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Reproducibility and validity of a quantitative food-frequency questionnaire among Jamaicans of African origin

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Abstract

Background: An interviewer-administered quantitative food-frequency questionnaire (FFQ) was developed to determine the energy and nutrient intakes of adult Jamaicans of African origin as part of a study of the epidemiology of diabetes and hypertension.
Methods: Reproducibility of the questionnaire was investigated in 123 participants aged 25–74 years. The relative validity of the FFQ was assessed against twelve 24-hour recalls administered over 12 months in 73 of the participants. In addition, energy intakes (EI) were compared with estimated basal metabolic rates (BMR).
Results: Reproducibility correlation coefficients (Pearson and intraclass) varied between 0.42 for retinol and 0.71 for carbohydrate, with most values falling between 0.50 and 0.60. When compared with repeated 24-hour recalls, the FFQ estimated slightly higher energy (mean 6%) and macronutrient intakes (mean 2–14%), and was within 5% when expressed as a percentage of energy intake. Micronutrients were higher by 1.19 (calcium) to 1.61 times (vitamin C). Unadjusted correlations between the FFQ and the reference method ranged from 0.20 for beta-carotene to 0.86 for alcohol. Cross-classification of nutrients into quartiles showed that 46–48% of participants in the lowest and highest quartiles were jointly classified by both methods. Misclassifications were low for most nutrients with one or two persons misclassified at the extreme quartiles. EI/BMR ratios suggested light to moderate activity levels appropriate for an urban population in a developing country.
Conclusions: The FFQ showed reasonable reproducibility and validity and is suitable for estimating the habitual intakes of energy and macronutrients, but was poor for some micronutrients (retinol and beta-carotene).

Keywords
Dietary assessment
Adult
African origin

The assessment of diet as a risk factor is central to the investigation of the epidemiology of the chronic diseases of diabetes, hypertension and obesity. Elucidation of diet–disease relationships requires dietary assessment methods that adequately describe and quantify intake, minimise systematic error and provide reasonably precise estimates of variability between individuals and/or groups[1]. The food-frequency questionnaire (FFQ) has become a widely used tool to measure usual consumption of nutrient intakes in epidemiological studies. This method of dietary assessment was developed to measure the variance in dietary intakes and rank participants according to levels of consumption, rather than to provide estimates of absolute quantities of energy and nutrient intakes[1,2]. Some investigations show that the method provides equally accurate estimates of both group and individual intakes[1,3–5], while others suggest that food-frequency data can only measure the consumption of groups[6]. Widespread use of the technique has been attributed also to its relative ease of administration, coding and analysis, thereby incurring lower cost of collecting and processing when compared with other methods of dietary assessment.

Reliability is defined as the degree to which a method yields similar results on two different occasions. Validity is the determination of how well a method measures what it is intended to measure[5]. Unfortunately, to date there is no 'gold standard' for directly assessing the validity of a dietary method[1,2,5,7]. To overcome this limitation, investigators determine the *relative* validity or calibrate the method by comparison with another method judged to be similar or with other methods involving different errors[1].

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Food-frequency questionnaires are often calibrated against 24-hour recalls[8,9] and food records[3,10,11]. Additionally, non-dietary methods such as biochemical indicators and the ratio between energy intake (EI) and estimates of basal metabolic rate (BMR)[12] may also be used. This report describes the reliability and calibration of a food-frequency questionnaire developed to determine energy and nutrient intakes of the Jamaican population of African origin as part of a study of the epidemiology of diabetes and hypertension[13–16].

Materials and methods

Development of the Jamaican Food Frequency Questionnaire (FFQ)

A quantitative food-frequency questionnaire was designed to categorise participants by intakes of energy and selected nutrients hypothesised to influence the development of obesity, hypertension and diabetes. Thus the dietary variables to be measured included total energy, protein, carbohydrate, fat (saturated and polyunsaturated), iron, calcium, retinol, beta-carotene, vitamin C, vitamin E, fibre and alcohol.

