

Reproducibility and validity of a quantitative food frequency questionnaire in an urban and rural area of northern India

R. MAHAJAN, M. MALIK, A.V. BHARATHI, P.V.M. LAKSHMI, B.K. PATRO, S.K. RANA, R. KUMAR

ABSTRACT

Background. Food frequency questionnaires (FFQs) have been used in epidemiological studies across the world to capture the usual food intake of individuals. As food habits vary in different population groups, FFQs should be validated before use. Hence, we determined the reproducibility and validity of FFQs designed for urban and rural populations of northern India.

Methods. Separate FFQs, designed for urban and rural populations using standard methods, were administered to a sample of 200 subjects (100 urban and 100 rural) in the age group of 35–70 years in the beginning (baseline FFQ) of the study and after an interval of 1 year (1-year FFQ) to assess their reproducibility. Six 24-hour dietary-recalls, taken at an interval of 2 months over a period of 1 year, were used as a reference method to test the validity. Crude and energy-adjusted nutrient intakes estimated from FFQs and 24-hour dietary-recalls were compared using Pearson correlation coefficients. Bland and Altman plots were also used to test the agreement between the two methods.

Results. Nutrient intakes were found to be similar at the baseline and 1-year FFQs in urban and rural areas. The unadjusted Pearson correlation between 24-hour dietary-recalls and 1-year FFQ ranged from 0.22 for vitamin C to 0.63 for iron in the urban area. It ranged from 0.06 for vitamin C to 0.74 for energy in the rural area. The correlations lowered after adjusting for energy and there was a minimal increase after de-attenuation.

Conclusion. The FFQs were reproducible and valid for assessing nutrient intakes except for some micronutrients.

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INTRODUCTION

In large-scale epidemiological studies, different nutritional assessment methods such as multiple-day diet-recall, food record

Post Graduate Institute of Medical Education and Research, Chandigarh 160012, India

R. MAHAJAN, P.V.M. LAKSHMI, B.K. PATRO, S.K. RANA, R. KUMAR School of Public Health

Home Science College, Chandigarh, India
M. MALIK

Indira Gandhi National Open University centre, Bengaluru, Karnataka, India
A.V. BHARATHI

Correspondence to R. KUMAR; dr.rajeshkumar@gmail.com

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and diet history have been used. However, each of these methods have both advantages and limitations.^{1,2} Food frequency questionnaires (FFQs) have emerged as a useful alternative tool in epidemiological studies across the world because of their low cost and ease of administration.³ The FFQ method is robust in capturing habitual dietary intakes and for measuring energy, macronutrient and micronutrient intakes over an extended period which is of interest in studying diet–disease relationships.^{4,5}

The use of FFQs has previously been reported mainly in studies from the West.^{6,7} As FFQs are cost-effective and pose less burden on subjects as compared to other dietary assessment methods, they have become popular in studies done in Indian settings as well.^{8–14} A single FFQ is not representative of dietary intakes of different populations with varying food habits,^{9,10,15} hence, specific FFQs need to be developed and validated for different regions of the country. We aimed to determine the reproducibility and validity of an FFQ developed in northern India by assessing the degree to which FFQs agree with 24-hour dietary-recalls conducted at regular intervals over a year.

METHODS

This study was done in an urban and a rural area of northern India. The urban area was in a sector of Chandigarh city. The rural area was located in Raipur Rani Block of Haryana, about 50 km from Chandigarh. The study areas were purposely selected as community health work is being done in these areas by the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh. The Prospective Urban Rural Epidemiological (PURE) study is also being done in these areas, and has recruited subjects in the age group of 35–70 years.¹⁶ The first 100 individuals each from the urban and the rural area, recruited in the PURE study, who were likely to be available for the next 12 months and agreed to participate, were included.

Food frequency questionnaires (FFQs)

Separate FFQs were developed for the urban and rural areas as food habits vary in these areas. An initial survey was done to obtain information on commonly consumed local foods and dietary habits of the residents. Local people, street vendors, shopkeepers and persons eating at food outlets were interviewed. Data on availability of fruits and vegetables during different seasons were obtained from local vendors. Based on this information, extensive food lists (backbone of an FFQ) were prepared which included raw, cooked and mixed dishes (e.g. *khichdi*: a preparation made from pulses and rice). A trained nutritionist checked the food list, reviewed Indian food composition

tables¹⁷ and included other locally available foods that were left unreported but were rich in nutrients.¹³

The food list was divided into nine food groups namely cereals (e.g. *chapati*), pulses (e.g. *moong dal*), *chutneys/soups* (e.g. coriander *chutney*, vegetarian/non-vegetarian soup), non-vegetarian/egg (e.g. boiled egg, roasted chicken), snacks (e.g. *samosa*), desserts/sweets (e.g. ice cream), beverages (e.g. milk), miscellaneous (e.g. butter, jaggery), fruits (e.g. banana) and vegetables (e.g. ladyfinger). There were 5–19 food items in each group. Related food items such as *chapati*, bread, etc. were grouped together. We showed different visual aids such as glass (200 ml), bowl (*katori*) (200 g), teaspoon (5 g), table (service) spoon (100 g), etc. to the subjects. The individuals reported usual portion sizes of foods consumed by viewing these standard household measures such as glass for milk, *katori* for bengal gram, tablespoon for vegetables, teaspoon for butter, etc. Natural units were used for some food items, e.g. a unit for egg, a slice of bread. The respondents reported the average consumption and frequency of intake of each item in the food list expressed as per day, per week, per month, per year or never for foods consumed by the individual in the past one year.

