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Validation of the second version of a quantitative food-frequency questionnaire for use in Western Mali

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Abstract

Objective: To assess the relative validity of the second version of a quantitative food-frequency questionnaire (QFFQ), designed to measure the habitual food and nutrient intake in one season in rural populations in Western Mali, West Africa.

Design: The dietary intake during the previous week was assessed with the 164-item QFFQ administered by interview. This was compared with the intake from a 2-day weighed record (WR) with weighed recipes.

Setting: The village of Ouassala in the Kayes region, Western Mali.

Subjects: Thirty-four women and 36 men aged 15–45 years, from 29 households.

Results: The QFFQ gave a lower intake of lunch and dinner and a higher intake of snacks than the WR. The discrepancies were larger for women than for men. The median proportion of subjects classified in the same quartile of intake was 29% for food groups and 36% for energy and nutrients. For classification into extreme opposite quartiles, the median proportion was 6% for food groups and 7% for energy and nutrients. Spearman's rank correlation for energy and nutrients ranged from 0.16 (% energy from protein) to 0.62 (retinol equivalents).

Conclusions: The second version of the QFFQ tends to underestimate total food weight. The methods used for estimating food portion size should therefore be applied with caution. The changes made from the first version had little effect. The ability to rank subjects according to dietary intake is similar with both versions. The improved layout of the new QFFQ makes it a more user-friendly tool for comparing dietary intake between population groups and for measuring changes over time.

Keywords
Evaluation studies
Nutrition surveys
Questionnaires
Food frequency
Validity
Adult
Mali
Africa

The food-frequency questionnaire (FFQ) is often the most feasible method for collecting data on regular dietary intake from large population samples. Its advantages include quicker administration and processing, and subsequently lower costs and participant burden than alternative methods such as diet history or repeated 24-hour recalls. Although the FFQ has traditionally been used in epidemiological studies[1,2], it can also be used to assess and monitor nutrition situations, and as a basis for policy planning[3].

The FFQ is a simple tool for ranking individuals according to dietary intake, but its ability to provide accurate quantitative measures of intake is generally limited[4]. Furthermore, FFQs should be developed and validated in the local setting to ensure that the method is adapted to the target population and culturally sensitive[5]. A number of recently published studies report the use of FFQs in various populations in South Africa[6–12]. However, the application of FFQs in other African countries appears much more limited[13–16]. To our knowledge, very few studies have been done on the development and validation of FFQs in African population groups[3,17–20], indicating a need for further development of quantitative methods for assessing their dietary intake.

This paper describes the relative validity of the second version of a quantitative food-frequency questionnaire (QFFQ), designed to measure the habitual food and nutrient intake in one season in rural populations in Western Mali, West Africa. The first version of the QFFQ was developed by researchers in Mali and Norway in 1996. After a validation study[3], the questionnaire was modified and used in a baseline study of food and nutrition security in 1997[21]. The second version had improved layout and a more detailed food list, including ingredients of special interest, such as sugar and milk in porridges, and meat and fish in sauces (Appendix A). The first and second versions of the QFFQ were validated in the Bafoulabé district, Kayes region, but in different villages and seasons. A 2-day

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weighed record (WR) served as the reference method in both studies.

Subjects and methods

Sampling

The present validation study was conducted in Ouassala, a rural village in the Bafoulabé district. The village is situated on the bank of the Bakoye River, 9 km north-east of Mahina market and train station on the rail line connecting the capitals of Mali and Senegal. The people are descended from several ethnic groups, mainly Fulani, Malinke and Bambara. The great majority speaks a Bambara dialect, and the predominant religion is Islam. The population usually eats their main meals from a shared serving dish with a ladle or as handfuls. This village was chosen because of its location, and for validation purposes was considered representative of the villages included in the baseline study in 1997.

The village had a total of 783 residents in 94 households (census by the research group). A household was defined as the people who eat food prepared in the same cooking pot. Households were selected randomly at a village meeting. A maximum of four participants was included from the households. A sample size of 70 was reached with the time and resources available. Inclusion criteria were village residence, age from 15 to 45 years, and presence in the village the week before the first day of the study and the following three days. Due to an uneven sex distribution of the target population (53% women and 47% men), eligible men were recruited first within the households to get a sample with approximately the same number of men and women. The study was explained in detail to the target population before recruitment, and those who agreed to participate gave their verbal consent.

During the selection process one selected household refused to participate, because the study would be too demanding. This household was replaced. The study team visited 32 households, of which three refused to participate. The final sample consisted of 29 randomly selected households (31% of the village households and 88% response rate) with a total of 70 persons: 36 men and 34 women (26% of the men and 22% of the women aged 15–45 years in the village). All participants entering the study completed. No rewards were used.

Study design

Four fieldworkers from the district, two men and two women, were recruited. They all had at least 12 years of education, were fluent in French and the local language, and had previous experience from doing similar studies. Before the validation study, they took part in a five-week training and preparation period. All pre-tests were done in the village of Samea, being similar to Ouassala.

The same fieldworker surveyed the assigned participant on three consecutive days. On day 1 the food consumed during the past week was assessed with the 7-day QFFQ. Background variables (including weight, height, illness, education, occupation, as well as pregnancy and lactation for women) were also collected with a separate questionnaire. Days 2 and 3 were used for the 2-day weighed record (WR), including weighed recipes and weighed recording of snacks between meals.

During the validation study, two supervisors were present in the households with the fieldworkers. All questionnaires were checked for errors and completeness the same day or the day after being administered. Missing data were usually collected by revisiting the participants. The supervisors processed the raw data after leaving the village.

The Malian research council (CNRST), district authorities in Bafoulabé and the village chief in Ouassala granted research permission.