Sampling

Investigations were conducted in Spanish Town, St. Catherine, the third largest town in Jamaica. It has a population distribution described as representative of Jamaica in its demographic and socio-economic characteristics (Statistical Institute of Jamaica (STATIN)). The most recent census available indicated a population of approximately 90 000.

The sample for the development of the FFQ consisted of free-living individuals residing in an 'Enumeration District' (ED), a community consisting of 80–400 households (STATIN). This ED was not included in the main study, but identified by STATIN to be similar in socio-economic characteristics to the main survey population. Every second household was systematically selected. Using the same age categories as the main study – 25–34, 35–44, 45–54 and 55–74 years, a sample of 104 persons divided equally into eight age/sex categories was selected.

Data collection

Detailed information was obtained by single 24-hour recalls. Trained nutrition personnel conducted recalls. Interviewers were equipped with food models and household measures to help participants quantify the amount of food and beverages consumed.

The 24-hour recalls were analysed for energy and protein content only, using a modified version of Nutritionist II[17], due to the incomplete nutrient database for local composite dishes. The FFQ food list comprised foods that together explained at least 90% of the variance in energy or protein. In addition, other commonly used foods that were known to contain appreciable amounts of the nutrients under investigation were included.

The food-frequency questionnaire was pre-tested and in its final form consisted of 70 food and drink items. Foods were grouped in nine categories on the basis of either physical composition (e.g. cereals, milk and milk products) or cultural use (e.g. desserts).

Frequency of usual food consumption was estimated using one of eight precoded categories of responses: almost never, once per month, 2–3 times per month, once per week, 2–4 times per week, 5–6 times per week, once per day, and 2 or more times per day. Two or more times per day was used as the maximum frequency as few foods or drink items were reported as being eaten more often than this during pre-testing. For each food item, participants were asked to supply information on portion size by using food models, commonly used household utensils, measuring cups and a measuring tape to indicate, on average, the portion size usually consumed. The questionnaire was administered by four trained personnel and took approximately 25 minutes to complete. Inter-observer agreement for frequency of consumption was 97% and for estimates of portion size it was 94%.

Nutrient intakes

The nutrient content of food items was calculated using the Microdiet[18] food composition database. Before analysis was started, the nutrient content of local dishes was computed for addition to the nutrient database. Recipes appended to Microdiet were from Landman[19]. To estimate portion weights, prepared dishes or food items in commonly used household measures used in the survey were weighed. On average, dishes or food items were obtained from four different sources. The average weight of the food item or composite dish was then used for the determination of portion weights in grams.

Daily nutrient intakes were calculated from the questionnaire by multiplying the frequency of use by the nutrient composition specified for each food item and its portion weight, using a computer program written for SPSS. In analysis, coefficients of 0.0, 0.03, 0.08, 0.14, 0.40, 0.80, 1.00 and 2.5 were used to indicate frequencies of almost never, once per month, 2–3 times per month, once per week, 2–4 times per week, 5–6 times per week, once per day, and 2 or more times per day, respectively. Nutrients from all foods were summed to obtain a total nutrient intake for each individual.

Reproducibility study

The reliability of the instrument was determined by the test–retest method. During the pilot phase of the main study, the FFQ was repeated 6–8 weeks later in a sample of 20 non-study participants, aged 25–74 years. Additionally, 13 subjects participating in the quality control measures of the main study provided FFQ data 4–8 weeks subsequent to enrolment. One hundred participants

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were randomly selected from the first 1000 participants for the relative validity study (see below) and 90 of these subjects repeated the FFQ 1 year later. Thus, the reproducibility of the FFQ was determined in a total of 123 participants.

Relative validity study

Repeated 24-hour recalls were used to determine the relative validity of the FFQ. A second comparison method was the comparison of energy intake (EI) with estimated basal metabolic rate (BMR).

Repeated 24-hour recalls

Participants were randomly selected from those enrolled in the epidemiological survey of risk factors for hypertension and diabetes. One hundred participants aged 25–74 years (50 males; 50 females) were invited to participate in the study; 27 participants (17 males; 10 females) who only partially completed the study were excluded from the analyses.

