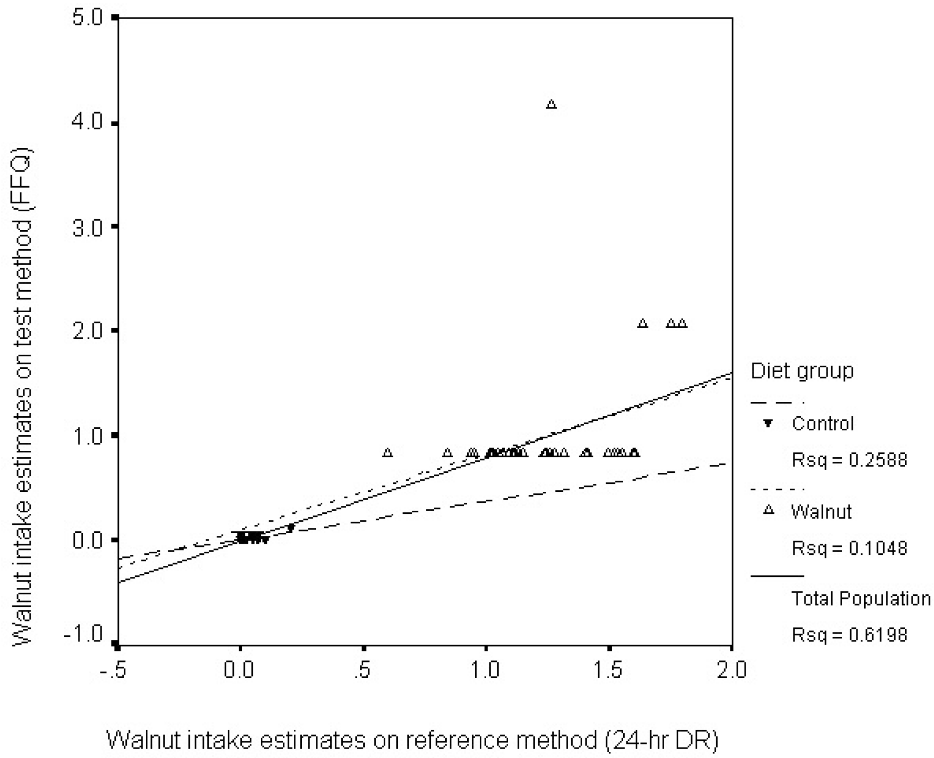

FIG. 2. Plot of walnut intake mean estimates (servings per day) on the test method [food frequency questionnaire (FFQ)] against walnut intake mean estimates (servings per day) on the reference method, multiple, 24-h dietary recalls (DR).

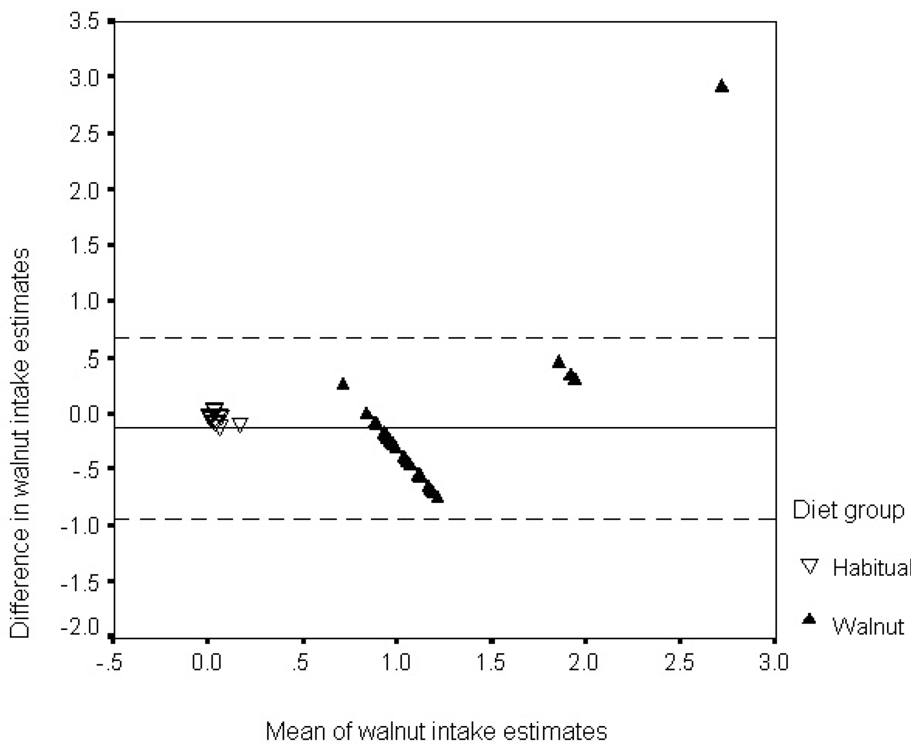

FIG. 3. Differences between the walnut intake estimates (servings per day) from the food frequency questionnaire and the reference method (24-h dietary recalls) plotted against the means of the 2 methods using the Bland–Altman technique. *Note*: broken lines (- - - -) represent the limits of agreement (95% confidence interval), whereas solid line (——) represents the mean.

was observed in another group of women (35). However, it has been demonstrated that the degree of overreporting or underreporting intake may be the same for both men and women and not limited to women alone (36). Our small sample size precluded analyses of intake by gender groups; however, our findings indicate that certain foods tend to be overestimated or underestimated as what has been reported in literature.

One limitation of our study is the use of a reference method that has similar sources of error as the test method: reliance on memory. However, the choice of using multiple unannounced, unscheduled, recalls by telephone interviews has specific advantages that need to be highlighted. Such a method may prevent subjects in an intervention study to plan a favorable intake or to deviate from their usual intake. Because the intervention effect (i.e., dietary intake changes effected by the intervention) is the variable of interest in intervention studies, dietary changes should then be a result of the intervention alone, with reduced contamination by biases of the dietary assessment method. A study that compared dietary assessment methods suggested that multiple, 24-h dietary recalls may be more appropriate for intervention studies (16). Thus, we consider the use of multiple, unannounced, 24-h dietary recalls to validate our FFQ to be reasonable.

Other limitations of this study include differences in portion sizes between the two methods, such as that for walnuts, and multiple food-items on the FFQ. Frequency and serving size differences between the test and reference methods may result in estimation errors on dietary assessment questionnaires, especially when there are multiple foods in an item (37). In our FFQ, the serving size indicated for all nuts, including walnuts, is $^1/_4$ cup, whereas on the dietary recalls, subjects reported their walnut intake in gram weight. One-fourth cup of walnuts amounts to less than 28 g, which explains the discrepancy between the two methods in assessing absolute walnut intake. Another possible source of estimation error is from FFQ items that require participants to average the amounts of intake over a long period of time (6 mo). This is subject to estimation misjudgment that may be different than estimation errors in reporting amounts of intake over the past few hours, as in dietary recalls (22). It is also noteworthy that we have not assessed the reliability of the FFQ in assessment of compliance to the intervention or of other specific foods.

We conclude that this FFQ proved to be a reasonably valid tool in assessing overall food and/or food group intake, especially of the test food, walnuts, in the context of a dietary intervention among free-living individuals. At the individual level, moderate to high degrees of correlation existed between the FFQ and the reference method for most of the food and food groups. However, at the group level, the FFQ overestimated foods considered to be healthy and underestimated foods considered less healthy or unhealthful. This implies that in the context of a dietary intervention, social approval and social desirability may influence the quality of a subject's responses to a dietary assessment tool.

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