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Performance of the quantitative food frequency questionnaire used in the Brazilian center of the prospective study "Natural History of HPV Infection in Men: the HIM Study"

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Abstract

The HIM Study is a prospective multicenter cohort study that, among other factors, analyzes participants' diet. A parallel cross-sectional study was designed to evaluate the validity and reproducibility of the quantitative food frequency questionnaire (QFFQ) used in the Brazilian center from the HIM Study. For this, a convenience subsample of 98 men aged 18 to 70 years from the HIM Study in Brazil answered three 54-item QFFQ and three 24-hour recall (24HR) interviews, with six-month intervals between them (data collection January-September, 2007). A Bland-Altman analysis indicated that the difference between instruments was dependent on the magnitude of the intake for energy and most nutrients included in the validity analysis, with the exception of carbohydrates, fiber, polyunsaturated fat, vitamin C and vitamin E. The correlation between the QFFQ and the 24HR for the deattenuated and energy-adjusted data ranged from 0.05

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(total fat) to 0.57 (calcium). For the energy and nutrients consumption included in the validity analysis, 33.5% of participants on average were correctly classified into quartiles, and the average value of 0.26 for weighted kappa shows a reasonable agreement. The intraclass correlation coefficients for all nutrients were greater than 0.40 in the reproducibility analysis. The QFFQ demonstrated good reproducibility and acceptable validity. The results support the use of this instrument in the HIM Study.

Keywords

Validation; Reproducibility; Food intake; Food frequency questionnaire; Cohort study

INTRODUCTION

"Natural History of HPV Infection in Men: The HIM Study" is an international multicenter prospective cohort study that seeks to determine the incidence, persistence and clearance of human papillomavirus (HPV) infection in men and to identify the factors associated with these outcomes among populations from three different cities: Tampa, United States of America; Cuernavaca, Mexico; and São Paulo, Brazil (1).

The quantitative food frequency questionnaire (QFFQ) method was utilized to evaluate the food and nutrient intake of participants in the HIM Study, and a different QFFQ was used in each of the three cities. Measurement errors in food frequency questionnaires generally lead to bias in estimates of the observed relative risk and a loss of power for detecting the relationship between diet and disease (2-5). Therefore, to correctly interpret epidemiologic studies based on this method, the instrument must be validated and calibrated (6). Moreover, the Brazilian QFFQ is the first food frequency questionnaire to be developed based on the reported food intake of a population-based sample of residents in São Paulo, Brazil. This study is the first to evaluate the performance of the Brazilian QFFQ in the context of a multicenter study (7,8). The present study aimed to evaluate the validity and reproducibility of the QFFQ in measuring the intake of energy, and 19 nutrients among men ages 18-70 years participating in the HIM Study in São Paulo, Brazil.

METHODS

The HIM Study

The HIM Study has been presented in detail in a previous paper (1). São Paulo is the most populous city in Brazil, with around 10.4 million inhabitants, of which 5 million are men (9). For the HIM Study, individuals were recruited from the population that attended the Reference and Training Center for Sexually Transmitted Diseases and AIDS (RTC-STD/AIDS) in São Paulo, and from the general population of the city through publicity in various institutions and the media.

Design

Between January and September 2007, the first 120 individuals from the HIM's Brazilian cohort who attended the scheduled visit to the reference center and agreed to participate were included in the validation and reproducibility study. During the visits, the reference method, the 24-hour recall (24HR), and the QFFQ were applied; both of the measures were administered by trained interviewers in the same day. The follow-up interviews were conducted over a one year period, with six-month intervals between each interview.

Participants who did not provide complete responses for the planned QFFQs and 24HRs and those whose energy intake was less than 500 kcal or greater than 4000 kcal (10) were excluded. Thus, 98 individuals for the validation study and 93 for the reproducibility study were assessed. Approval for human subjects research was granted by the Ethical Committee of the School of Public Health at the University of Sao Paulo. The participants signed consent forms after an explanation of the purpose of the study.

