Validation of a Food Frequency Questionnaire for Assessment of Calcium and Bone-Related Nutrient Intake in Rural Populations

JANE M. OSOWSKI, MS, RD; TIANNA BEARE; BONNY SPECKER, PhD

ABSTRACT
Objective To assess the ability of a semiquantitative food frequency questionnaire (FFQ) to measure calcium and bone-related nutrient intakes in a rural South Dakota population.

Design Intake estimates from FFQ were compared with four 24-hour recalls obtained quarterly during the preceding year.

Subjects Convenience sample of 100 participants of the South Dakota Rural Bone Health Study were recruited, with 81 completing the FFQ.

Main outcome measures Calcium and bone-related nutrient intakes were expressed as milligrams per day, milligrams per 1,000 kcal, or quartiles.

Statistical analyses performed Intakes by FFQ and 24-hour recalls were compared using paired t test and quartiles were formed to examine cross-classification.

Results Calcium intakes from FFQ and recalls were 1,287 and 1,141 mg/day (P=0.01), but calcium per 1,000 kcal did not differ. Calcium intake by FFQ correlated with intake by recall when expressed as milligrams per day (r=0.49, P<0.001) or milligrams per 1,000 kcal (r=0.59, P<0.001). Bland-Altman graphs indicated fairly good agreement between methods. Seventy-eight percent of subjects fell into the same or within one quartile category when calcium intake was expressed as milligrams per day and 83% when expressed as milligrams per 1,000 kcal. Gross misclassification occurred in 0% to 4% of the nutrients.

Conclusions Although FFQ may not be a valid indicator of an individual's intake, it does adequately classify rural populations into quartiles of calcium and bone-related nutrient intakes, making it a useful tool for assessing dietary calcium and bone related intake in rural populations.


The food frequency questionnaire (FFQ) is often the method used for assessing nutrient intake in epidemiologic studies. The underlying principle of the FFQ approach is that average long-term diet, such as consumption patterns over weeks, months, or years, is theoretically a more relevant determinant of chronic disease than intake on a few specific days. Therefore, it may be more useful to give up the precise intake measurements obtainable on one or a few days in exchange for more crude information relating to an extended period of time. FFQs must be validated against more detailed and accurate methods of assessment, such as diet records (1).

In several studies of their validity, FFQs have been found to be reasonably accurate and are inexpensive to administer and process (2-13). The majority of these studies were completed in urban populations or with groups of people who maybe be more keenly aware of their diet, including nurses and health professionals (2,5). The educational background of these two groups could influence their diet record keeping and accuracy. In a rural farming population, the Willett FFQ has not yet been validated.

The assessment of dietary calcium intake is of interest when studying bone health in population groups because dietary calcium has long been considered to play a role in the development of age-related osteoporosis. Several validation studies using FFQs designed to specifically assess calcium intake have been completed (14-19). Angus and colleagues (18) compared a short FFQ with 4-day weighed food records and found that a short, simple questionnaire can be used to rank individuals according to adequacy of calcium intake. In a study completed by Cummings and colleagues (17) two FFQ methods were evaluated for their ability to measure current dietary calcium intake in elderly women. The responses from the FFQs were compared to 7-day food records and the authors concluded that brief food frequency instruments that rate portion sizes on a simple qualitative scale may be suitable for many clinical uses and adequate for some types of epidemiologic studies of calcium intake in elderly women. Other studies have similar findings (14-16,19).

To determine the ability of an FFQ to measure intakes of calcium and calcium-related nutrients in rural populations, we compared estimates of intakes of dietary calcium and bone-related nutrients using the Willett semi-
quantitative FFQ, which has been previously validated in a population of male health professionals (5), with results of four 24-hour dietary recalls obtained during a previous 1-year span. We hypothesized that the FFQ may not work as well in our populations due to consumption of foods that may not be captured through the FFQ (ie, from hunting, fishing, and production of own food products as well as recipes or food items unique to the Hutterites that have been passed down through many generations [20]).

METHODS AND MATERIALS

Subjects

The subjects in this study are a sample drawn from a longitudinal study of lifestyle (rural vs nonrural) factors on bone mass accretion (21). The South Dakota Rural Bone Health Study consists of rural (n = 937), and nonrural (n = 337) populations. Within the rural population there were Hutterites (n = 587) and non-Hutterites. To be considered as rural the subject had to have spent 75% or more of their life on a working farm or ranch while working fewer than 1,040 hours per year off the farm. To be classified as Hutterite an individual had to be of Hutterite descent and currently residing on a Hutterite colony (21). The non-Hutterite population was recruited from an eight-county area in eastern South Dakota that included at least one participating Hutterite colony. For the duration of the study, all participants completed a 24-hour dietary recall every 3 months with one recall per season. During the year after the 24-hour recalls were collected, a convenience sample of 50 rural non-Hutterite and 50 Hutterite subjects were recruited to take part in the validation study. The rural non-Hutterite subjects were recruited through telephone calls and asked to participate by completing the self-administered semiquantitative FFQ. The FFQs were mailed to the rural non-Hutterite participants to complete. Written information was included on how to complete the questionnaire and they were instructed to return them in postage-paid return envelopes. For the Hutterite population the FFQ information was completed during a visit to the colony. Verbal instructions were provided for completing the FFQ. All participants were provided a $5 gift card for their involvement. The South Dakota State University Institutional Review Board approved the study, and the participant’s willingness to complete the form was their consent to participate.

