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Reproducibility and validity of a food-frequency questionnaire for use among low-income Brazilian workers

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Abstract

Objectives: To assess the reproducibility and validity a 127-item, habitual intake, food-frequency questionnaire (FFQ), developed for low-income and low-literacy Brazilian workers, by comparison with a 24-hour dietary recall (24-HDR).
Design: The FFQ and 24-HDR were interviewer-administered at the local workplace to each subject twice, with a period of 6 months between estimates; and four 24-HDRs were conducted during the 4-month period between the two FFQs (FFQ1 and FFQ2). Reproducibility was tested by comparing mean nutrient intakes from the two FFQs. Validity was determined by comparing the mean nutrient intakes from the FFQs with the corresponding averages of the six 24-HDRs (reference method).
Setting: Goiânia City, in Central West Brazil.
Subjects: The study was based on 104 (62 women and 42 men) subjects, aged 18 to 60 years, who were randomly selected.
Results: Dietary intake from the FFQ was higher than from the 24-HDR. Reproducibility was assessed by Pearson correlation coefficients for nutrients from FFQ1 and FFQ2, and ranged from 0.23 for retinol to 0.69 for total energy (mean 0.52). Intra-class coefficients for nutrients averaged by the 24-HDRs ranged from 0.29 for vitamin C to 0.76 for total energy; retinol was not significant. In the validation study, correlation between the FFQ and the 24-HDR ranged between 0.21 for vitamin C and 0.70 for total energy (mean 0.50). Adjusting for total energy lowered the coefficients, except for calcium, retinol and vitamin C. Coefficients increased with attenuation, ranging from 0.35 for carbohydrate to 0.65 for calcium.
Conclusions: Results indicate that this questionnaire had satisfactory reproducibility and reasonable validity.

Keywords
Reproducibility
Validity
Food-frequency questionnaire
Low-income Brazilian workers
Dietary recall

For most epidemiological studies, long-term diet is the conceptually relevant exposure parameter[1]. Numerous investigators have established associations between the intake of nutrients and the occurrence of disease. In Brazil, low-income people suffer more from dietary excesses than the rich, with non-communicable diseases being higher among the low-income population[2]. Therefore, it is necessary to develop and evaluate simple dietary assessment methods to be applied to large populations.

The choice of an appropriate dietary assessment method depends on the requirements of the study being conducted[3]. The 24-hour dietary recall (24-HDR) is the most common method, which attempts to obtain a complete description of all foods eaten during the 24 h preceding the interview[1]. Repeated collections of the 24-HDR are needed to estimate usual food intake and can be used to validate the use of a food-frequency questionnaire (FFQ)[4]. A major strength of the recall method is that it does not require literacy of the subject, which is considered a critical factor in obtaining a representative sample of the population in low-income countries[1].

On the other hand, the FFQ is used for the assessment of past diet. The method is relatively inexpensive and easy to administer, and is established as the primary method for assessing dietary intake in epidemiological studies[1].

Validation studies among low-literacy, low-income populations are rare: a few previous FFQ validation studies have been done for Brazilian adults, but most of them were among highly educated populations[5–7]. The present study estimated the reproducibility and validity of a 127-item, habitual intake FFQ, developed for low-income and low-literacy Brazilian workers, by comparing mean energy and nutrient intakes from the FFQ with the mean intakes from six 24-HDRs.

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Study population and methods

Study population

The present study was conducted among a random sample of low-income workers, aged 18 to 60 years, from Goiânia City. Workers were recruited from several workplaces (university hospital: food service, laundry and sewing room; university: cleaners; city buildings: doorkeepers and cleaners; city cleaning firm: street-sweepers and gardeners; food industry: food service workers).

One hundred and twenty subjects were enrolled in the study; however, 16 had incomplete information. Therefore the results are based on 104 individuals, interviewed in their workplace by interviewers following the same protocol with basic structure.

Development of the FFQ

To develop the dietary instrument (FFQ), a list of foods was compiled from data obtained from a previous single 24-HDR and local surveys on the frequency of food consumption. The first version of the FFQ was tested among university cleaners; after this pre-test, a few regional food items were added. The list was composed of 127 Brazilian food items, excluding supplements, structured into 11 food groups: dairy products, leguminous, meats and eggs, grain and cereals, sweet and salty doughs, fruits and natural juice, vegetables, fats, sweets, alcohol and non-alcoholic beverages, and spices and condiments.