Assessment of food intake

QFFQ—The QFFQ was developed based on the foods cited by 708 men on the 24HR in the ISA-SP study: “Health survey of the State of São Paulo – population-based household survey in municipalities in the state of São Paulo, 1999-2000” (7,8). The QFFQ contained 54 food items and four portion size options (small, medium, large and extra-large). The participants were asked to recall their frequency of consumption over the past year for each food item (from 0 to 10 times a day, week, month or year), along with the size of the portion consumed. To help participants visualize the portion sizes, household measures were available in the interview room.

24HR—The 24HR was collected using the multiple-pass method (11,12). All of the recalls were critically reviewed by a nutritionist or undergraduate nutrition students with appropriate training to identify errors concerning the descriptions of the foods or preparations consumed as well as portion sizes and quantification. To quantify the nutrient intake, the Nutrition Data System for Research software (NDSR, version 2.0, 2007, University of Minnesota, Minneapolis, MN, USA) was used. The intake was adjusted for within-person variability (deattenuated) by the method proposed by Iowa State University, using the PC-SIDE software (version 1.0, 2003, Department of Statistics, Iowa State University, Ames, IA, USA) (13,14). PC-SIDE generates within- and between-person variances that were used to calculate the ratio of variances (V_{within}/ $V_{between}$) (13,14).

Statistical analyses

The statistical analyses were performed using the STATA Statistical Software (STATA, version 10, 2007, StataCorp LP; College Station, TX, USA), and the significance level was set at 5%. Variables that did not present a symmetrical distribution in relation to the means and medians were transformed to their natural logarithm or Box-Cox form (15). The adjustment of the dietary variables for energy from both the QFFQ and 24HR was performed by the residuals method (16).

For the validation study, Pearson or Spearman correlation coefficients were used to investigate the crude, deattenuated and energy-adjusted relationships between the energy and nutrient intake estimated by the third QFFQ and the average of the three 24HRs. The reproducibility was verified between the second and third QFFQ. Crude and energy-adjusted intraclass correlation coefficients were used to investigate the linear correlations of consumption between the two QFFQs (17). Correlation values between 0.40 and 0.70 were considered acceptable (18-21).

The intake of energy and each nutrient variable were categorized into quartiles to investigate the proportion of individuals classified in the same quartile using both instruments (percentage concordance) and the proportion of individuals classified in opposing quartiles. Weighted kappa statistics were calculated for validation and reproducibility analysis, and values greater than 0.40 indicated nutrients with moderate concordance (22-24).

The divergences between the information on the dietary variables were examined in accordance with the methodology proposed by Bland & Altman (25), both for validation and reproducibility. The energy and nutrient intake values were transformed into their natural logarithms, and linear regression analysis was performed. It was expected that the regression coefficients (β_1) would be close to zero and would not present statistical significance. The mean agreement (MA) and limits of agreement (LOA) were obtained from the exponential of the mean difference and from the agreement limits transformed into percentages, respectively (26). A mean agreement of 100% represented the ideal, according to the methodology proposed by Ambrosini and colleagues (27).

RESULTS AND DISCUSSION

There were no statistically significant differences between the subsample of the validation study and the entire group of participants from São Paulo. The mean age of the subsample was 35.8 ± 10.0 (p=0.27) and the mean of 26.1 ± 3.6 kg/m^2 to body mass index (BMI) indicated overweight (p=0.10). Almost 48% of the subsample presented more than 12 years of schooling (p=0.21) and 51% presented family income per month between US$501 and US$1500 (p=0.13). The same variables were tested to identify differences between the subsample and those individuals who were excluded or did not provide sufficient responses (n=22), but no differences were detected in age (p=0.27), BMI (p=0.14), schooling (p=0.98) or family income per month (p=0.98).

Validity and Reproducibility

The correlation coefficients between the QFFQ and 24HR for the energy-adjusted nutrients ranged from 0.05 (total fat) to 0.57 (calcium), with acceptable accuracy for the estimates of energy, fiber, riboflavin, calcium and phosphorous. In the reproducibility analysis, it was observed that the QFFQ had estimated most of the nutrients investigated with acceptable reproducibility. The mean for the intraclass correlation coefficients was 0.54 for the crude data and 0.50 after adjustment for energy (Table 1).