Three 24-hour recalls were administered on consecutive days to each participant at 3-month intervals, yielding a total of 12 recalls for each subject over 1 year. Recalls for each subject included all days of the week: 8 weekdays and 4 weekend days. Interviewers requested participants to recall all food and drink consumed over the previous 24 hours. Portions were carefully estimated by use of food models, household measures and utensils in conjunction with a detailed description of the food and method of preparation. At the end of the year, the same participant completed a second FFQ.

Comparison of EI and BMR

For validation of reported energy intakes, estimates of BMR were calculated using age- and sex-specific equations[12]. For a non-dieting population (i.e. one in energy balance), an EI/BMR ratio of less than 1.35 is unlikely to reflect habitual intake at the group level. For individuals, an EI/BMR ratio of <1.2 has been used to identify individuals whose energy requirements would not be met[12] and who are likely to be underreporting their habitual dietary intakes.

Statistical analyses

Data on all dietary intakes were converted to nutrient intakes by a computerised dietary analysis system[18]. The distributions of energy and nutrients were examined for deviations from normality: all nutrients except carbohydrate, vitamin C and fibre were skewed to the right and were log-transformed.

Pearson product–moment correlation coefficients and intraclass correlation coefficients were computed to assess reproducibility of the two food-frequency questionnaires and to compare the FFQ and 24-hour recalls.

Nutrient intakes were adjusted for total energy by computing residuals from regression analyses, with energy intake as the independent variable and nutrient intake as the dependent variable[1]. Residuals were added to the expected nutrient value for the mean energy intake of the sample to obtain a score adjusted to the average energy intake. Pearson product–moment correlation coefficients among the methods were computed before and after adjustment for total energy intake.

Results from the FFQ and 24-hour recall were grouped in quartiles with cut-off points for quartiles determined separately for each method. The percentage of participants correctly classified by the FFQ into the lowest and highest quartiles of the 24-hour recall result, and the percentage misclassified into extreme quartiles, were calculated.

Statistical analyses were performed using the Statistical Package for the Social Sciences[20]. Statistical significance was accepted when $P < 0.05$.

Results

Characteristics of the sample in the reproducibility and validation studies are presented by gender in Table 1. Both studies included more women than men. Within gender, characteristics were similar but differences between genders were evident. Significantly more women than men were obese.

Reproducibility

The mean daily intakes of energy and nutrients in the reproducibility study are presented in Table 2. On the first

Table 1 Characteristics of participants enrolled in the Jamaican dietary assessment reproducibility and validity studies

	Reproducibility study		Validity study	
	Males ($n = 50$)	Females ($n = 73$)	Males ($n = 33$)	Females ($n = 40$)
Age (years): mean±SD	45.2±14.5	43.6±13.2	46.0±15.3	45.4±13.5
Weight (kg): mean±SD*	67.3±12.2	74.6±20.9	67.8±12.5	76.4±24.2
Height (m): mean±SD***	1.7±0.1	1.6±0.1	1.7±0.1	1.6±0.1
Body mass index, BMI (kg m^{-2}): mean±SD***	23.0±3.8	28.7±7.4	22.9±4.0	29.3±8.3
Obesity (BMI≥30.0 kg m^{-2}) (%)***	6.3	33.3	9.7	30.8

SD = standard deviation.
*$P < 0.05$; ***$P < 0.0001$; genders significantly different.

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Table 2 Mean daily nutrient intakes estimated by the food-frequency questionnaire administered at baseline (FFQ1) and one year later (FFQ2), and correlations between the two questionnaires ($n = 123$)