The FFQs were pretested to determine completeness of the food list and to check the feasibility of the questionnaire. Appropriate changes were made and final FFQs were developed to capture dietary intake of subjects over the past one year. The urban FFQ had 113 food items and the rural FFQ had 90 food items. Seventy-nine food items were common in both the FFQs. The common food items included 12 cereals, 7 pulses, 4 *chutneys*, 4 non-vegetarian items, 6 snacks, 7 desserts, 11 beverages, 12 fruits, 11 vegetables and 5 miscellaneous food items (data available at www.nmji.in; Annexures I and II).

Recipes of some foods prepared at home were obtained from the housewife or the person involved in cooking. The nutritionist weighed all the raw ingredients (edible portion) and then measured the total cooked weight or volume. Recipes for foods such as sweets, pizza, burger, *samosa*, etc. were obtained from vendors, sweet shops, bakery, cooking books, etc. The ingredients involved in preparation were estimated. The nutrient content of cooked food was calculated by using yield and retention factors to adjust for weight/volume changes. The nutrient values of raw ingredients included in the recipes were obtained using food composition tables from the nutritive value of Indian foods.¹⁷ The information for the nutrients which were not available in these tables were obtained from McCance and Widdowson's Composition of foods¹⁸ and the United States Department of Agriculture's National Nutrient Database (USDA, Release No.14).¹⁹

24-hour dietary-recall

An interview was conducted and detailed information on type and quantity of food consumed on the day before the day of interview was obtained. The subjects were asked to recall and report detailed information on whatever they ate or drank in chronological order, i.e. from the first food item to the last item consumed including bed tea, breakfast, lunch, dinner or anything that they consumed before, after or between meals. The subjects were also prompted for miscellaneous items that might be added to the main dishes, e.g. did they add table salt or butter in their food? They were also asked whether they had consumed anything outside their home.

Data collection

A nutritionist and trained field staff administered the FFQ in the beginning of the study period (baseline FFQ) and at an interval of

1 year (1-year FFQ) to test the reproducibility. The FFQs were administered by the interviewer as a large number of subjects in our study were illiterate. This reduced the burden on subjects and was convenient for them to report the frequency of consumption of different foods. The interviewer took about 25–30 minutes to administer the FFQ.

The FFQ was validated against a mean of six 24-hour dietary-recalls. Six 24-hour dietary-recalls were administered at 2-monthly intervals over a period of 1 year to cover seasonal variations. This included four weekdays and two weekends to capture variability in weekend versus weekday food intakes. Multiple (six) 24-hour dietary-recalls were taken as they represent the average food consumed by the individual and cover the time corresponding to the FFQ.

Statistical analysis

The information obtained from the FFQs and multiple 24-hour dietary-recalls were entered into a Microsoft Excel spreadsheet. The amount of foods in the food list consumed by the individual was determined by multiplying the average consumption with frequency of intake and portion size of the food item. The food intake of each food item was recomputed for a day and multiplied with the nutrient amount per gram to obtain the daily nutrient intake. The estimated nutrient intakes per day were summed to obtain the total daily nutrient intakes. The people in urban and rural areas reported that they used multiple cooking oils such as sunflower oil, mustard oil, *dalda* (a brand of hydrogenated vegetable) and groundnut oil. Thus, a separate database was developed and nutrient intakes of subjects were obtained by transferring information into an appropriate database, i.e. according to the major type of oil consumed by them.

Nutrient intakes of β -carotene, thiamine, riboflavin and vitamin C were log-transformed to normalize the distribution. Descriptive statistical analysis, i.e. mean and standard deviation (SD), of all nutrients estimated from the baseline FFQ, 1-year FFQ and mean of six 24-hour dietary-recalls was calculated. The difference of mean nutrient intakes obtained from the baseline and 1-year FFQs was compared by paired *t*-test. Pearson correlation coefficient was used for assessing reproducibility and validity of the FFQs.

As all the nutrients estimated from the dietary assessment methods were correlated with energy intake, it was necessary to remove the variation due to energy intake. Energy-adjusted nutrient intakes were calculated by regression with energy intake as the independent variable and the nutrient of interest as the dependent variable.²⁰ De-attenuation was done to correct for variability in month-to-month variation in the nutrient intake estimated from 24-hour dietary-recall.²¹ Subjects were classified into quartiles to assess extreme misclassification between the two methods. Correlation coefficients express only the strength of a relationship between two variables. So, the 1-year FFQ and the mean of 24-hour dietary-recalls were compared graphically to test the agreement between them by using the method suggested by Bland and Altman.²² The limits of agreement (1.96 SD) were revealed by plotting the differences between the 1-year FFQ and 24-hour dietary-recalls against their mean results.