The interviewer-administered FFQ was created to assess usual, long-term total diet for epidemiological studies. The dietary factors to be estimated were intakes of total calories, protein, carbohydrate, fat, retinol, vitamin C, calcium and iron.

Data collection

The FFQ was preceded by questions on social and demographic variables, followed by questions on eating habits. The FFQ and 24-HDR were administered twice, at the beginning and at the end of the study period, and four intermediate 24-HDRs were conducted during the 4-month period between the two FFQs (Fig. 1).

A 6-month retrospective FFQ was used to determine food consumption frequency. A trained nutritionist or an undergraduate student interviewed each participant. Respondents were asked to average the frequency of consumption of specific foods over the entire 6 months and to describe the usual amount consumed or portion size of these foods[8], using as reference habitual regional utensils (cups, glasses, spoons, slices and pieces). Additional questions were asked about the type of fat used in cooking or preparing meals.

Food consumption frequency was coded into one of nine categories[9]: never; once per month or less; 2–4 times per month; 2–4 times per week; 5–6 times per week; once a day (considered the 6 months with 180 days); 2–3 times per day; 4–5 times per day; and 6 or more times per day. To translate food consumption into daily nutrient intakes we used the computer program DietPro Version 3.0 (Agromídia Software; UFV/FUNARBE, Viçosa, MG, Brazil, 2000).

Statistical analysis

Descriptive analysis was performed for each nutrient. For comparing intakes estimated by each of the two FFQs and the average of the six 24-HDRs, we calculated the ratio of means. Means for energy and nutrients were tested for significant differences at the 5% level. To assess the reproducibility of the FFQ, Pearson correlation coefficients were used to evaluate agreement on nutrient intakes between the first administration (FFQ1) and the second administration (FFQ2) of the FFQ. To measure the FFQ's relative validity, Pearson correlation coefficients were again used to evaluate agreement on nutrient intakes between the average of FFQ1 and FFQ2 and the average of the six 24-HDRs. To assess the variability in daily intakes, intra-class correlation coefficients for energy and nutrients were calculated[1,10] from the monthly spaced (six) 24-HDRs.

Crude and adjusted Pearson correlation coefficients were computed to compare nutrient intakes assessed by the FFQs and the average of the six 24-HDRs. The adjustment for energy was done according to the published method[11,12].

The Pearson correlation coefficients were also corrected for attenuation due to intra-individual variation in the reference method. The variance ratio was calculated as the ratio of within-person variance to between-person variance[1].

All dietary variables generated by the 24-HDRs or FFQs required log transformation to approximate a normal distribution. Significance was adopted as $P \leq 0.05$ and

Nov/99	Dec/99	Jan/00	Feb/00	Mar/00	Apr/00
24-HDR1	24-HDR2	24-HDR3	24-HDR4	24-HDR5	24-HDR6
FFQ1	....	......	......	......	FFQ2

Fig. 1 Study design to assess the reproducibility and validity of a food-frequency questionnaire (FFQ) for use among low-income Brazilian workers. Reference method is the 24-hour dietary recall (24-HDR)

statistical analyses were performed using the Statistical Analysis System, Version 6.12 (SAS Institute, Inc., Cary, NC, USA, 1996).

Results

Table 1 summarises the sociodemographic characteristics of the Brazilian workers. The study was based on 104 subjects, 62 women and 42 men, mean age 38.8 and 28.5 years, respectively. Sixty-six per cent of the sample reported elementary educational level or less. The reported monthly family income was lower than five times the minimal salary for 75% of the individuals in this study.