	FFQ1	FFQ2	Correlation coefficient*, FFQ1 versus FFQ2		
	Mean ± SD	Mean ± SD	Pearson	Intraclass	Pearson energy-adjusted
Total energy (kcal)	2595±1055	2509±943	0.69	0.69	
Total carbohydrate (g)	390.5±168.7	374.1±140.5	0.71	0.69	0.57
Protein (g)	77.5±31.4	75.5±30.5	0.58	0.58	0.53
Total fat (g)	87.5±38.8	85.8±37.9	0.62	0.62	0.51
PUFA (g)	9.2±4.8	9.2±4.3	0.57	0.57	0.52
Saturated fat (g)	23.2±13.3	22.3±14.6	0.51	0.51	0.47
Calcium (mg)	1045±566	999±425	0.65	0.62	0.56
Iron (mg)	14.4±6.3	13.7±5.0	0.63	0.61	0.54
Retinol (μg)	2157±2408	1950±2238	0.42	0.42	0.55
Beta-carotene (μg)	6093±3921	5441±3167	0.56	0.54	0.57
Vitamin C (mg)†	190.3±108.0	165.1±85.1	0.59	0.55	0.59
Vitamin E (mg)	6.1±3.1	6.1±3.1	0.65	0.65	0.42
Fibre (g)	26.4±11.2	24.8±9.2	0.52	0.51	0.44
Alcohol (g)	5.2±15.4	4.9±18.7	0.61	0.60	0.60
Protein, % energy	12.2±2.2	12.5±4.5	0.62	0.62	0.57
Fat, % energy	30.2±5.7	31.4±11.9	0.67	0.67	0.55
Carbohydrate, % energy	60.2±6.9	61.5±20.5	0.69	0.68	0.56

SD = standard deviation.
PUFA = polyunsaturated fatty acid.
* All analysis on log-transformed values, excluding carbohydrate, vitamin C and fibre.
† *t*-test; $P < 0.05$ (estimate of mean intake in FFQ1 is significantly different from that in FFQ2).

FFQ estimates of energy and nutrient intakes tended to be marginally higher than on the second FFQ, significant only for vitamin C.

Correlation coefficients between the first and second FFQ (Table 2) for macronutrients ranged from 0.71 for total carbohydrate to 0.51 for saturated fat. Correlation coefficients were somewhat lower among the micronutrients, mostly between 0.51 and 0.65, with the lowest for retinol at 0.42. The intraclass correlation coefficients also ranged from 0.42 for retinol to 0.69 for total energy and carbohydrate. Reproducibility of the mean daily intake of macronutrients as a percentage of energy, based on Pearson correlation coefficients, were similar for all, ranging from 0.69 for carbohydrate to 0.62 for protein. Adjustment for energy intake lowered the correlation between the FFQs except for retinol, beta-carotene and vitamin C (Table 2).

Unadjusted and energy-adjusted correlations between intakes on the first and second FFQ were somewhat higher for short-term (4–8 week) reproducibility compared with long-term reproducibility (1 year) (Table 3). Correlations for energy were 0.78 for short-term and 0.68

Table 3 Unadjusted and energy-adjusted Pearson product–moment correlation coefficients* of energy and nutrients estimated by the FFQ at short-term (4–8 week) and long-term (1 year) intervals

	Short-term reproducibility ($n = 33$)		Long-term reproducibility ($n = 90$)	
	Unadjusted energy	Energy-adjusted	Unadjusted energy	Energy-adjusted
Total energy (kcal)	0.78		0.68	
Total carbohydrate (g)	0.81	0.75	0.67	0.52
Protein (g)	0.72	0.82	0.55	0.39
Total fat (g)	0.68	0.61	0.60	0.46
PUFA (g)	0.49	0.57	0.60	0.50
Saturated fat (g)	0.70	0.78	0.45	0.48
Calcium (mg)	0.86	0.73	0.40	0.46
Iron (mg)	0.75	0.77	0.60	0.43
Retinol (μg)	0.77	0.71	0.29	0.52
Beta-carotene (μg)	0.75	0.52	0.48	0.68
Vitamin C (mg)	0.78	0.49	0.54	0.58
Vitamin E (mg)	0.55	0.63	0.67	0.44
Fibre (g)	0.57	0.63	0.50	0.34
Alcohol (g)	0.94	0.93	0.50	0.59
Average	0.72	0.68	0.52	0.49

PUFA = polyunsaturated fatty acid.
* All analysis on log-transformed values, excluding carbohydrate, vitamin C and fibre.