RESULTS

The mean (SD) age of the study population was 52.6 (10.9) and 46.4 (10.2) years in urban and rural areas, respectively. One-third of the participants were illiterate and 61% of them were women. The mean (SD) body mass index (BMI) of the participants was 26 (4.2) and 23 (4.3) kg/m² in urban and rural areas, respectively.

Reproducibility

In the urban area, the mean nutrient intakes obtained from the baseline FFQ were significantly higher than the values obtained from the 1-year FFQ for fat ($p<0.01$), riboflavin ($p<0.05$) and calcium ($p<0.01$). The intake of rest of the nutrients was similar in the baseline FFQ and 1-year FFQ (Table I). In the rural area, the mean intakes estimated from the baseline FFQ were significantly higher for fat ($p<0.01$), β -carotene ($p<0.01$), vitamin C ($p<0.01$), iron ($p<0.01$) and calcium ($p<0.05$) compared to the 1-year FFQ. For other nutrients, there was no significant difference (Table I).

Validity

Both FFQs (at baseline and 1 year) overestimated the daily energy and nutrients intake as compared to the mean of 24-hour dietary-recalls in urban and rural settings (data not shown). In the urban area, the Pearson correlation coefficient between the mean 24-hour dietary-recall and the baseline FFQ was statistically significant for all nutrients except vitamin C and calcium. The correlations ranged from 0.06 for calcium to 0.61 ($p<0.01$) for iron intake. Adjusting for energy intake decreased the correlations of all nutrients except vitamin C and fibre. However, a modest increase in the correlations was observed between the mean 24-hour

dietary-recall and baseline FFQ on de-attenuating except for calcium. A similar pattern of lower correlations after adjusting for energy and a modest increase in correlations after de-attenuation was observed for correlations between the 24-hour dietary-recall and 1-year FFQ (Table II).

In the rural area, unadjusted and de-attenuated coefficients were statistically significant except for β -carotene, vitamin C, calcium and fibre at baseline. At 1 year, the correlations followed a similar pattern with the baseline FFQ but were significant for calcium that improved on de-attenuation. The unadjusted correlation coefficients ranged from 0.01 for β -carotene to 0.57 ($p<0.01$) for carbohydrate and de-attenuated correlation coefficients ranged from 0.01 for β -carotene to 0.59 ($p<0.01$) for carbohydrate at baseline. The unadjusted and de-attenuated correlation coefficient between the mean 24-hour dietary-recall and 1-year FFQ ranged from 0.06 for riboflavin to 0.74 ($p<0.01$) for energy, and from 0.07 for vitamin C to 0.76 ($p<0.01$) for energy, respectively. These differences were expected because the 1-year FFQ represents the time period during which the 24-hour dietary-recalls were collected. There was no improvement in the correlation after de-attenuation (Table III).

We also classified the unadjusted and energy-adjusted nutrient

TABLE I. Comparison of nutrient intakes at the baseline and 1-year food frequency questionnaires (FFQs) in an urban and rural area of northern India

Nutrient	Urban area			Rural area		
	Baseline FFQ (n=100)	1-year FFQ (n=100)	p value	Baseline FFQ (n=100)	1-year FFQ (n=100)	p value
Energy	2147 (447.2)	2098 (445.5)	0.2	1868 (484.1)	1929 (353.8)	0.2
Protein	71.3 (15.5)	69.8 (15.3)	0.3	67.0 (15.8)	67.4 (11.7)	0.8
Fat	50.1 (13.2)	45.0 (10.2)	<0.01	43.2 (13.8)	39.7 (10.5)	<0.01
Carbohydrate	355.6 (83.1)	354.1 (84.1)	0.9	316.2 (84.5)	325.3 (62.2)	0.2
β -carotene	1317.7 (382.3)	1265.8 (297.7)	0.1	1237.2 (546.7)	1063.5 (164.2)	<0.01
Thiamine	2.3 (0.6)	2.3 (0.5)	0.6	2.1 (0.6)	2.2 (0.4)	0.3
Riboflavin	1.7 (0.3)	1.6 (0.3)	0.02	1.5 (0.4)	1.5 (0.3)	0.8
Vitamin C	86.4 (23.0)	87.9 (23.2)	0.5	49.7 (17.8)	39.9 (9.6)	<0.01
Zinc	23.7 (5.9)	23.5 (5.8)	0.8	11.4 (2.8)	11.3 (2.1)	0.9
Iron	11.8 (2.6)	11.7 (2.8)	0.9	25.2 (5.8)	24.4 (4.4)	<0.01
Calcium	944.0 (161.7)	859.3 (119.3)	<0.01	863.2 (260.3)	808.1 (158.7)	< 0.05
Fibre	10.0 (3.6)	10.5 (3.8)	0.2	11.3 (2.7)	11.8 (2.1)	0.1

TABLE II. Correlation of mean 24-hour dietary-recall, baseline and 1-year food frequency questionnaires (FFQs) in an urban area of northern India