Anthropometry

The participants were weighed lightly clothed, using digital scales (Soehnle 7505, 100 g precision for 0–150 kg). The estimated weight of clothing was subtracted from the body weight, 0.4 kg for men and 0.5 kg for women. Standing height was measured using wooden measuring boards with a measuring tape with 0.1 cm precision, based on the UNICEF model from 1986[22].

The 7-day quantitative food-frequency questionnaire (test method)

Due to large seasonal differences in diet in the study area, the QFFQ was designed to cover only one part of the year. However, within each season the variation is much smaller, and one week was considered sufficient to capture the habitual diet. The validation study of the first QFFQ and the baseline study using the second QFFQ both covered the harvest season from October to December. The validation study of the second QFFQ was undertaken during eight weeks in the dry post-harvest season from March to May in 1999. An additional two-week interruption was included to avoid any influence on the habitual diet by the Muslim Tabaski festival. Owing to the different seasons, the food list was expanded from 104 items to 164 (Appendix B). Of the 60 additional foods, 63% concerned snacks and beverages. The foods were added based on the outcome of discussion groups about diet that were organised in the village before the validation study for all men and women aged 15–45 years.

The QFFQ was administered by interview to each participant at home. It consisted of the food list and a part for recording frequency, estimated portion size and mealtime (breakfast, lunch, dinner or snack). The frequency question was open-ended, but the number of breakfasts, lunches and dinners in a week was verified with the respondent when it did not equal seven.

For liquid and semi-solid foods, the respondents were asked to show the quantities eaten using cereal bran in their own household measures, or household measures typical of the area (plastic cup and aluminium serving dish). For meat and fish, the respondents moulded full-size models of the pieces eaten, mixing cereal bran and water. The fieldworker then measured the volume using a measuring jug (10 dl with 0.2 dl precision or 5 dl with 0.1 dl precision), and recorded the volume in decilitres.

For certain foods (e.g. bread, cassava and papaya), the respondents showed the length of the piece eaten on a measuring tape (0–150 cm with 0.1 cm precision). Other foods (e.g. fish balls, fritters and many fruits) were recorded in units. Weight equivalents were calculated using conversion factors for grams per decilitre/centimetre/unit, edible percentage, and weight ratio of sauce to staple. The factors were developed by weighing local foods during previous and present fieldwork or estimated from tables.

The 2-day weighed record (reference method)

In Ouassala village breakfast was usually porridge, eaten with a calabash ladle. Lunch and dinner typically consisted of a cereal staple with sauce, eaten as mixed handfuls. The techniques for weighing food eaten from a shared serving dish and for weighing the corresponding recipes have been described earlier[3]. Digital scales were used (Soehnle 8020, 2 g precision for 0–2.5 kg and 5 g precision for 2.5–5 kg).

If the fieldworkers could not be present to record snacks between meals, they were notified by someone within the household, or scales were left in the household with a literate person who received instructions for using it. Recalls were taken of the food consumed between dinner and breakfast the following morning. For trips to Mahina market, the participants were either accompanied by a fieldworker or provided with money to bring back a double portion of food to the village for weighing. Missing quantities were estimated by the methods described for the QFFQ.

Validity of the reference method

The validity of the weighing technique was examined using Goldberg cut-off values[23]. The mean physical activity level (PAL) of the study population, expressed as a multiple of basal metabolic rate (BMR), was estimated to be 1.8. This corresponds to a lifestyle with much walking in doubly labelled water studies of free-living adults in affluent societies[24]. The 95% confidence limits for a PAL of 1.8 were 1.70 and 1.90 using a diet recording period of 2 days and revised factors for the sources of variation in the Goldberg equation[23]. The ratio of weighed energy intake to basal metabolic rate (EI/BMR) was calculated using standard equations for prediction of BMR based on sex, age and weight[25].

Nutrient calculations

The intakes of foods and nutrients were calculated using a computer program developed for the Danish Cancer Society, FoodCalc version 1.3, which is available from the Internet[26]. This software was run with the food composition table for Mali[27]. Missing food composition data were added from tables for Africa[28], Italy[29] and Norway[30]. The intake of dishes from the WR was calculated using the recorded recipes adjusted for weight change during cooking, which was assumed to be caused by the absorption or evaporation of water. The intake of dishes from the QFFQ was calculated using an independent set of recipes developed for the baseline study in 1997, as recommended by Nelson[31]. This set was, however, supplemented with some new recipes from the WR.

Statistical analysis

The data were analysed using the computer program SPSS version 10.0[32]. Non-parametric statistical methods were chosen, since the intakes of most food groups and nutrients were positively skewed. The sample median and the 25th and 75th percentiles were computed. Paired differences between the WR and the QFFQ were reported either as the ratio QFFQ/WR in per cent or as the percentage of subjects with a difference $<20\%$ of the mean of both methods[33]. Paired differences were visualised by scatter plots and Bland–Altman plots[34], and tested using the Wilcoxon signed-rank test. The significance level was set at 5%. The ability to rank individuals was assessed by Spearman's rank correlation and by classification of subjects in quartiles of intake. Differences in recorded intake between fieldworkers were tested for with the Kruskal–Wallis rank test for independent samples.

Results

Study population

Table 1 shows some characteristics of the study participants. Six men (17%) fell below the body mass index (BMI) cut-off value of 18.5 kg m^{-2} for mild malnutrition, of which five were aged 15–19 years. Eight women (24%) had BMI below 18.5 kg m^{-2}, of which five were lactating. Of the women, 68% had no formal education (defined as more than three years of primary school in the French educational system) versus 17% for the men.

Intake of meals

Table 2 shows the weight of the daily food intake for each meal (breakfast, lunch, dinner and snacks) and the meal energy distribution, measured with the QFFQ and WR. The intake of all meals, except snacks, was lower with the QFFQ than the WR. The difference was significant for lunch and dinner, but not for breakfast. For snacks, the intake was significantly higher with the QFFQ than the WR.