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Table 4 Mean daily intake of energy and selected nutrients based on twelve 24-hour recalls and food-frequency questionnaires administered at the beginning (FFQ1) and end (FFQ2) of the validity study ($n = 73$)

	24-hour recalls	FFQ1		FFQ2	
	Mean ± SD	Mean ± SD	FFQ1/Recalls	Mean ± SD	FFQ2/Recalls
Total energy (kcal)	2398±541	2554±1106	1.07	2548±987	1.06
Total carbohydrate (g)	373.5±89.7	381.3±174.6	1.02	379.6±144.4	1.02
Protein (g)	69.7±16.7	77.1±34.2	1.14	77.2±33.1	1.12
Total fat (g)	76.7±20.4	85.9±40.2	1.14	86.3±40.9	1.14
PUFA (g)	7.2±2.6	9.4±5.2	1.30	9.5±4.2	1.32
Saturated fat (g)	15.9±8.5	22.7±12.8	1.43	22.4±15.5	1.41
Calcium (mg)	836.8±283.0	1045±566	1.25	999±425	1.19
Iron (mg)	14.6±4.9	14.2±6.4	1.03	14.2±5.0	1.01
Retinol (μg)	1272±1445	2160±2296	1.70	1853±2239	1.46
Beta-carotene (μg)	5698±3068	5814±3669	1.30	5614±3193	1.23
Vitamin C (mg)	122.0±54.1	189.2±114.8	1.79	167.8±86.5	1.61
Vitamin E (mg)	5.9±16.0	6.0±3.0	1.52	6.0±2.7	1.52
Fibre (g)	26.7±7.5	25.3±11.1	0.98	24.6±9.1	0.95
Alcohol (g)	3.8±10.3	6.6±16.6	2.68	5.9±20.7	1.55
Protein, % energy	11.7±1.8	12.3±2.3	1.05	12.3±2.3	1.05
Fat, % energy	28.7±3.8	30.2±6.0	1.05	29.7±5.5	1.04
Carbohydrate, % energy	62.3±5.4	59.8±7.2	0.96	60.4±6.9	0.97
Alcohol	1.1±3.2	1.7±4.3	1.54	1.4±4.9	1.27

SD = standard deviation.
PUFA = polyunsaturated fatty acid.

for the long-term reproducibility; for macronutrients, correlations ranged from 0.68 (fat) to 0.81 (carbohydrate) short-term, and between 0.55 (protein) and 0.67 (carbohydrate) long-term. Adjustment for energy generally decreased correlations.

Relative validity

Table 4 shows the daily mean energy and nutrient intakes for the two FFQs and repeated 24-hour recalls. Except for fibre, both FFQs gave higher estimates of intakes than the 24-hour recalls. Evaluation of intakes measured by FFQs as a percentage of the 24-hour recalls (reference method) showed 6% and 7% higher energy intakes on the first and second questionnaires, respectively, compared with the recalls, and 2–14% higher intakes for macronutrients. Estimates of micronutrient intakes were also higher from the FFQ when compared with 24-hour recalls, particularly for vitamins C and E and retinol (1.5–1.8 times). Alcohol intakes were also higher by the FFQ. The methods agreed fairly well for the proportion of energy from macronutrients.

The unadjusted Pearson correlation coefficients between 24-hour recalls and FFQ1 ranged from 0.22 for iron to 0.71 for alcohol, and with FFQ2 from 0.20 (retinol and beta-carotene) to 0.86 (alcohol) (Table 5). Energy adjustment tended to reduce the correlations. Partial correlations between the reference method and FFQ2

Table 5 Pearson correlation coefficients between daily intake of nutrients assessed by the food-frequency questionnaire at the beginning (FFQ1) and end (FFQ2) of the validity study and by twelve 24-hour recalls