Nutrients	24-hour dietary-recall v. baseline FFQ			24-hour dietary-recall v. 1-year FFQ		
	Unadjusted	Adjusted*	De-attenuated†	Unadjusted	Adjusted*	De-attenuated†
Energy	0.50‡	—	0.52‡	0.46‡	—	0.48‡
Protein	0.50‡	0.23§	0.52‡	0.44‡	0.03	0.46‡
Fat	0.52‡	0.46‡	0.54‡	0.35‡	0.23‡	0.36‡
Carbohydrate	0.51‡	0.46‡	0.53‡	0.48‡	0.39‡	0.50‡
β -carotene	0.39‡	0.30‡	0.44‡	0.26‡	0.22§	0.29‡
Thiamine	0.47‡	0.39‡	0.49‡	0.49‡	0.29‡	0.51‡
Riboflavin	0.24§	-0.13	0.25§	0.39‡	0.14	0.40‡
Vitamin C	0.18	0.31‡	0.19	0.22§	0.17	0.23§
Zinc	0.47‡	0.28‡	0.49‡	0.52‡	0.19	0.54‡
Iron	0.61‡	0.25‡	0.63‡	0.63‡	0.17	0.65‡
Calcium	0.06	-0.12	0.06	0.31‡	0.08	0.32‡
Fibre	0.43‡	0.47‡	0.45‡	0.39‡	0.34‡	0.40§

* Energy-adjusted correlation between dietary assessment methods uses the residuals from regressing each nutrient on the total calories as estimated by FFQ or 24-hour dietary-recall † De-attenuated correlation coefficient is calculated using the ratio of the within-person to between-person variance measured from mean 24-hour dietary-recall. The formula for this corrected correlation is $p_c = p_o [1 + ((\sigma_w^2/\sigma_b^2)/n)]^{1/2}$, where p_o is the observed correlation between energy-adjusted nutrients estimated from FFQ and 24-hour dietary recall, σ_w^2 is the within-person variation, σ_b^2 is the between-person variation estimated from 24-hour dietary-recall and n is the number of replicates

‡ $p<0.01$ § $p<0.05$

TABLE III. Correlation of mean 24-hour dietary-recall, baseline and 1-year food frequency questionnaires (FFQs) in a rural area of northern India

Nutrients	24-hour dietary-recall v. baseline FFQ			24-hour dietary-recall v. 1-year FFQ		
	Unadjusted	Adjusted*	De-attenuated†	Unadjusted	Adjusted*	De-attenuated†
Energy	0.39‡	—	0.40‡	0.74‡	—	0.76‡
Protein	0.50‡	0.07	0.51‡	0.69‡	0.36‡	0.71‡
Fat	0.48‡	0.33‡	0.49‡	0.66‡	0.65‡	0.67‡
Carbohydrate	0.57‡	0.07	0.59‡	0.38‡	0.64‡	0.39‡
β-carotene	0.01	-0.01	0.01	0.14	0.09	0.16
Thiamine	0.49‡	0.01	0.51‡	0.73‡	0.41‡	0.76‡
Riboflavin	0.42‡	-0.02	0.43‡	0.56‡	-0.06	0.58‡
Vitamin C	0.03	0.06	0.03	0.06	0.05	0.07
Zinc	0.25‡	0.09	0.26‡	0.42‡	0.20§	0.43‡
Iron	0.53‡	0.09	0.54‡	0.69‡	0.18	0.71‡
Calcium	0.08	-0.15	0.08	0.26‡	0.17	0.27‡
Fibre	0.12	0.05	0.12	0.15	0.09	0.16

* Energy-adjusted correlation between dietary assessment methods uses the residuals from regressing each nutrient on the total calories as estimated by FFQ or 24-hour dietary-recall † De-attenuated correlation coefficient is calculated using the ratio of the within-person to between-person variance measured from mean 24-hour dietary-recall. The formula for this corrected correlation is $p_c = p_o \{1 + [(\sigma_w^2/\sigma_b^2)/n]\}^{1/2}$, where p_o is the observed correlation between energy-adjusted nutrients estimated from FFQ and 24-hour dietary-recall, σ_w^2 is the within-person variation, σ_b^2 is the between-person variation estimated from 24-hour dietary-recall and n is the number of replicates

‡ $p < 0.01$ § $p < 0.05$

intakes estimated from the mean of six 24-hour dietary-recalls and 1-year FFQ into quartiles. In the urban area, among unadjusted nutrients the percentage of subjects classified by 24-hour dietary-recalls and 1-year FFQ ranged from 24% for fat to 57% for carbohydrate in the lowest quartile and from 31% for β-carotene to 57% for energy in the highest quartile. Among unadjusted nutrients there was no extreme misclassification for protein, thiamine, zinc and iron in the lowest quartile and for fibre in the highest quartile. In the rural area, among unadjusted nutrients the percentage of subjects classified by 24-hour dietary-recalls and 1-year FFQ ranged from 26% for vitamin C to 74% for carbohydrate in the lowest quartile and from 25% for calcium to 78% for carbohydrate in the highest quartile. There was no extreme misclassification for protein and thiamine in the lowest quartile and for energy, protein, carbohydrate, thiamine and riboflavin in the highest quartile. In urban as well as rural area, there was no improvement in cross-classification after adjusting for energy in the lowest and highest quartiles (data available at www.nmji.in; Annexures III and IV).