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Table 1 Characteristics of the study population in the validation study. Men and women aged 15–45 years ($n = 70$), Mali 1999

	Women ($n = 34$)		Men ($n = 36$)	
Age (years)*	25	(19, 33)	25	(18, 33)
Body weight (kg)*	55.6	(48.5, 62.1)	59.9	(54.2, 65.9)
Height (m)*	1.65	(1.59, 1.69)	1.71	(1.67, 1.76)
BMI (kg m^{-2})*†	19.8	(18.2, 22.2)	19.9	(18.9, 22.2)
Pregnant (%, n)	12	(4)	–	
Lactating (%, n)	29	(10)	–	
Illness affecting appetite (%, n)‡	26	(9)	14	(5)
No formal education (%, n)§	68	(23)	17	(6)
Occupations (%, n)				
Household chores	94	(32)	31	(11)
Home gardening	62	(21)	44	(16)
Construction	0	(0)	39	(14)
Petty trade	35	(12)	3	(1)
Schoolwork	3	(1)	36	(13)

* Values are median and (25th, 75th percentile).
† BMI is calculated for non-pregnant women ($n = 30$).
‡ Women reported fatigue, abdominal pain, malaria, common cold, back pain, leg sprain and wounds. Men reported diarrhoea, fatigue, abdominal pain and toothache.
§ Formal education is defined as more than three years of primary school in the French educational system and excludes religious schooling (Koran studies), French–Arabic schooling and literacy programmes.

The meal providing most of the energy with the QFFQ was snacks (35%), but with the WR it was dinner (31%).

The pattern of lower intakes of breakfast, lunch and dinner was much stronger for women than for men ($P < 0.01$ for women and $P > 0.05$ for men for every meal, data not shown). For snacks, women had a higher intake with the QFFQ than with the WR ($P < 0.01$), but for men the intake was almost identical with the two methods ($P = 0.62$, Wilcoxon signed-rank test).

Intakes of food groups

Table 3 shows the intakes of 11 different food groups measured with the QFFQ and the WR. For the total sample the QFFQ intakes were significantly lower for cereals and salt and significantly higher for milk, legumes, fruit, vegetables and edible fats, compared with the WR. The difference in intake was not significant for meat/eggs, fish, green leaves and sweets. The percentage of participants with a difference $< 20\%$ of the mean intake varied from 9% for vegetables to 49% for cereals.

The intake of cereals with the QFFQ was significantly lower for women only. The intake of fruit was significantly higher for women only. For meat/eggs, vegetables, sweets and edible fats, men had higher intakes with the QFFQ, but for women there was little difference.

Spearman's correlation coefficient for the intakes of food groups measured with the QFFQ and the WR ranged from -0.04 (edible fats) to 0.56 (fruit) for the total sample (Table 4), the median coefficient was 0.28. The median coefficient for men and women was 0.24 and 0.14, respectively. The food groups with negative correlation coefficients – edible fats (for the total sample and for men), meat/eggs, vegetables and green leaves (for women) – were consumed in relatively small amounts. Some coefficients had characteristically shaped scatter plots (Appendix C). The proportion of subjects correctly

Table 2 Intake of meals (g day^{-1}) and energy distribution (%) with the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR). Men and women aged 15–45 years ($n = 70$), Mali 1999

	QFFQ		WR			
	Median	(P_{25}, P_{75})*	Median	(P_{25}, P_{75})*	P-value†	QFFQ/WR × 100 (median)
Meal weight (g day^{-1})						
Breakfast	535	(395, 762)	687	(407, 861)	0.24	86
Lunch	568	(438, 729)	690	(504, 907)	$<$0.01	74
Dinner	527	(369, 633)	674	(456, 865)	$<$0.01	77
Snacks	533	(361, 933)	443	(251, 766)	0.02	122
Total	2207	(1768, 3172)	2514	(2097, 3111)	0.06	88
Energy distribution (%)						
Breakfast	16	(10, 22)	16	(11, 22)	0.99	
Lunch	22	(16, 28)	27	(20, 37)	$<$0.01	
Dinner	26	(19, 31)	31	(22, 38)	$<$0.01	
Snacks	35	(24, 46)	23	(13, 33)	$<$0.01	

* 25th and 75th percentiles.
† Differences are tested with the Wilcoxon signed-rank test.

Table 3 Intake of food groups (g day^{-1}) with the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR). Men and women aged 15–45 years ($n = 70$), Mali 1999

	Total sample ($n = 70$)						Men ($n = 36$)					Women ($n = 34$)				
	QFFQ		WR			< 20% difference‡	QFFQ		WR			QFFQ		WR		
	Median	(P_{25}, P_{75})*	Median	(P_{25}, P_{75})*	*P*-value†	(%)	Median	(P_{25}, P_{75})*	Median	(P_{25}, P_{75})*	*P*-value†	Median	(P_{25}, P_{75})*	Median	(P_{25}, P_{75})*	*P*-value†
Cereals[a]	384	(273, 499)	409	(323, 527)	0.01	49	475	(333, 538)	460	(328, 549)	0.52	307	(250, 407)	372	(289, 458)	0.01
Milk[b]	7	(0, 73)	0	(0, 16)	<0.01	23	24	(0, 88)	0	(0, 17)	0.01	2	(0, 37)	0	(0, 16)	0.01
Meat/eggs	19	(0, 39)	0	(0, 32)	0.19	14	29	(20, 51)	0	(0, 46)	0.07	0	(0, 18)	0	(0, 26)	0.83
Fish	11	(1, 36)	12	(6, 38)	0.61	10	13	(5, 53)	9	(4, 18)	0.13	9	(0, 23)	20	(6, 45)	0.04
Legumes[c]	84	(51, 139)	67	(50, 100)	0.01	21	117	(72, 183)	95	(64, 132)	0.04	73	(39, 98)	56	(34, 68)	0.04
Fruit[d]	161	(53, 302)	116	(3, 306)	0.02	16	183	(50, 290)	139	(4, 409)	0.59	123	(54, 421)	100	(2, 220)	<0.01
Vegetables[e]	25	(9, 55)	21	(9, 37)	0.04	9	29	(12, 55)	15	(9, 37)	0.02	21	(9, 56)	23	(9, 37)	0.64
Green leaves[f]	30	(18, 51)	37	(19, 63)	0.29	11	40	(22, 56)	39	(20, 80)	0.96	27	(16, 40)	37	(15, 54)	0.11
Salt[g]	9	(6, 13)	11	(8, 15)	<0.01	24	12	(8, 14)	13	(10, 15)	0.01	7	(6, 9)	10	(8, 16)	<0.01
Sweets[h]	54	(26, 95)	45	(23, 72)	0.11	14	73	(43, 130)	53	(31, 98)	0.06	31	(21, 60)	42	(14, 58)	0.88
Edible fats[i]	5	(0, 18)	1	(0, 7)	0.01	10	8	(2, 21)	0	(0, 7)	0.01	4	(0, 18)	2	(0, 7)	0.33