The eating pattern of the study group consisted of cereals (rice, white bread and noodles), red beans, milk and poultry, processed meats, low intake of red meat, vegetables (tomatoes, squash, roots), low intake of leafy green vegetables, fruits (orange, banana, papaya, water-melon), refined sugar, vegetable oils (soy) and margarine. Dietary intakes of total energy and nutrients estimated from the FFQs were higher than estimated from the six monthly spaced 24-HDRs, except for protein and total fat (Table 2). Intake of retinol estimated from the 24-HDRs and from FFQ1, FFQ2 and FFQ1–2 presented a highly skewed distribution, with median (25th percentile, 75th percentile) of 375.8 (286, 644), 754 (529, 1116), 729.6 (453, 1089) and 810 (541, 1177) $\mu g\, day^{-1}$, respectively. The mean ratio for energy and nutrient intakes estimated from the two FFQs versus the average of dietary recalls was 1.21 ± 0.42 and the median was 1.11. Percentage of energy from protein and fat was slightly lower with the questionnaire than from the reference method. There were no significant differences among macronutrient values (% of total energy).

Reproducibility

The reproducibility of unadjusted selected nutrient intakes measured by FFQ1 and FFQ2 at 6 months ranged from 0.23 for retinol to 0.69 for total energy (mean = 0.52); adjustment for total energy lowered the coefficients (Table 3). By the 24-HDR, vitamin C had the

Table 1 Sociodemographic characteristics of the low-income Brazilian workers participating in the study; Goiânia, Brazil, 1999–2000

Characteristic	Sex		Total	Percentage
	Female	Male		
Number of participants	62	42	104	100
Age (years)				
Median (P_{25}, P_{75})	38 (32, 47)	27 (23, 32)	32 (26, 40)	
Education				
Illiterate	2	–	2	2.0
First primary school	10	8	18	17.3
Primary school	31	18	49	47.1
High school	19	16	35	33.6
Family income (MS*)				
< 1 MS	1	–	1	1.0
1–2.9 MS	26	12	38	36.5
3–4.9 MS	21	18	39	37.5
≥ 5 MS	14	12	26	25.0

P_{25} – 25th percentile; P_{75} – 75th percentile.
* 1 MS (minimal salary) = US$80.00.

Table 2 Daily nutrient intakes (mean ± standard deviation) estimated by six 24-hour dietary recalls (24-HDR1–6) and two food-frequency questionnaires (FFQ1 and FFQ2), and various ratios of mean intakes, among low-income Brazilian workers, 1999–2000 (*n* = 104)

Nutrient	24-HDR1–6	FFQ1	FFQ1/ 24-HDR1–6	FFQ2	FFQ2/ 24-HDR1–6	FFQ1–2	FFQ1–2/ 24-HDR1–6
Total energy (kcal)	1967 ± 527	1997 ± 771	1.02	2057 ± 995	1.05	2027 ± 811	1.03
Total carbohydrate (g)	251.1 ± 75.7	280 ± 108.8	1.12	282.7 ± 139.9	1.13	281.4 ± 112.7	1.12
Protein (g)	84.4 ± 24.9	66.1 ± 29.3	0.78	71 ± 36.3	0.84	68.5 ± 28.9	0.81
Total fat (g)	70.1 ± 17.8	64.8 ± 33.4	0.92	67.1 ± 37.6	0.96	65.9 ± 30.9	0.94
Calcium (mg)	362.6 ± 156.9	470.1 ± 256	1.29	474.8 ± 273	1.31	472.5 ± 220	1.30
Iron (mg)	11.3 ± 4	13.7 ± 5.6	1.21	14.4 ± 7.6	1.27	14 ± 5.7	1.24
Retinol equivalents (μg)	971.6 ± 1341	978.6 ± 778	1.01	1151 ± 1654	1.18	1065 ± 946.2	1.10
Vitamin C (mg)	95 ± 89.1	226.5 ± 160	2.38	185.7 ± 138.4	1.95	206.1 ± 131.6	2.17
Carbohydrate (% of energy)	50.9 ± 4.7	56.4 ± 7.6	1.11	55.2 ± 8.7	1.08	55.8 ± 6.8	1.10
Protein (% of energy)	17.2 ± 2.2	13.3 ± 3.1	0.77	13.8 ± 3.8	0.80	13.5 ± 2.4	0.78
Fat (% of energy)	32.4 ± 4.2	29.1 ± 6.8	0.90	29.5 ± 8.1	1.10	29.3 ± 6.3	0.90

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Table 3 Reproducibility of six 24-hour dietary recalls (24-HDR1–6) and two food-frequency questionnaires (FFQ1 and FFQ2) for assessing mean daily nutrient intakes among low-income Brazilian workers, 1999–2000 ($n = 104$)