The Bland and Altman plot of the difference between energy (kcal/day), fat (g/day), carbohydrate (g/day) and calcium (mg/day) derived from six 24-hour dietary-recalls and 1-year FFQ with mean of these two dietary assessment methods in the urban and rural areas is shown in Figs 1 and 2. For energy, the mean difference between the two dietary methods was -334 kcal/day and -376 kcal/day in urban and rural areas, respectively. The limits of agreement ranged from 453 to 1122 kcal/day for the urban and 86 to 838 kcal/day for the rural areas, respectively. Figures 1 and 2 show that there was a discrepancy in the mean difference of nutrient intake between the two methods in the urban group. For all nutrients, there was overestimation by the 1-year FFQ when compared to the 24-hour dietary-recall in the urban group. However, when the rural group was observed, except for fat, other nutrients were underestimated by the 1-year FFQ when compared to the 24-hour dietary-recall. The differences tended to increase as the absolute nutrient increased suggesting a proportional bias in the rural group for energy, carbohydrate and calcium. A reverse relationship was observed for fat intake in the rural group.

DISCUSSION

We developed separate FFQs for the urban and rural areas of northern India and administered these to the same individuals at different time intervals to test their reproducibility. The validity of the FFQs was determined using 24-hour dietary-recall as the reference method. Both the urban and rural FFQs were found to be reproducible and valid tools for dietary assessment in a northern Indian population.

There were 113 food items in the urban FFQ and 90 food items in the rural FFQ. We did not consider food items which were rarely consumed (e.g. sea foods, coconut oil preparations, etc.). The choice of food items to be included in an FFQ depends on a number of factors such as purpose of the study, nutrients of interest, availability, dietary preferences, cultural preferences, etc. The length of food list also varies according to the need of the study. Fewer as well as a larger number of food items have been reported in several studies done in India, i.e. 81 in Kerala,⁵ 92 in Gujarat,⁸ 102 in an urban area of northern India,¹¹ 132 in Thiruvananthapuram¹⁴ and 222 in Chennai.¹² A study reported that FFQs with more food items are better in ranking people according to their intake.²³

As there is no gold standard for directly assessing the validity of a dietary assessment method, the reference methods that have been used include diet history, weighed food records, diet records and 24-hour dietary-recalls. We assessed the validity of the FFQ with six 24-hour dietary-recalls as the reference method as it is conceptually different from a FFQ⁶ and covered the time interval corresponding to the FFQ. Multiple recalls (six) were taken owing to daily variations in dietary intakes of individuals. Studies with few (two) and higher (twelve) number of 24-hour dietary-recalls have also been reported.^{14,24} Although the validity of a questionnaire improves on increasing the number of days of administration of the reference method,²⁵ 4–5 diet records have been considered sufficient for an optimal study design.²⁶

People generally tend to remember what they had reported if questionnaires are administered at short intervals of time, e.g. a couple of weeks²⁷ or months.^{11,24} In our study, the FFQs were administered in the beginning and at an interval of 1 year which