* 25th and 75th percentiles.
† Differences are tested with the Wilcoxon signed-rank test.
‡ Percentage of subjects with a difference in intake between the QFFQ and WR <20% of mean intake of both methods.
[a] Yellow maize, sorghum, rice, millet, fonio (*Digitaria exilis*) and wheat.
[b] Cow's milk (fresh and curdled), goat's milk (fresh and curdled) and powdered milk.
[c] Peanuts, Bambara groundnuts (*Voandzeia subterranea*) and dried cow-peas (*Vigna unguiculata*).
[d] Apple, banana, mandarin, lemon, date, guava, mango, orange, papaya, watermelon, sweetsop (*Annona squamosa*), sweet dattock (*Detarium microcarpum*), akee fruit (*Blighia sapida*), cashew fruit, jujube (*Zizyphus spina-Christi*), tamarind, shea-butterseed (*Butyrospermum parkii*), red sorrel (*Hibiscus sabdariffa*), baobab pulp (*Adansonia digitata*).
[e] Cassava, potato, sweet potato, yam, African fan palm (fruit and germinating radicle), cabbage, carrot, cucumber, eggplant, garlic, okra, onion, tomato, tomato paste, bitter tomato (*Solanum incanum*) and ginger.
[f] Lettuce, amaranth leaves, baobab leaves, onion leaves, mint leaves, horseradish-tree leaves (*Moringa oleifera*), cassava leaves and cow-pea leaves.
[g] Salt as cooking ingredient.
[h] Sugar, honey, chewing gum and candy.
[i] Peanut oil and shea-butterseed butter.

Table 4 Spearman's rank correlation and classification of subjects in quartiles of food intake with the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR). Men and women aged 15–45 years, Mali 1999

	Spearman's r*						Correctly classified (%)† ($n = 70$)	Grossly misclassified (%)‡ ($n = 70$)
	Total sample ($n = 70$)		Men ($n = 36$)		Women ($n = 34$)			
Cereals[a]	0.50		0.40		0.43		37	4
Milk§[b]	0.41		0.48		0.33	NS	–	–
Meat/eggs§	0.12	NS	0.32	NS	−0.16	NS	–	–
Fish	0.13	NS	0.17	NS	0.15	NS	34	13
Legumes[c]	0.35		0.17	NS	0.14	NS	30	1
Fruit[d]	0.56		0.50		0.62		44	3
Vegetables[e]	0.09	NS	0.24	NS	−0.12	NS	23	10
Green leaves[f]	0.10	NS	0.11	NS	−0.02	NS	17	7
Salt[g]	0.28		0.26	NS	0.08	NS	27	6
Sweets[h]	0.29		0.16	NS	0.22	NS	29	6
Edible fats[i]	−0.04	NS	−0.14	NS	0.12	NS	27	17

* If not indicated, correlation coefficients are significantly different from zero with $P < 0.05$. NS – not significant.
† Percentage of subjects classified in the same quartile of food intake with the QFFQ and the WR.
‡ Percentage of subjects classified into the extreme opposite quartile of food intake with the QFFQ and the WR.
§ Subjects not classified in quartiles since median intake with the WR is 0 g day^{-1}.
[a] Yellow maize, sorghum, rice, millet, fonio (*Digitaria exilis*) and wheat.
[b] Cow's milk (fresh and curdled), goat's milk (fresh and curdled) and powdered milk.
[c] Peanuts, Bambara groundnuts (*Voandzeia subterranea*) and dried cow-peas (*Vigna unguiculata*).
[d] Apple, banana, mandarin, lemon, date, guava, mango, orange, papaya, watermelon, sweetsop (*Annona squamosa*), sweet dattock (*Detarium microcarpum*), akee fruit (*Blighia sapida*), cashew fruit, jujube (*Zizyphus spina-Christi*), tamarind, shea-butterseed (*Butyrospermum parkii*), red sorrel (*Hibiscus sabdariffa*), baobab pulp (*Adansonia digitata*).
[e] Cassava, potato, sweet potato, yam, African fan palm (fruit and germinating radicle), cabbage, carrot, cucumber, eggplant, garlic, okra, onion, tomato, tomato paste, bitter tomato (*Solanum incanum*) and ginger.
[f] Lettuce, amaranth leaves, baobab leaves, onion leaves, mint leaves, horseradish-tree leaves (*Moringa oleifera*), cassava leaves and cow-pea leaves.
[g] Salt as cooking ingredient.
[h] Sugar, honey, chewing gum and candy.
[i] Peanut oil and shea-butterseed butter.

classified in the same quartile of food intake with the two methods ranged from 17% (green leaves) to 44% (fruit) with a median value of 29% (Table 4). The proportion of subjects misclassified into extreme opposite quartiles ranged from 1% (legumes) to 17% (edible fats) with a median value of 6%. For milk and meat/eggs, median intake with the WR was zero, and the subjects were classified above or below the median. The proportion of subjects correctly classified for milk was 64% (36% misclassified) and for meat/eggs 50% (50% misclassified).