24-Hour Dietary Recalls

All study participants had completed four 24-hour dietary recalls within the previous year except for one participant who had completed only three recalls. The 24-hour dietary recalls were obtained by trained interviewers approximately every 3 months. The timing and quantity of recalls provided information throughout all seasons (1). During the first visit for the South Dakota Rural Bone Health Study, trained interviewers displayed measuring cups and spoons, as well as food models to educate participants about how to estimate serving sizes in the 24-hour recall. For the rural non-Hutterite population, the 24-hour recalls were conducted by face-to-face interviews for one visit and over the telephone for three visits. Because these participants had their 24-hour recall interviews scheduled at different dates and were not in one central location, three of the visits were done over the telephone. For the Hutterite population, the 24-hour recall information was gathered through face-to-face interviews for all visits. The large number of participants living in one location made it feasible to do the 24-hour recalls during one trip to a colony every 3 months. The 24-hour recalls were obtained at random times to help capture a typical intake during the week. The analyses of the 24-hour recalls were performed using Nutritionist Pro (version 2.3.1, 2004, First Databank, Inc, San Bruno, CA). For foods that were not in the database, recipes were obtained from the participants and the component foods were entered and the recipes were added to the database. The mean daily intakes of energy, carbohydrate, fat, protein, and bone-related nutrients such as calcium, vitamin D, phosphorus, and magnesium were determined for each participant. Throughout the Rural Bone Health Study, a quarterly quality assessment was performed to ensure accuracy and consistency in the analysis of dietary intake records. Each quarter a total of 10 completed diet analyses from each person analyzing diets were randomly selected and reanalyzed by a registered dietitian. The registered dietitian compared the results of the original diet analysis vs the reanalysis, wrote a report of the findings and communicated the results appropriately.

Self-Administered Semiquantitative FFQ

Study participants were asked to complete the Willett 97GP 2003 version self-administered semiquantitative FFQ (22) (97GP copyrighted at Harvard University). The 20-page semiquantitative FFQ consisted of 138 foods, including low-fat and nonfat foods. This tool was designed to group individuals according to levels of average daily intake of selected nutrients during the past year. Participants were asked to report on average their usual eating pattern during the past year of a specific food or dietary supplement. The subjects were required to indicate the number of times per day, per week, or per month that food or drink items or dietary supplements were consumed. Estimation of serving sizes were indicated in usual household measures (eg, a turkey sandwich, one orange, or a slice of bread) whenever possible, or otherwise typical serving sizes were provided (eg, 8 oz glass of skim milk, or ½ c blueberries, fresh or frozen). For specific vitamin and mineral supplements, subjects were required to indicate if they currently consume the supplement, have consumed it in the past only or have never taken the supplement. They also were required to indicate how much of the supplement, on average, they consumed per day choosing from a dosage range and how long the supplement had been consumed (a series of ranges from 0 to 1 years to 10 or more years). The completed FFQs were checked for completeness and then were mailed to the Harvard School of Public Health for analysis.

Statistical Methods

The majority of the distributions for calcium and the bone-related nutrient intakes were skewed to the higher
end. Therefore the geometric means and 95% confidence intervals for the means were calculated and a paired t test was performed to determine if they differed. Bland-Altman graphs also were obtained to determine if the difference between the FFQ and mean intake from the recall varied depending upon the nutrient intake (23,24).

Energy adjustment was done by expressing nutrient intake per 1,000 kcal. Spearman correlation coefficients were used to compare the two dietary assessment methods for both unadjusted and energy-adjusted nutrients. Spearman correlation coefficients also were obtained to assess agreement over time between the FFQ and the four 24-hour recall visits. Quartiles were formed for intakes based on both the 24-hour recalls and the FFQ to examine their cross-classification using contingency table analysis. For both FFQ and 24-hour diet recalls, separate quartile cutpoints were established from their respective distributions of nutrient intake. If a correlation coefficient of approximately 0.60 between the amount of intake estimated by the 24-hour recalls and that intake estimated by the FFQ is expected, at a 5% significance level and 80% power approximately 110 subjects were required to guarantee that the lower limit of the 95% confidence interval of the correlation coefficient was at least 0.40 (1). Our sample size of 81 subjects resulted in a power of 67%.