Nutrient*	24-HDR1–6 Intra-class *r*†	FFQ1 vs. FFQ2 Unadjusted *r*‡	FFQ1 vs. FFQ2 Adjusted *r*§
Total energy (kcal)	0.76	0.69	–
Total carbohydrate (g)	0.73	0.63	0.32
Protein (g)	0.63	0.58	0.23
Total fat (g)	0.49	0.56	0.34
Calcium (mg)	0.38	0.48	0.30
Iron (mg)	0.43	0.50	0.25
Retinol equivalents (μg)	NS	0.23	0.25
Vitamin C (mg)	0.29	0.48	0.33

* Nutrient values were transformed ($\log_e$) to improve normality.
† Intra-class correlation coefficients; NS – not significant.
‡ Unadjusted Pearson correlation coefficients.
§ Intakes adjusted for total energy using regression analysis.

lowest significant coefficient followed by calcium; total energy intake and carbohydrate had the highest reproducibility. In contrast, retinol intake showed more variability[10]: the intra-class correlation coefficient was not significant (Table 3).

Validity

Both FFQs were compared with the average of the six 24-HDRs to measure the relative validity. Pearson correlation coefficients between FFQ2 and the 24-HDRs were higher than between FFQ1 and the 24-HDRs, except for carbohydrate and vitamin C (Table 4).

For all nutrients, the correlation coefficients between the average of the two FFQs and the average of the six 24-HDRs (Table 5) were consistently higher than those obtained from FFQ1 and FFQ2 separately (Table 4). The Pearson coefficients between the recalls and FFQ1 ranged from 0.18 to 0.62 (mean 0.40), from 0.16 to 0.66 (mean 0.45) for FFQ2 (Table 4), and from 0.21 to 0.70 (mean 0.50) for FFQ1–2 (Table 5).

Comparing instruments administered at the same time, Pearson correlation coefficients were higher for the first administration (24-HDR1 vs. FFQ1) than the second (24-HDR6 vs. FFQ2), except for calcium, retinol and vitamin C. The coefficients improved when comparing instruments administered separately (24-HDR2–5 vs. FFQs) (Table 4).

After energy adjustment the correlation coefficients were remarkably lower for most nutrients (Tables 4 and 5). The decrease in the correlation coefficients between the nutrient means from the 24-HDRs and the FFQs averaged 0.50 to 0.37 (Table 5).

The coefficients were also corrected for attenuation due to intra-individual variation in the 24-HDR intakes. The correlation coefficients between the energy-adjusted nutrients (except for total energy) from the average of the FFQs and the 24-HDRs tended to increase with attenuation, from 0.31 to 0.36 for carbohydrate and from 0.54 to 0.65 for calcium. Deattenuated coefficients ranged from 0.36 to 0.65, with the highest coefficient being observed for total energy (0.81) (Table 5).

Table 4 Pearson correlation coefficients comparing crude and energy-adjusted mean daily nutrient intakes between six 24-hour dietary recalls (24-HDR1–6) and two food-frequency questionnaires (FFQ1 and FFQ2) among low-income Brazilian workers, 1999–2000 ($n = 104$). 24-HDR1 and 24-HDR6 were collected at the same time as FFQ1 and FFQ2, respectively; 24-HDR2–5 were collected separately

Nutrient*	24-HDR1–6 vs. FFQ1 Unadjusted *r*†	24-HDR1–6 vs. FFQ2 Unadjusted *r*†	24-HDR1 vs. FFQ1 Unadjusted *r*†	24-HDR1 vs. FFQ1 Adjusted *r*‡	24-HDR2–5 vs. FFQ1–2 Unadjusted *r*†	24-HDR2–5 vs. FFQ1–2 Adjusted *r*‡	24-HDR6 vs. FFQ2 Unadjusted *r*†	24-HDR6 vs. FFQ2 Adjusted *r*‡
Total energy (kcal)	0.61	0.66	0.60	–	0.69	–	0.54	–
Total carbohydrate (g)	0.62	0.60	0.57	0.29	0.66	0.22	0.53	0.24
Protein (g)	0.57	0.60	0.59	0.23	0.63	0.25	0.51	0.23
Total fat (g)	0.37	0.45	0.32	0.21	0.49	0.24	0.27	0.18
Calcium (mg)	0.32	0.33	0.37	0.28	0.31	0.39	0.32	0.37
Iron (mg)	0.40	0.56	0.35	0.20	0.56	0.21	0.35	0.19
Retinol equivalents (μg)	0.18	0.28	0.17	0.33	0.30	0.22	0.21	0.30
Vitamin C (mg)	0.20	0.16	0.18	0.17	0.21	0.20	0.18	0.16