Bland–Altman plots revealed increasing discrepancies between the QFFQ and the WR with increasing mean intake for most food groups. This is illustrated for cereals in Fig. 1.

Intakes of energy and nutrients

Table 5 presents the intakes of energy and nutrients measured with the QFFQ and WR. For the total sample, the QFFQ intake was significantly lower for calcium, sodium and % energy from both protein and carbohydrate. The intake was significantly higher for fat, % energy from fat and vitamin C. The difference from the WR ranged from 28% lower intake for sodium to 58% higher intake for vitamin C. The percentage of participants with a difference < 20% of the mean intake with both methods varied from 11% for vitamin C to 89% for % energy from carbohydrate.

Spearman's correlation coefficient for the intakes of energy and nutrients measured with the QFFQ and the WR ranged from 0.16 (% energy from protein) to 0.62 (retinol equivalents) for the total sample (Table 6), with a median coefficient of 0.37. The median coefficient for both men and women was 0.27. The proportion of subjects correctly classified in the same quartile of intake with the two methods ranged from 27% (% energy from carbohydrate) to 43% (vitamin C) with a median value of 36%. The proportion of subjects misclassified into extreme opposite

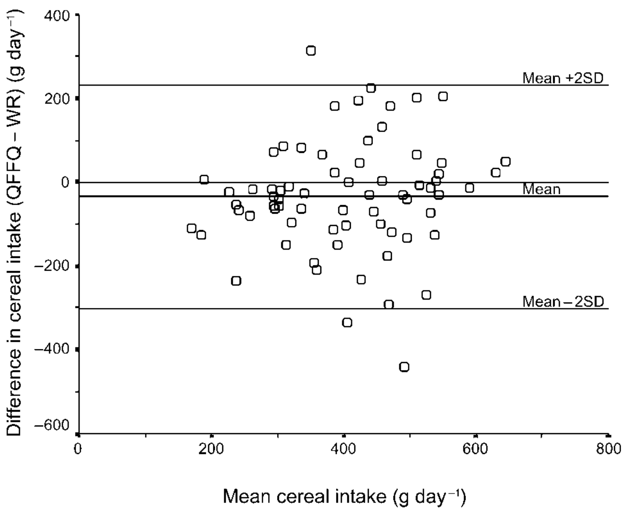

Fig. 1 Bland–Altman plot showing the difference in cereal intake between the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR), plotted against the mean cereal intake with the two methods

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Table 5 Daily intake of energy and nutrients with the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR). Men and women aged 15–45 years, Mali 1999

	QFFQ ($n = 70$)		WR ($n = 70$)				
	Median	(P_{25}, P_{75})‡	Median	(P_{25}, P_{75})‡	*P*-value*	QFFQ/WR × 100 (median)	<20% difference† (%)
Energy (MJ)	10.0	(8.3, 14.5)	10.6	(9.1, 12.9)	0.29	103	43
Protein (g)	69	(59, 98)	78	(62, 97)	0.99	96	41
Fat (g)	63	(47, 96)	58	(40, 78)	<0.01	121	30
Carbohydrate (g)	400	(304, 554)	423	(328, 503)	0.76	96	40
Retinol equivalents	628	(193, 1240)	581	(167, 1334)	0.20	116	19
Thiamin (mg)	1.8	(1.4, 2.6)	1.8	(1.4, 2.4)	0.44	104	39
Riboflavin (mg)	1.2	(0.99, 1.7)	1.2	(0.99, 1.6)	0.32	105	34
Niacin (mg)	26.1	(20.2, 38.7)	24.7	(19.1, 31.4)	0.26	103	39
Vitamin C (mg)	117	(38, 216)	59	(28, 154)	<0.01	158	11
Calcium (mg)	675	(471, 944)	823	(572, 1113)	0.05	80	23
Iron (mg)	49	(35, 69)	50	(37, 69)	0.46	91	29
Sodium (g)	6.8	(4.8, 9.9)	8.7	(6.5, 11.5)	<0.01	72	20
% energy							
Protein	11.7	(10.8, 12.7)	12.2	(11.2, 13.7)	0.01	94	73
Fat	24.0	(19.8, 27.2)	20.1	(16.6, 23.6)	<0.01	121	41
Carbohydrate	65.2	(60.3, 68.6)	67.3	(63.2, 71.8)	<0.01	96	89

* Differences are tested with the Wilcoxon signed-rank test.
† Percentage of subjects with a difference in intake between the QFFQ and WR <20% of the mean of both methods.
‡ 25th and 75th percentiles.

quartiles ranged from 3% (retinol equivalents) to 13% (calcium) with a median value of 7%.

Bland–Altman plots showed increasing discrepancies between the QFFQ and the WR with increasing mean intakes for energy and most nutrients, and outliers for high mean intakes of energy and macronutrients. This is illustrated for energy in Fig. 2.

Validity of the reference method

The mean value of the estimated EI/BMR ratio with 95% confidence limits for the 2-day WR was 1.78 (1.67, 1.90). The energy intake on each day of the 2-day WR was similar; the median (25th, 75th percentiles) value for the total sample was 10.5 MJ (8.6, 12.3) on day 1 and 10.5 MJ (8.1, 13.3) on day 2, with $P = 0.45$ (Wilcoxon signed-rank test). No significant differences were found when the energy and nutrient intakes measured with the QFFQ and WR were compared according to the fieldworker who recorded them.