All statistical procedures were performed using the JMP IN statistical software package (version 5.1, 2003, SAS Institute, Cary, NC).

RESULTS

Of the 100 subjects initially invited to participate in the study, 81 (47 women) completed the FFQ. The 81 who completed the study had an average age of 42 years with a range of 17 to 74 years. Forty-five were Hutterites and 36 were rural non-Hutterites. Hutterites reported a greater intake of energy, carbohydrate, and fat than non-Hutterites. Nineteen subjects (five Hutterites) chose not to complete the FFQ. There was no difference in age or sex distribution between those subjects who completed the FFQ and those who did not.

The average nutrient intake calculated from the FFQ was statistically greater than that calculated from the average of the 24-hour recalls for all nutrients except total energy and fat (Table 1). When the calcium and bone-related nutrients were adjusted for energy intake, the difference between the means was no longer significant for calcium. The difference between the two means did not vary depending upon mean nutrient intake for the majority of nutrients (Table 1). The Bland-Altman plot for calcium is shown in the Figure. These results indicate that the two methods showed fairly good agreement; however, phosphorus and magnesium showed poor agreement after adjusting for energy, despite fairly good correlation coefficients (Table 2).

The correlation between FFQ and 24-hour recall was 0.55 for energy intake, 0.41 for protein intake, 0.47 for carbohydrate intake, and 0.55 for fat intake (all $P<0.05$). The correlations for the bone-related nutrients are given in Table 2, with and without adjustment for total energy intake. To check for agreement over time between the 24-hour recalls and the FFQ, calcium intake (milligrams per day) assessed by the FFQ was correlated with each of the 24-hour recalls. At each of the four visits there was correlation of $r=0.41$, $r=0.41$, $r=0.37$, and $r=0.31$, (all $P<0.01$), for the most recent 24-hour recall to the most remote. To determine if the relationship between FFQ and 24-hour recall of bone-related nutrient intake varied by the potential confounders of sex, age, or population group (Hutterite vs non-Hutterite) the interaction of each of these potential confounders with 24-hour recall intake was tested while modeling for FFQ intake. The interaction term was not significant for any of the minerals, implying that these different variables did not modify the relationship between 24-hour recall and FFQ.

Comparisons of quartiles by each method were used to assess the degree of misclassification. Using calcium as an example, Table 3 summarizes the joint classifications for calcium intake (milligrams per day) assessed by FFQ and 24-hour diet records. Seventy-eight percent of subjects when classified by the FFQ for calcium intake (milligrams per day) fell into the same or within one quartile category when classified by the 24-hour diet recalls. Thirty-three percent were classified into the same quartile by both methods. Only two subjects (2%) were grossly misclassified. When looking at energy-adjusted calcium int-

### Table 1. Calcium and bone-related nutrients based on average intakes from 24-hour recalls and food frequency questionnaire (FFQ) completed by a sample of a rural US population. Data are geometric means and 95% confidence intervals (CIs) for the mean (n=81)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Method</th>
<th>Mean</th>
<th>95% Cl</th>
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<tbody>
<tr>
<td><strong>Daily Intake</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Calories (kcal/d)</td>
<td>24-h recall</td>
<td>1,942</td>
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<td>Protein (g/d)</td>
<td>24-h recall</td>
<td>84b</td>
<td>78-90</td>
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<tr>
<td></td>
<td>FFQ</td>
<td>92</td>
<td>86-99</td>
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<tr>
<td>Carbohydrate (g/d)</td>
<td>24-h recall</td>
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<td>211-241</td>
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<td></td>
<td>FFQ</td>
<td>247</td>
<td>227-269</td>
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<tr>
<td>Fat (g/d)</td>
<td>24-h recall</td>
<td>78</td>
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<td>70-83</td>
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<td>Calcium (mg)</td>
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<td>Vitamin D (IU/d)</td>
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<td>FFQ</td>
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<td>293-411</td>
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<td>Phosphorus (mg/d)</td>
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<td>FFQ</td>
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<tr>
<td><strong>Intake per 1,000 kcal</strong></td>
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<td>Calcium (mg/1,000 kcal)</td>
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<td></td>
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<td>169</td>
<td>162-176</td>
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</table>

*Positive slope for the relationship between the difference of mean intake by FFQ and 24-h recall vs the mean intake by FFQ and 24-h recall ($P<0.05$).

bIntake by 24-h recall significantly different than by intake by FFQ ($P<0.05$).

cNegative slope for the relationship between the difference of mean intake by FFQ and 24-h recall vs the mean intake by FFQ and 24-h recall ($P<0.05$).
take by 24-hour recalls and FFQ, 83% of subjects fell into the same or into the within-one-quartile category (Table 4) and 44% were classified into the same quartile by the two methods. Only one subject was grossly misclassified by the FFQ. For all nutrients, approximately 2% were grossly misclassified into extreme quartiles (Table 5).