	FFQ1 versus 24-hour recalls ($n = 73$)		FFQ2 versus 24-hour recalls ($n = 73$)	
	Unadjusted	Energy-adjusted*	Unadjusted	Energy-adjusted
Total energy (kcal)†	0.55		0.60	
Total carbohydrate (g)	0.56	0.43	0.61	0.55
Protein (g)†	0.41	0.37	0.45	0.44
Total fat (g)†	0.54	0.47	0.53	0.48
PUFA (g)†	0.37	0.34	0.27	0.28
Saturated fat (g)†	0.24	0.21	0.35	0.33
Calcium (mg)†	0.26	0.25	0.43	0.40
Iron (mg)†	0.22	0.21	0.46	0.39
Retinol (μg)†	0.29	0.27	0.20	0.19
Beta-carotene (μg)†	0.27	0.34	0.20	0.17
Vitamin C (mg)	0.34	0.43	0.30	0.31
Vitamin E (mg)†	0.49	0.44	0.45	0.43
Alcohol (g)	0.71	0.69	0.86	0.85

* Energy-adjusted correlations between dietary methods as suggested by Willett[1].
† Variables were log-transformed before analysis.

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Table 6 Cross-classification of the second food-frequency questionnaire with nutrient intakes derived from twelve 24-hour recalls based on joint classification by quartiles ($n = 73$)

	Proportion (%) of subjects classified							
	Unadjusted nutrients, lowest quartile*		Unadjusted nutrients, highest quartile*		Energy-adjusted nutrients, lowest quartile*		Energy-adjusted nutrients, highest quartile*	
	Agreement†	Misclassification‡	Agreement†	Misclassification‡	Agreement†	Misclassification‡	Agreement†	Misclassification‡
Total energy (kcal)	66.7	6.7	68.8	6.3				
Total carbohydrate (g)	52.9	11.8	56.3	6.3	71.4	0	57.6	5.3
Protein (g)	38.9	11.1	38.9	5.6	60.0	5.0	57.9	0
Total fat (g)	68.4	0	64.7	5.9	37.5	6.3	56.3	18.8
PUFA (g)	41.2	11.8	46.7	29.4	50.0	0	40.0	20.0
Saturated fat (g)	36.8	15.3	37.5	12.5	23.5	11.8	50.0	14.3
Calcium (mg)	38.9	11.1	58.8	5.6	33.3	5.6	52.9	5.9
Iron (mg)	56.3	0	36.4	13.6	46.2	7.7	47.4	10.5
Retinol (μg)	31.6	15.8	23.5	17.6	19.0	14.3	46.3	23.1
Beta-carotene (μg)	31.6	10.5	34.8	17.4	50.0	20.0	37.5	6.7
Vitamin C (mg)	44.4	5.6	33.3	15.0	33.3	11.8	27.8	16.7
Vitamin E (mg)	44.4	5.6	58.8	0	22.7	22.7	23.1	23.1
Fibre (g)	31.6	10.5	38.9	16.3	38.9	14.3	36.8	0
Alcohol (g)	100	0	60.9	0	100	0	60.4	8.3

PUFA = polyunsaturated fatty acid.
* Quartile by 24-hour recalls.
† Classified in the same quartile by the FFQ.
‡ Misclassified in the opposite extreme quartile by FFQ.

controlling for age and body mass index revealed coefficients that were similar to those in Table 4 (data not shown).

Agreement in cross-classification by the two methods was assessed as the proportion of participants similarly classified in the highest or lowest quartiles, and misclassification as the proportion classified into the opposite extreme quartile, for unadjusted and energy-adjusted nutrients (Table 6). Thus 25% would be expected to fall into the same quartiles by chance. Among unadjusted nutrients, the percentage of participants similarly classified by both instruments ranged from 31.6% for retinol, beta-carotene and fibre to 100% for alcohol in the lowest quartile, and from 24% for retinol to 69% for total energy in the highest quartiles. Misclassification was low (one or two persons) for most nutrients but was higher for saturated fats (15%) and retinol (16%) in the lowest quartile, and polyunsaturated fat (29%) and retinol (18%), beta-carotene (17%), vitamin C (15%) and fibre (16%) in the highest quartile. In general, cross-classification was not improved by energy adjustment.