Discussion

Validity of the reference method

This study assesses the relative validity of the second version of a 7-day quantitative food-frequency questionnaire (QFFQ) developed for surveying the food and

Table 6 Spearman's rank correlation and classification of subjects in quartiles of nutrient intake with the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR). Men and women aged 15–45 years, Mali 1999

	Spearman's *r**							
	Total sample ($n = 70$)		Men ($n = 36$)		Women ($n = 34$)		Correctly classified (%)† ($n = 70$)	Grossly misclassified (%)‡ ($n = 70$)
Energy (MJ)	0.44		0.27	NS	0.34		39	7
Protein (g)	0.39		0.33		0.30	NS	39	7
Fat (g)	0.37		0.17	NS	0.27	NS	36	10
Carbohydrate (g)	0.45		0.25	NS	0.44		40	7
Retinol equivalents	0.62		0.61		0.61		40	3
Thiamin (mg)	0.53		0.45		0.30	NS	40	4
Riboflavin (mg)	0.30		0.23	NS	0.26	NS	36	7
Niacin (mg)	0.43		0.31	NS	0.23	NS	33	7
Vitamin C (mg)	0.49		0.46		0.53		43	4
Calcium (mg)	0.19	NS	0.27	NS	0.01	NS	29	13
Iron (mg)	0.35		0.32	NS	0.21	NS	34	7
Sodium (mg)	0.29		0.27	NS	0.10	NS	34	9
% energy								
Protein	0.16	NS	0.14	NS	0.28	NS	31	9
Fat	0.28		0.22	NS	0.13	NS	31	7
Carbohydrate	0.27		0.17	NS	0.23	NS	27	6

* If not indicated, correlation coefficients are significantly different from zero with $P < 0.05$. NS – not significant.
† Percentage of subjects classified in the same quartile of nutrient intake with the QFFQ and the WR.
‡ Percentage of subjects classified into the extreme opposite quartile of nutrient intake with the QFFQ and the WR.

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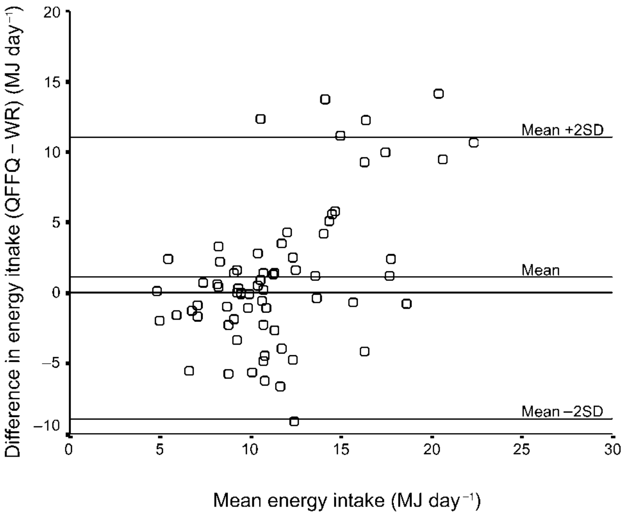

Fig. 2 Bland–Altman plot showing the difference in energy intake between the quantitative food-frequency questionnaire (QFFQ) and the weighed record (WR), plotted against the mean energy intake with the two methods

nutrition situation in rural populations in Western Mali. A 2-day weighed record (WR) completed by fieldworkers served as the reference method. External validation by estimated energy expenditure showed that the mean ratio of estimated EI/BMR for the total group of 1.78 is close to the estimated PAL of 1.8. As a comparison, the mean ratio of EI/BMR for the QFFQ was 1.95. However, excluding outliers with the three highest energy intakes ($>25\,\mathrm{MJ\,day}^{-1}$) lowered the ratio to 1.85.

To minimise the influence of fieldworkers, they had a separate camp in the village and were instructed not to eat in the households or accept food gifts. The energy intake of the participants did not decrease during the WR in the present study, a phenomenon found in other studies using fieldworkers[35,36]. No systematic differences were found when recorded intake was compared according to fieldworker. The presence of fieldworkers may have influenced food preparation in the participating households, but to an uncertain extent. According to village informants, two households refused to participate due to little food, or the concern that the 'quality' of the food would be judged.

The present study indicates that two days were insufficient to measure the habitual intake of some food groups. For milk, meat/eggs and edible fats, the intakes were close to zero with the WR, but a little higher with the QFFQ. Scatter plots of the negative correlation coefficients for meat/eggs and edible fats show a vertical line that presents subjects with no intake with the WR, but some with the QFFQ (Appendix C). The horizontal line presents subjects with no intake with the QFFQ, but some with the WR. This may indicate low precision of the QFFQ for small quantities of these foods, a difference in recipes, very irregular intakes, or a wish to impress the study team by eating high-status foods during the WR[37]. Most indications are still that the WR is a valid reference method. The choice of reference method has previously been discussed[3].

Intakes of meals

The underestimation of total food weight with the second version of the QFFQ was unexpected, as it was overestimated with the first version[35]. The misreporting was more profound for women than men with both versions. In the present study the general underestimation of food weight with the QFFQ was caused by a lower reported intake of all main meals (breakfast, lunch and dinner). Since the frequency of consumption of main meals was verified to add up to seven times per week, the low intake was probably caused by an underestimation of portion size. It is possible that the size of serving dish carried by the fieldworkers for estimating quantity was smaller than many dishes used in the households, and that participants therefore may systematically have underestimated portion size.

One explanation for the greater underestimation among women in the present study might be that they had more difficulty than men estimating the quantity eaten. This could be related to the lower education level of women in the study population. One study has reported that those with no education had the lowest percentage of correct responses (not statistically significant) when testing food portion photographs in a South African population[38]. Other studies have found associations between underreporting and literacy or educational level in Western women[39,40]. Underreporting has been found to be more prevalent in women than men, but then usually linked to adiposity and weight consciousness in women[40–42]. It is our impression that this does not apply to the women in the present study, who also overestimated the intake of snacks. The most important snacks by weight were mangoes, tea and bread for both men and women. Since women overestimated the intake of mangoes, which were estimated in units, the reported frequency appears to be a source of error. Explanatory factors could include misconception of the frequency question (eating occasions per week), lack of motivation or time to report accurately due to high workloads, and under-recording of snacks during the 2-day WR.