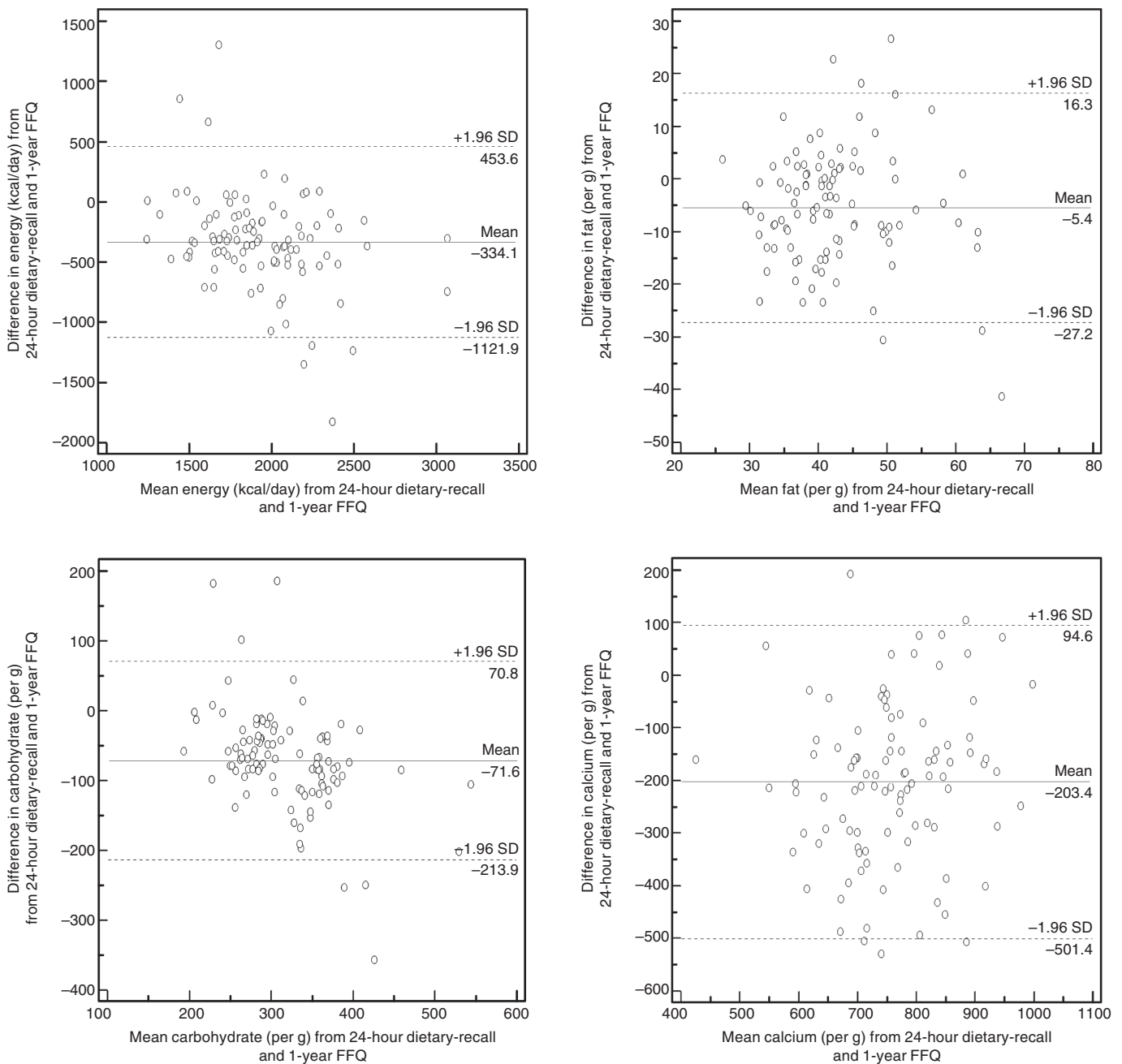


Fig 1. Bland–Altman plot showing the difference between energy, fat, carbohydrate and calcium of 24-hour dietary-recall and 1-year food frequency questionnaire (FFQ) and mean of these two methods in an urban area of northern India

was helpful in reducing seasonal variability. We observed that after 1 year in the urban area, there was a significant decrease in the intake of fat, riboflavin and calcium. In the rural area, there was a significant decrease in the intake of fat, β -carotene, vitamin C, iron and calcium. This may be due to familiarity and a learning effect due to repeated administration of the questionnaire. It was encouraging to note that there were no significant differences in the intake of most nutrients between the FFQs in the urban area.

In validation studies, a correlation of 0.50–0.70 is desired between the study and the reference method.²⁸ In a study, a correlation of 0.40 also was considered to be indicative of good agreement between the two methods.⁴ We found that in the urban

area, the average correlation was similar when nutrient scores derived from 24-hour dietary-recalls were compared with the baseline FFQ and 1-year FFQ. But in the rural area, there was a better correlation between the mean of 24-hour dietary-recalls and 1-year FFQ. Similar results were observed in a study done on male health professionals.²⁹ In our study, there was no improvement in correlation after adjusting for energy.^{11,24}

In both study areas, the results derived from classification of individuals by nutrient intakes were accurate and consistent with a study done in southern India.¹² There was no extreme misclassification for some nutrients and no improvement in cross-classification after adjusting for energy in the lowest and highest quartiles. Bland and Altman plots show that there was good