EI/BMR

Table 7 shows that the mean EI/BMR for males and females exceeded the ratio of 1.35, the level above which diets are likely to reflect habitual intakes at the group level for non-dieting populations. For males the mean EI/BMR ratio obtained from the FFQ was higher than from the recalls but both were consistent with a moderate activity level. Among females, both instruments yielded similar EI/BMR ratios indicative of light activity.

Individuals with an EI/BMR of less than 1.2 were considered low energy reporters and may have underreported dietary intakes. The proportion of participants with EI/BMR less than the cut-off point of 1.2 was much higher in females than in males.

Discussion

Food-frequency questionnaires are often used in developed countries for the study of diet–disease associations[3,4,6,8–11,21–23]; however, there is limited information on their use in developing countries[24]. We developed an FFQ to measure the habitual intakes of adult Jamaicans as part of a study investigating risk factors for diabetes and hypertension[13–16]. Although the FFQ is considered to give reliable estimates of nutrient intake suitable for use in epidemiological studies, potential sources of error include the ability of individuals to report their usual frequency of consumption and portion sizes. The adequacy of the food list in reflecting an individual's typical diet is another limitation[1,25]. Thus, an essential step in the development of an FFQ is to establish the reproducibility and validity of the estimates of nutrient intakes.

Table 7 EI/BMR and proportion with values less than the cut-off points of EI/BMR* by gender

	Mean ± SD	Percentage below EI/BMR = 1.2 cut-off point
FFQ2		
Males (33)	1.75±0.64	12.5
Females (40)	1.58±0.58	31.5
24-hour recalls		
Males (33)	1.65±0.28	6.3
Females (40)	1.52±0.39	24.4

SD = standard deviation.
* Reference for energy requirements[12].

Reproducibility

Reproducibility of the FFQ was generally good, with Pearson and intraclass correlation coefficients for most of the nutrients varying between 0.4 and 0.7, similar to correlations reported elsewhere[10,11,23]. As might be expected if habits alter over time, short-term (4–8 week) reproducibility was somewhat higher than long-term reproducibility. Repeating administration of the questionnaire within 4–8 weeks should minimise chances of real dietary changes in the interim period and should also be long enough to prevent participants from remembering responses given earlier. At 1 year, administration of the second questionnaire allows assessment of habitual intakes. The mean long-term reproducibility unadjusted coefficient of 0.52 was lower than the short-term reproducibility coefficient of 0.72. These coefficients are somewhat higher than those obtained by Riboli *et al.*[26] in the New York University Women's Health investigation, where average correlations of 0.65 and 0.48 were found for short- and long-term reproducibility, respectively. Adjustment for energy both increased and decreased correlation coefficients for each reproducibility period depending on the nutrient, as in other studies of similar design[26–28].

The first questionnaire gave generally higher estimates of nutrient intakes than the second questionnaire, but intakes were not significantly different except in the case of vitamin C. There is no obvious explanation why the first measurement produced higher mean estimates than the second questionnaire, but it has been suggested that participants are likely to have a more realistic idea of their diets and could therefore quantify their food intake better at the second administration of the questionnaire[28].

Relative validity

24-hour recalls

Repeated 24-hour recalls were used as the primary reference method to calibrate or to determine the relative validity of the FFQ. Twelve recalls were conducted over a 1 year period to allow for seasonal variations and included all days of the week. Repeated 24-hour recalls are often used as the reference method to study the

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relative validity of food-frequency questionnaires[30–33] but their limitations for individual assessments of habitual intakes are well known[2,10,29]. However, no dietary assessment method can be regarded as a 'gold standard' and it may be unrealistic to accord special status to any method[1]. Twenty-four hour recalls were selected to ensure a high degree of compliance so that participants were representative of the study population, because other methods that require high motivation and literacy are not suitable for a developing country like Jamaica.

Correlation coefficients between FFQ2 and the 24-hour recalls were higher than those obtained for FFQ1. This finding is not unusual as the questionnaire that was first administered measures diet in the previous year, whereas the second questionnaire measured dietary intake over the 1 year period in which the 24-hour recalls were collected. It is also possible that participants may have become more aware of their diet, hence the higher correlation values.