Intakes of food groups

The first version of the QFFQ overestimated the intakes of most food groups[3]. The present version underestimated the intake of cereal, caused by an underestimation of main meals (breakfast, lunch and dinner) that were cereal-based. Nevertheless, Fig. 1 shows that the difference in cereal intake between the QFFQ and WR varies from under- to overestimation over a wide range at the individual level.

Similar to cereals, the intakes of the food groups legumes, green leaves and salt were expected to be underestimated with the QFFQ, since peanuts, leaves and salt are important ingredients in the sauces accompanying the cereal staple dishes. This was confirmed for salt and green leaves. However, more subjects reported eating green salad in the QFFQ, concealing the underestimation of green leaves from sauce. The overestimation of legumes is largely explained by an overestimation of peanuts eaten as snacks. The overestimated intake of snacks with the QFFQ is also reflected in the overestimated intake of fruit. The intake of edible fats was low since peanuts contribute most of the fat in the diet. The consumption of alcohol was never reported or observed in this Muslim population during the study, although underreporting cannot be dismissed.

The range of Spearman's correlation coefficients for food groups is similar to the range for the validation study of the first version of the QFFQ for Mali[3] and of a QFFQ developed by MacIntyre and co-workers for South Africa[18], but lower than for other studies[43–45]. The low correlation for vegetables and green leaves can be explained by very little variation in intake in the study population. This is also reflected in a low proportion being classified in the same quartile of intake with the QFFQ and the WR.

Intakes of energy and nutrients

The first version of the QFFQ significantly overestimated the intakes of energy and most nutrients[3]. With the present version, median energy intake was similar to that with the WR. It appears that the overestimation of snacks with the QFFQ balances the underestimation of main meals with regard to energy. However, Fig. 2 shows large differences in energy intake between the QFFQ and WR at the individual level. The higher intake of fat with the QFFQ mostly came from the overestimation of peanuts, and explains the difference in energy distribution between the QFFQ and WR. Median carbohydrate intake was similar with both methods, but with the QFFQ more was provided by fruit and sweets and less by cereals than with the WR. The higher intake of vitamin C with the QFFQ mostly came from a higher intake of certain fruit varieties, such as baobab fruit, cashew fruit and guava. The lower intake of calcium with the QFFQ was mainly caused by the lower intake of green leaves from sauce, especially bean leaves which are very calcium-rich.

Spearman's correlation coefficients for energy and nutrients were higher than for food groups. The range was comparable to that for the first version of the QFFQ for Mali[3] and those found in other studies[18,46,47]. Some studies have reported higher ranges[44,47–49]. For most nutrients (not retinol equivalents, vitamin C and calcium), the coefficients were higher for the total sample than for men and women separately. This is because the intake range for the total sample was wider than for each subgroup. Also, more coefficients were significant for the total sample. This is likely due to higher statistical power for the whole group. Most retinol equivalents were provided as carotene from mangoes, consumed frequently in the study period. This may explain the high correlation compared with other studies[18,46,47,49]. The low coefficient for calcium mirrors the low coefficient for green leaves, whereas the low coefficients for protein and carbohydrate, when expressed as % of energy, reflect the difference in energy distribution between the QFFQ and WR.

The ability of the QFFQ to classify subjects in the same quartile of intake as the WR was also evaluated for energy and nutrients. The performance of the present version was similar to that of the first[3]. The percentage of correctly classified subjects for the nutrients analysed was similar to or slightly better than that reported in some studies[46,47], but lower than for others[47,50].

In summary, the validation study of the second version of the QFFQ for Mali was done in another village, in another season and with a modified questionnaire having more food items, compared with the validation study of the first version[3]. For ranking subjects in quartiles of energy and nutrient intake, the second version is similar to the first version and to some food-frequency questionnaires developed for Western populations. The correlation coefficients were similar to the coefficients for the QFFQ developed by MacIntyre and co-workers for South Africa, but weaker than for most Western questionnaires. In this study, the questionnaire performance was influenced negatively by poor estimates of portion size, especially for women, and low intake or low variation in the intakes of some food groups and nutrients. These factors are not directly related to the questionnaire layout, indicating that it is appropriate. The improved layout makes the QFFQ a more user-friendly tool for comparing dietary intake between population groups and for measuring changes over time.

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Appendix A: Food items added to the food list of the first version of the 7-day quantitative food-frequency questionnaire (QFFQ) from 1996, to make the second version from 1997

Local name (Bambara)	Description/main ingredients
Additives to porridge	
Nono	Milk
Sukaro	Sugar
Zira (mougou)	Baobab fruit* (powdered)
One-pot dishes	
Bassi ni nono	Dried couscous with milk
Boufidi	Cereal bran with peanut butter and okra
Denkou	Couscous with peanut butter and sugar
Same	Fried rice
Sauces	
Damanan	Kulandji (thin peanut sauce) with red sorrel
Gnugumagafengno	Peanut butter and green leaves
Sossodji	Kulandji (thin peanut sauce) with beans
Tiganiguelendji	Kulandji (thin peanut sauce) with Bambara groundnuts
Tomatenan	Kulandji (thin peanut sauce) with tomato
Meat/fish in sauces	
Sogo	Meat
Djèkè	Fish
Beverages	
Castel	Bottled beer
Djinibéré	Drink with ginger
N'Tombidji	Drink with tamarind*
Sébédji	Drink with decoction of fruit from the African fan palm*
Ziradji	Drink with baobab fruit* or lemon
Other food items/snacks	Estimated in decilitres in the QFFQ
Supusalato	Cabbage salad
Tiganiguenlen	Bambara groundnuts
Other food items/snacks	Estimated in centimetres in the QFFQ
Dissi (kènè)	Germinating racine of the African fan palm* (raw)
Melon	Melon
Sébé	Boiled fruit of the African fan palm*
Zèrè	Water melon
Other food items/snacks	Estimated in units in the QFFQ
Bouren	Wild fruit* (*Gardenia ternifolia*)
Bouyagui	Guava
Brochetti	Skewer with beef
Djakato	Bitter tomato (*Solanum incanum*)
Djèkèboletti	Fish balls
Gateau	Wheat fritters, sweet with egg