* Nutrient values were transformed ($\log_e$) to improve normality.
† Unadjusted Pearson correlation coefficients.
‡ Intakes adjusted for total energy using regression analysis.

Table 5 Pearson correlation coefficients comparing crude, energy-adjusted and deattenuated mean daily nutrient intakes between six 24-hour dietary recalls (24-HDR1–6) and two food-frequency questionnaires (FFQ1 and FFQ2) among low-income Brazilian workers, 1999–2000 ($n = 104$). Pearson correlation coefficients are significantly different from zero at the 5% level ($P < 0.05$)

	24-HDR1–6 vs. FFQ1–2			24-HDR1–6 vs. FFQ2		
Nutrient*	Unadjusted *r*	Adjusted *r*†	Deattenuated *r*	Unadjusted *r*	Adjusted *r*†	Deattenuated *r*
Total energy (kcal)	0.70	–	0.81	0.66	–	0.76
Total carbohydrate (g)	0.68	0.31	0.36	0.60	0.21	0.25
Protein (g)	0.65	0.46	0.58	0.60	0.20	0.25
Total fat (g)	0.48	0.25	0.36	0.45	0.21	0.30
Calcium (mg)	0.40	0.54	0.65	0.33	0.41	0.49
Iron (mg)	0.56	0.27	0.41	0.56	0.23	0.35
Retinol equivalents (μg)	0.33	0.43	0.48	0.28	0.42	0.47
Vitamin C (mg)	0.21	0.26	0.39	0.16	0.28	0.42

* Nutrient values were transformed ($\log_e$) to improve normality.
† Intakes adjusted for total energy using regression analysis.

Discussion

Measuring regular dietary intake is necessary to study the relationship between diet and disease[13]. Therefore, development of an accurate measurement instrument is obviously a critical step in designing an epidemiological study[14].

If a suitable number of recalls are collected over a long period (in our case, monthly interviews during 6 months), this method may also be used to estimate usual intake in prospective studies[1]. We employed six 24-HDRs spaced monthly to account for seasonal as well as short-term variability. Because of the tropical weather in this region, available fruits and vegetables do not vary very much during the entire year. Instead of four seasons there are two annual seasons, namely dry and rainy. The data collection period takes into account part of both seasons.

Most validation studies are actually based on volunteers rather than on a truly representative sample of the study population[15]. FFQs have to be developed and validated specifically for each region and cultural group[16]. The length of time covered by the reference method is important because of the large daily variation in individual nutrient intakes[17].

It is important to develop a dietary assessment instrument to assess food intake among low-literacy and low-income populations in most developing countries. In this study we used repeated (six) 24-HDRs to represent the reference method and to assess the accuracy of the FFQ instrument. According to Dwyer *et al.*[18], the major limitations of the recall method include its reliance on memory, both for identification of food eaten and for quantification of portion sizes.

In validation studies, the exposure measure of interest is often compared with an imperfect but more precise measure of exposure[14]. Therefore, one should evaluate whether there are potential sources of correlated errors between the two measures. Error in measurement of the exposure can be introduced during almost any phase of a study[14]. In this case, a possible cause could be limitations due characteristics of the study subjects, e.g. poor memory of past diet, tendency to overreport socially desirable behaviours and underreport socially undesirable behaviours. In an attempt to reduce some of these errors, we did not use standardisation of portion sizes. Well-trained interviewers administered both instruments, taking more time than is typically required for the interview process.