**DISCUSSION**

Other researchers have reported on validation studies using various FFQs for dietary calcium intake (14-19). However, comparisons among studies can be difficult due to differences in sample size; age, sex, racial composition, and educational background of the study group; design of the FFQ (for example the number of food items, the amount of open and closed questions, and length of reference period of the recall); and the method used as the gold standard. All of these factors, in addition to others, may be related to the degree of agreement among methods.

In the validation of nutritional assessment methods, the reference measurement should be as accurate and as precise as possible, and any errors associated with the two methods should be independent (1). For this study we compared individual nutrient intakes estimated by a semiquantitative FFQ with intakes calculated from four quarterly 24-hour diet recalls collected by interview during the previous year in a rural population of both Hutterite and non-Hutterite men and women. The 24-hour recalls, which depend on recent memory, may have more reliable and valid mean values for nutrients than those from the FFQ, which depend on long-term memory. The timing and number of 24-hour recalls provided data during all seasons (1). One limitation of using FFQs in our rural population is the difficulty with estimating what is consumed on average throughout the year because some of the foods consumed vary depending upon season. For example, fresh garden fruits and vegetables may be consumed in greater amounts when they are in season compared to when they are not readily available, whereas cream-based soups may be consumed more often during the fall and winter months.

Our FFQ validation method is comparable to the validation method used by Subar and colleagues (7). For their study, four 24-hour recalls, scheduled 3 months apart...
were collected and compared to three different FFQs. The authors concluded that after energy adjustment, all three methods were comparable for purposes of assessing diet–disease risk.

The estimate of mean calcium intake and other bone-related nutrients recorded in this study using the FFQ were higher than the estimates recorded using the 24-hour recall. Other researchers have reported the usual tendency of FFQs to overreport nutrient intakes more than 24-hour recalls (8,16,25-28). To reduce extraneous between-person variation due to general overreporting or underreporting of food intake, nutrient intakes per 1,000 kcal were calculated. Our results showed the difference in calcium intake per 1,000 kcal between the FFQ and the 24-hour recalls was not different from zero, consistent with other reports (2,5,7,13,28). However, the difference between estimated intakes obtained from the two methods for the other bone-related nutrients persisted even after adjusting for energy intake. Using the Bland and Altman plots we also found for the majority of nutrients...
that the difference between the two methods varied depending upon the mean intake of the nutrient.

Despite these results, the nutrients compared well when cross-classified by quartiles of intake. Cross-classification according to quartiles of intake showed reasonable agreement between the two methods. For all nutrients, approximately 2% were grossly misclassified into extreme quartiles and is consistent with other reports (5,14). Rimm and colleagues (5) found that on average only 4% were grossly misclassified into extreme quintiles in their study. For epidemiologic purposes, the potential of a questionnaire to categorize individual subjects by level of nutrient intake is more important than the capacity to measure group means (1).

Our study sample represents a population of individuals who have lived a rural lifestyle for the majority of their lives. The correlation coefficients of unadjusted calcium intake assessed by the two methods was comparable to those obtained for other validation studies in the general population, which usually reported correlations in the range of 0.45 to 0.79 (4,7,8,13,17,18,28). Longnecker and colleagues (28) studied a rural population and found the energy-adjusted correlation between diet records and the FFQ for calcium was 0.58, similar to our findings.

It is assumed that the most recent 24-hour recall would correlate more closely with the FFQ because it is most recent in memory. Our study found that the correlations between the four dietary recalls visits and the FFQ were similarly correlated. We speculate that for our study the reason the correlations were similar over time is that there was sufficient time between the last 24-hour recall and the administration of the FFQ that the participants were not influenced by their memory of their most recent 24-hour recalls.

**Strengths and Limitations**

The use of 24-hour diet recalls is not a perfect standard for judging the accuracy of assessing dietary intake because it may not necessarily be representative of usual intake. However, the timing and number of 24-hour recalls should help capture variability of usual intake, and is an important strength of this study.

This study has some limitations. One limitation is a relatively small sample size; 81 respondents completed both the 24-hour recalls and the FFQ. This study population is a select group of people from rural areas of South Dakota and is not a representative sample of the general US population. However, we believe this study provides evidence that a semiquantitative FFQ can adequately group rural individuals into appropriate intake categories to study the relationship between diet and disease among populations.

**CONCLUSIONS**

The significant differences in mean intakes between the two methods, and the fact that the differences in the mean intake varied across intake levels indicates that the FFQ may not be a valid indicator of an individual’s intake. However, these findings do provide evidence that the semiquantitative FFQ developed by Willett and colleagues (22) was able to adequately classify the population into quartiles of calcium and bone-related nutrient intakes.

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**References**