The validity study demonstrated that the food-frequency questionnaire provided mean estimates of macronutrient intakes that were within 15% of the reference method and within 5% when expressed as a percentage of energy intakes. Estimates of fibre and iron were within ±3% of the reference method. However, the FFQ gave higher mean intakes of other micronutrients and of alcohol.

Unadjusted correlation coefficients between recalls and the FFQ ranged from 0.20 to 0.86. This compares well with values obtained in other validation studies[10,11,27,28]. Correlation coefficients for energy and macronutrients were generally higher than some studies[11,28,34] but lower than in others[8,10], although methodological differences make precise comparisons difficult.

Correlations of estimates of micronutrient intakes between the recalls and second FFQ were moderate for vitamin E, calcium and iron, but low for vitamin A (retinol and beta-carotene). Low correlations for vitamins are not unusual and may reflect not only limitations of the FFQ but also the difficulty in estimating retinol and beta-carotene intake by the reference method. Prolonged recording periods in excess of the 12 days used in this study may be necessary[35].

Adjustment for energy intake is based on the assumption that each participant reports nutrients in similar proportions on both instruments, even though the absolute amounts may differ[36]. Energy adjustment produced only minor changes (less than or equal to 0.07) in the Pearson correlation coefficients in this study. Adjusting for energy has improved the magnitude of correlation coefficients in some validation studies[10,23,37] but not in others[28,38]. Adjustment should at least partially remove the correlation error between nutrient and energy intake and thus improve the correlation between the two dietary assessment methods. However adjustment may also reduce the between-subject variability, leading to a reduction in the correlation coefficients.

In epidemiological investigations, nutrient intakes are often categorised for calculation of disease associations. Cross-classification of nutrients into quartiles showed that on average 46–48% of participants in the lowest and highest quartiles according to the 24-hour recalls were classified in the same quartiles by the FFQ. This level of agreement is comparable to that in other studies[11,39]. Misclassification into extreme quartiles tended to be low for most nutrients, with few persons grossly misclassified into extreme quartiles. As expected, agreement in cross-classification for macronutrient intakes was better than for micronutrients.

EI/BMR

Errors in dietary assessment apply to instruments that measure habitual food intake as well as assessment of intakes during the actual measurement period, hence agreement between the methods will not necessarily reflect validity of either of the methods. Garrow[40] recommended that results of a dietary questionnaire should be validated against a method that has different sources of error; for example, estimated BMR or urinary nitrogen excretion. We therefore examined the extent to which both dietary assessment methods gave valid estimates of energy intake by determining the EI/BMR ratio.

Estimates of energy intakes by gender showed that, on both instruments, the means were greater than the group cut-off of $1.35 \times$ BMR that has been suggested to reflect habitual intake at the group level[12]. The EI/BMR ratios indicated light to moderate activity levels, which would be appropriate for an urban population in a developing country such as Jamaica, suggesting that mean energy estimates by the FFQ were valid.

At the individual level, the findings suggest that there may be substantial underreporting (EI/BMR < 1.2) and this was greater with the food-frequency questionnaire than with repeated recalls. Low energy reporting was particularly evident among females. Studies comparing energy intake and energy expenditure, measured by the doubly labelled water method, found that both obese and non-obese participants underreported habitual energy intake and that underreporting was greater in obese individuals[41,42]. An inverse association between body mass index and reported energy intake has also been documented[9,43–45].

In summary, the Jamaican food-frequency questionnaire showed good reproducibility comparable to that reported elsewhere. The relative validity to estimate mean intakes and to classify participants into quartiles of energy, macronutrients and alcohol was comparable with or higher than those of FFQs used in other populations. These results are encouraging in view of the fact that macronutrient intake is an important focus in

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our study of the epidemiology of diabetes and hypertension. Agreement between the two dietary assessment methods was moderate for some micronutrients (iron, calcium, vitamin E) and fibre, but was poor for retinol and beta-carotene. While poor agreement probably reflects limitations of both methods, further modifications of the food list may be necessary before using the FFQ for these nutrients.

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