In the present study the mean intakes derived from FFQ2 were higher than from the FFQ1 measurement, the opposite trend to the results reported by Kassam-Khamis *et al.*[15]. Overestimation by FFQ is a common problem as reported by other authors[16,19,20]. Moreover, opposite results to our ones were reported elsewhere (except for total fat) by Willett *et al.*[21], Johansson *et al.*[22] and Kim *et al.*[23]. Sichieri and Everhart[5] found similar mean values between FFQ and recalls.

According to Hunter *et al.*[8], within-person variance is responsible for substantially more of the population consumption variance than between-person variance. The Pearson correlation coefficients for total energy and macronutrient intakes, estimated from our FFQ, and the intra-class coefficients were close to those reported by Willett *et al.*[21] and Martin-Moreno *et al.*[24], although the first study used nutrient scores and both used diet records as the reference method. The intra-class coefficients for 24-HDR reported by Wengreen *et al.*[20] indicated more variability. Results from Salvo and Agostinho Gimeno[7] showed no significant correlation, except for protein. The correlation coefficients for the FFQ used by Pietinen *et al.*[25] were slightly lower for energy and higher for total fat and vitamin C. Cardoso *et al.*[6] reported higher Pearson correlation coefficients between their FFQs except for protein. Also, among Brazilians[7] with higher education level, the lowest correlation coefficients between nutrients were observed when comparing the questionnaires.

Comparing the correlation coefficients of instruments administered at the same time (24-HDR1 vs. FFQ1, 24-HDR6 vs. FFQ2) and of those administered separately (24-HDR2–5 vs. FFQ1–2), we did not observe the possibility of a learning effect[1,21]. The coefficients improved when comparing those collected separately (except for calcium) with those collected at the same time.

In general, the crude Pearson correlation coefficients between the recalls and FFQ2 were higher than those obtained for FFQ1, in accordance with Jackson *et al.*[19]. The same authors[19] assessed the validity of their FFQ against twelve 24-HDRs; when comparing FFQ1 with the average of the recalls, coefficients were higher than those reported in this study for total fat, retinol and vitamin C.

When validity was tested between the average of the recalls and the questionnaires, the coefficients were improved. In spite of the low literacy of the population, our results are in agreement with the range (0.4 to 0.7) mentioned by Thompson and Byers[26], except for vitamins. Comparing the study nutrients, lower coefficients have been reported by Torheim *et al.*[16], except for retinol and vitamin C. Also, comparing an FFQ with the average of 24-HDRs in another Brazilian population, Sichieri and Everhart[5] reported lower correlation coefficients for assessments among university support staff than among professionals. Perhaps the large difference between the coefficients may have been because of literacy differences between the subjects.

In the present study, energy adjustment by regression analysis did not improve the correlation coefficients. A similar effect has been reported by Martin-Moreno *et al.*[24], Kim *et al.*[23] and Jackson *et al.*[19], except for vitamin C. Other authors[17,25] observed minimal improvement after adjustment. On the other hand, Willett *et al.*[21], Wengreen *et al.*[20] and Cardoso *et al.*[6] reported higher coefficients after adjustment.

The correction for attenuation improved the adjusted coefficients. The same effect for attenuation has been obtained by other authors[24], using the diet record as reference method, and elsewhere[17,23,25]. Subar *et al.*[27] showed that the correlation coefficients varied with one another depending on the method used to measure nutrient intakes. In general, correlation coefficients >0.7 are rare in dietary validation studies, probably to the inherent complexity of the diet that cannot be fully captured by a structured questionnaire[28].

This study, like most validation studies, evaluated correlation coefficients between the methods. Low correlation coefficients are usually interpreted as a lack of precision of the methods studied. Some authors[29,30] have shown that the type of population studied has a great impact on these coefficients. A sample selected according to energy intake strata may be more useful for assessing the validity of a method than a random sample of the population. In general, heterogeneous populations (sex, age, location, etc.) will be a better choice than homogeneous ones, because they will have a wider range of energy intakes and a greater variability of diet composition.

Conclusion

The FFQ had a satisfactory reproducibility to rank participants by intake of total energy and selected nutrients. Overall, the FFQ appeared to be reasonably valid and had good reproducibility. These data indicate that the FFQ will be a useful tool to obtain information on usual long-term dietary intake for studying diet–disease relationships in regional Brazilian workers. Additional validity and reproducibility studies are needed among low-income population groups.

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