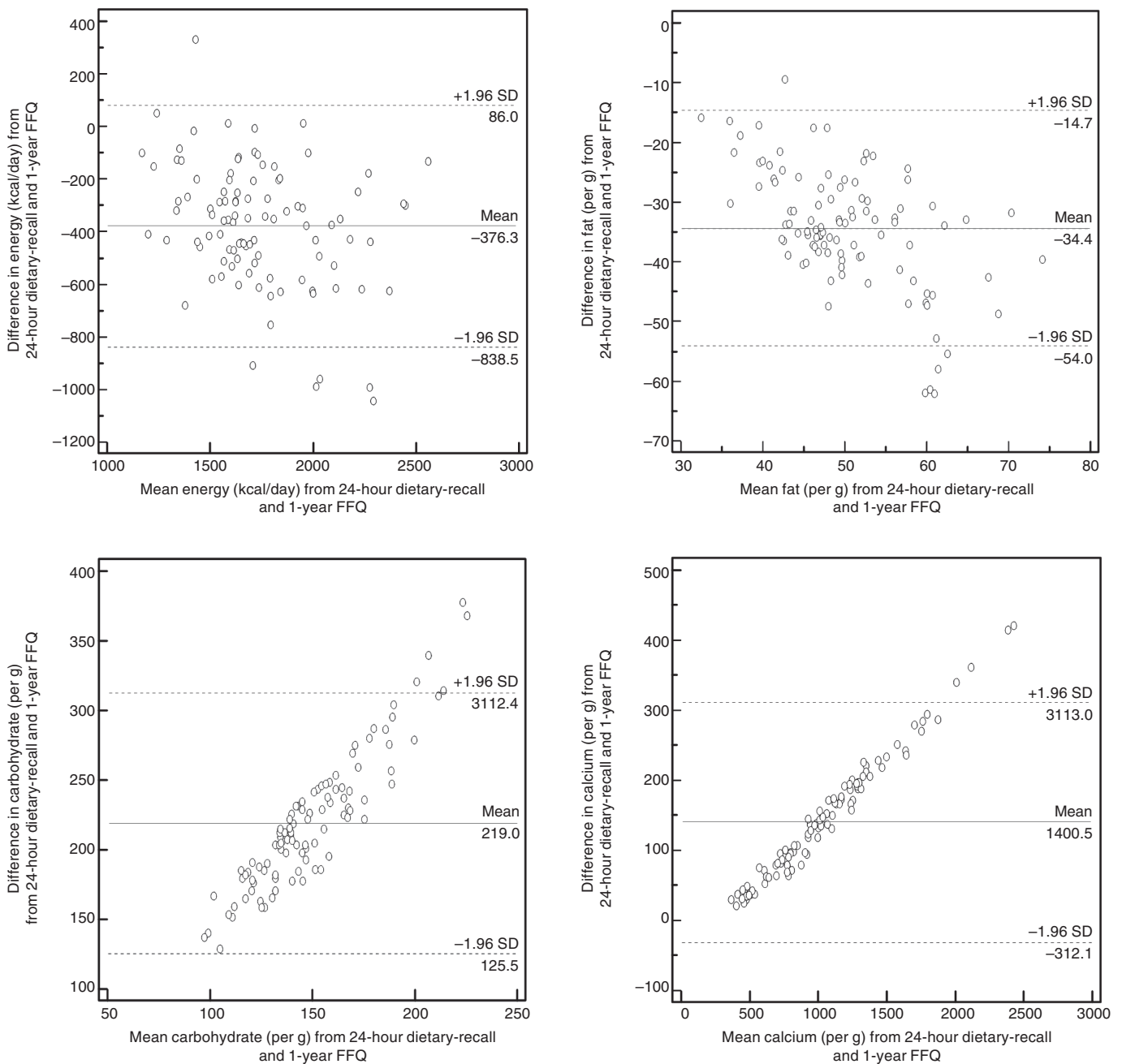


Fig 2. Bland–Altman plot showing the difference between energy, fat, carbohydrate and calcium of 24-hour dietary-recall and 1-year food frequency questionnaire (FFQ) and mean of these two methods in a rural area of northern India

agreement between the two methods. Similar results were observed in a study done in Gujarat, India.⁸

The urban and rural FFQs used in our study provide a good estimate of intakes over 1 year for most nutrients except β -carotene, vitamin C and fibre in the rural area. A low correlation for vitamin C was also observed in a study done among adults in Guatemala.³⁰ In a study, correlations between the FFQ and the reference method were found to be good for total energy and poor for β -carotene, but the lowest correlation for a particular nutrient was not thought to be representative of a poor FFQ.³¹ The correlations observed in our study for most nutrients are similar to what has been observed in FFQ validation studies in India and other regions except for some micronutrients.

Overall, there was good agreement for macronutrients and some micronutrients between both methods of dietary assessment, i.e. FFQ and 24-hour dietary recall. The FFQs used in our study are reproducible and valid dietary assessment methods which can be used in epidemiological studies to study diet–disease relationship in northern India. FFQs should be developed and validated on a larger sample of subjects for each region to reflect the local food habits.