Appendix A. *Continued*

Local name (Bambara)	Description/main ingredients
Kili	Egg
Kobo	Wild fig* (*Ficus* spp., unidentified)
Lemuruba	Orange
Mandreni	Mandarin
Namasa	Banana
Pâté	Wheat fritters, salty
Pome	Apple
Pomme de terre (yiralen)	Potato (deep fried)
Sardines	Canned sardines
Sounssoun	African custard-apple* (*Annona senegalensis*)
Suro	Wild fig* (*Ficus dicranostyla*)
Tamaro	Date
Tibabu sounssoun	Sweetsop (*Annona squamosa*)
Tomi	Tamarind*
Toro	Bush fig* (*Ficus capensis*)
Zeguenè	Desert-date* (*Balanites aegyptiaca*)

* Food gathered in the wild in the study area.

Appendix B: Food items added to the food list of the second version of the quantitative food-frequency questionnaire (QFFQ) from 1997 before the validation study in 1999

Local name (Bambara)	Description/main ingredients
Additives to porridge	
Lemurukumuni	Lemon juice
Tomi*	Tamarind†
Zaban*	Gumvine† (*Saba senegalensis*)
One-pot dishes	
Banankou tobilen*	Cassava stew
Bouyèlèlen*	Cereal bran steamed with spices
Fri	Crushed and roasted cereal cooked with peanut flour and spices
Ku tobilen	Yam stew
Lakka*	Cereal flour cooked with peanut butter and baobab fruit†
N'Ganayèlèn*	Couscous with fresh okra and spices
Njambi tobilen*	Wild yam† (*Dioscorea dumetorum*) stew
Pomme de terre tobilen*	Potato stew
Tièkè*	Steamed manioc flour with onion, sweet pepper and oil
Tiganikurun*	Cooked Bambara groundnuts with oil
Wossonaranga*	Mashed sweet potato with peanut flour
Wosso tobilen	Sweet potato stew
Staple dishes	
Baya*	Crushed and roasted cereal, cooked
Niokoutouroukini*	Whole millet grains, cooked
Sauces	
Fakouhoye	Dried leaves (*Corchorus tridens*†), shea-butterseed butter† and spices
N'Gamboura*	Fresh okra and peanut butter
Saga-saga*	Cassava or sweet potato leaves and palm oil
Tokorodji	Tomato, onion and oil
Yassa*	Vegetables, meat, oil and vinegar
Beverages	
Baraoulendji	Infusion of wild tree leaves† (unidentified) with sugar
Café ni sukaro	Black coffee with sugar
Citronelle	Infusion of lemongrass with sugar
Dabléni	Infusion of red sorrel with sugar
Kinkélibadji	Infusion of tree leaves (*Combretum micranthum*) with sugar
Lemurubadji	Orange juice with water and sugar
Lemurukoumounidji	Lemon juice with water and sugar
Lydji	Honey† with water
Vin*	Wine
Other food items/snacks	Estimated in decilitres in the QFFQ
Djèkèyiranlen	Fried fish
M'Peku*	Wild fruit† (*Lannea microcarpa*)

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Appendix B. *Continued*

Local name (Bambara)	Description/main ingredients
Maribatiga	Salted peanuts
N'Tomonon	Jujube† (*Zizyphus spina-Christi*)
Other food items/snacks	Estimated in centimetres in the QFFQ
Banankou (kènè)	Cassava (raw)
Dissi (balabalalen)	Germinating racine of the African fan palm† (boiled)
Ku	Yam
M'Pié*	Wild tuber† (*Raphionacme brownii*)
Sandwich	Sandwich
Wosso (kènè)	Sweet potato (raw)
Other food items/snacks	Estimated in units in the QFFQ
Acra furufuru	Bean fritter
Baro*	Guinea peach† (*Nauclea latifolia*)
Biscuit	Biscuit
Brochetti	Skewer with liver
Fari	Steamed bean flour
Farine+nio furufuru	Wheat and millet fritter
Fukagnè*	Shakama plum† (*Hexalobus monopetalus*)
Gnuguni	Green leaf balls
Loko*	Fried plantain
N'Tabakoumba	Dattock† (*Detarium microcarpum*)
N'Tabanoko*	Wild fruit† (*Cola cordifolia*)
N'Tonguè*	Spiny-plum† (*Ximenia americana*)
Nogoni	Grilled intestine of sheep or goat
Pomme de terre (yiralen)	Potato (deep-fried)
Si	Shea-butterseed fruit†
Sogobouletti	Meat balls
Somo	Cashew fruit†
Woro	Colanut
Zaban*	Gumvine† (*Saba senegalensis*)

* The consumption of this food item was not recorded during the validation study with the 7-day quantitative food-frequency questionnaire or the 2-day weighed record (WR).
† Food gathered in the wild in the study area.

Appendix C

Figure shows the scatter plot of the daily intake of edible fats for the total sample ($n = 70$) measured with the weighed record (WR) and the quantitative food-frequency questionnaire (QFFQ). Spearman's correlation coefficient (r) is -0.04. The shape of the plot is characteristic of other negative correlation coefficients for food groups (not vegetables and green leaves) in Table 4.