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REFERENCES

- 1 Block G. A review of validations of dietary assessment methods. *Am J Epidemiol* 1982;**115**:492–505.
- 2 Bingham SA, Gill C, Welch A, Day K, Cassidy A, Khaw KT, *et al.* Comparison of dietary assessment methods in nutritional epidemiology: Weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br J Nutr* 1994;**72**:619–43.
- 3 Willett WC. *Nutritional epidemiology*. Oxford:Oxford University Press; 1990.
- 4 Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J, *et al.* Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol* 1985;**122**:51–65.
- 5 Hebert JR, Gupta PC, Bhonsle RB, Murti PR, Mehta H, Verghese F, *et al.* Development and testing of a quantitative food frequency questionnaire for use in Kerala, India. *Public Health Nutr* 1998;**1**:123–30.
- 6 Subar AF, Thompson FE, Kipnis V, Midthune D, Hurwitz P, McNutt S, *et al.* Comparative validation of the Block, Willett, and National Cancer Institute food frequency questionnaires: The Eating at America's Table Study. *Am J Epidemiol* 2001;**154**:1089–99.
- 7 Dehghan M, Al Hamad N, Yusufali A, Nusrath F, Yusuf S, Merchant AT. Development of a semi-quantitative food frequency questionnaire for use in United Arab Emirates and Kuwait based on local foods. *Nutr J* 2005;**4**:18.
- 8 Hebert JR, Gupta PC, Bhonsle RB, Sinor PN, Mehta H, Mehta FS. Development and testing of a quantitative food frequency questionnaire for use in Gujarat, India. *Public Health Nutr* 1999;**2**:39–50.
- 9 Kapil U, Pathak P, Singh P, Dwivedi DN. Reproducibility and validity of the food frequency questionnaire methodology in an urban middle income group area of Delhi, India. *Pak J Nutr* 2003;**2**:33–5.
- 10 Kapil U, Singh P, Pathak P, Pradhan R. Reproducibility and validity of the food frequency questionnaire methodology in a rural block of Haryana, India. *Pak J Nutr* 2004;**3**:35–7.
- 11 Pandey D, Bhatia V, Boddula R, Singh HK, Bhatia E. Validation and reproducibility of a food frequency questionnaire to assess energy and fat intake in affluent north Indians. *Natl Med J India* 2005;**18**:230–5.
- 12 Sudha V, Radhika G, Sathya RM, Ganesan A, Mohan V. Reproducibility and validity of an interviewer-administered semi-quantitative food frequency questionnaire to assess dietary intake of urban adults in southern India. *Int J Food Sci Nutr* 2006;**57**:481–93.
- 13 Bharathi AV, Kurpad AV, Thomas T, Yusuf S, Saraswathi G, Vaz M. Development of food frequency questionnaires and a nutrient database for the Prospective Urban and Rural Epidemiological (PURE) pilot study in South India: Methodological issues. *Asia Pac J Clin Nutr* 2008;**17**:178–85.
- 14 Iqbal R, Ajayan K, Bharathi AV, Zhang X, Islam S, Soman CR, *et al.* Refinement and validation of an FFQ developed to estimate macro- and micronutrient intakes in a south Indian population. *Public Health Nutr* 2009;**12**:12–18.
- 15 Jain M. Culture-specific food frequency questionnaires: Development for use in a cardiovascular study. *Can J Diet Pract Res* 1999;**60**:27–36.
- 16 Yusuf S, Islam S, Chow CK, Rangarajan S, Dagenais G, Diaz R, *et al.*; Prospective Urban Rural Epidemiology (PURE) Study Investigators. Use of secondary prevention drugs for cardiovascular disease in the community in high-income, middle-income, and low-income countries (the PURE Study): A prospective epidemiological survey. *Lancet* 2011;**378**:1231–43.
- 17 Gopalan C, Ramasastry BV, Balasubramanian SC. *Nutritive value of Indian foods*. 2nd ed. Hyderabad:National Institute of Nutrition, Indian Council of Medical Research; 1991.
- 18 Holland B, Welch AA, Unwin ID, Buss DH, Paul AA, Southgate DAT. *McCance and Widdowson's the composition of foods*. 5th ed. UK:Royal Society of Chemistry; 1991.
- 19 United States Department of Agriculture. Nutrient data laboratory. Available at <http://www.ars.usda.gov/nutrientdata> (accessed on 10 Nov 2007).
- 20 Willett W, Stampfer MJ. Total energy intake: Implications for epidemiologic analyses. *Am J Epidemiol* 1986;**124**:17–27.
- 21 Rosner B, Willett WC. Interval estimates for correlation coefficients corrected for within-person variation: Implications for study design and hypothesis testing. *Am J Epidemiol* 1988;**127**:377–86.
- 22 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;**1**:307–10.
- 23 Fontaine KR, Redden DT, Wang C, Westfall AO, Allison DB. Years of life lost due to obesity. *JAMA* 2003;**289**:187–93.
- 24 Bohlscheid-Thomas S, Hoting I, Boeing H, Wahrendorf J. Reproducibility and relative validity of energy and macronutrient intake of a food frequency questionnaire developed for the German part of the EPIC project. European Prospective Investigation into Cancer and Nutrition. *Int J Epidemiol* 1997;**26** Suppl 1:S71–S81.
- 25 Potosky AL, Block G, Hartman AM. The apparent validity of diet questionnaires is influenced by number of diet-record days used for comparison. *J Am Diet Assoc* 1990;**90**:810–13.
- 26 Stram DO, Longnecker MP, Shames L, Kolonel LN, Wilkens LR, Pike MC, *et al.* Cost-efficient design of a diet validation study. *Am J Epidemiol* 1995;**142**:353–62.
- 27 Xing X, Burr JA, Brasure JR, Neugut AI, Marshall JR. Reproducibility of nutrient intake in a food frequency questionnaire used in a general population. *Nutr Cancer* 1996;**25**:259–68.
- 28 Willett WC. *Nutritional epidemiology*. 2nd ed. New York:Oxford University Press; 1998.
- 29 Rimm EB, Giovannucci EL, Stampfer MJ, Colditz GA, Litin LB, Willett WC. Reproducibility and validity of an expanded self-administered semiquantitative food frequency questionnaire among male health professionals. *Am J Epidemiol* 1992;**135**:1114–26.
- 30 Rodríguez MM, Méndez H, Torún B, Schroeder D, Stein AD. Validation of a semi-quantitative food-frequency questionnaire for use among adults in Guatemala. *Public Health Nutr* 2002;**5**:691–9.
- 31 Grootenhuys PA, Westenbrink S, Sie CM, de Neeling JN, Kok FJ, Bouter LM. A semiquantitative food frequency questionnaire for use in epidemiologic research among the elderly: Validation by comparison with dietary history. *J Clin Epidemiol* 1995;**48**:859–68.