In Brazil, only two studies of validation and reproducibility have been conducted on the adult population with a different QFFQ; however neither study was done in São Paulo, which is the most developed city in Brazil. One of the studies, conducted by Zanolla and colleagues (28) on a city in the South Brazil, reported correlation coefficients higher than those observed in the current study, both for validation and for reproducibility. However, the time interval between the interviews was 28 days, which is shorter than the time interval in the HIM Study.

Fornes and colleagues (29) validated a food frequency questionnaire by comparing with the average dietary intake of six 24HRs in a population of low-income workers in the Brazilian Midwest. The Pearson correlation coefficients ranged from 0.25 (carbohydrates and protein) to 0.76 (energy). These values are closer to those found in the validation of the QFFQ in the HIM Study. However, the difference between the populations regarding sociodemographic characteristics and even the difference in the retrospective period that the QFFQ proposed to evaluate (12-month vs. 6-month) limit comparisons between these studies.

Validation studies on food frequency questionnaires that used 24HRs or food records as the reference methods, including studies with larger samples that used food frequency questionnaires with greater numbers of items and/or repetitions of the reference method, have generally obtained correlations similar to those observed in the current study (30-33). In the QFFQ of the HIM Study, the fat intake (total fat, saturated fat, monounsaturated fat, polyunsaturated fat, trans fat and cholesterol) in particular was poorly assessed, even after adjustment for energy. A validation study of the food frequency questionnaire used in the EPIC study in Italy, for which the reference method used was twelve repetitions of the 24HR, found the same performance of the questionnaire in relation to low correlation coefficients and the poor assessment of fat intake among men (correlation of 0.28 for the crude data and 0.33 after adjustment for energy) (30).

Food frequency questionnaires with a large list of items (200 items) have correlation coefficients that are greater than the coefficients for questionnaires with shorter lists (100 items), with a difference ranging from 0.01 to 0.17 (33). On the other hand, a large number of foods in the questionnaire leads to the overestimation of intake and fatigue while completing the form (34). The QFFQ used in the HIM Study in Brazil had a relatively short list of foods (54 items), and this may have influenced the low correlations observed. However, the methodology that was adopted to identify this list was developed by other researchers and used in several studies (35,36). Through this methodology, an open food intake evaluation instrument (in the present study, the 24HR) was used to identify the foods that made the most important contributions toward the intake of certain nutrients within a specific population (10). This methodology included the main foods that composed the diet of the study population (10).

Some researchers have identified the limitations of using correlation coefficients to assess whether the method tested is concordant with the method used as the reference (25,26,34,37-41). A positive correlation is expected between two instruments that supposedly measure the same variable (25,26). Moreover, one of the main requirements when using a food frequency questionnaire in a study that seeks to analyze the diet-disease relationship is that the questionnaire rank individuals rather than assess their absolute level of intake (10). The classification of nutrients into quartiles showed that the proportion of individuals classified in the same quartile using 24HR and QFFQ ranged from 24% (saturated fat and polyunsaturated fat) to 50% (fiber). On average, the two instruments classified 7% of the individuals in opposing quartiles. For the validation, the weighted kappa values ranged from 0.01 for total fat to 0.48 for phosphorous. Among the nutrients evaluated, 20% presented a weighted kappa value greater than 0.40. In the analysis of reproducibility, 65% presented a weighted kappa value greater than 0.40 (Table 2). These findings are comparable to similar studies, both for validity and reproducibility (42,43).

The methodology proposed by Bland & Altman (25) makes it possible to identify whether the QFFQ presents errors of over or underestimation and whether these biases appear at different intake levels for a given nutrient. In the HIM Study, the difference between the instruments was shown to be dependent on the magnitude of the intake in relation to energy and most nutrients in the validity analysis, with the exception of carbohydrates, fiber, polyunsaturated fat, vitamin C and vitamin E.

The QFFQ provided significantly lower intakes of energy and nutrients than did the 24HR (mean agreement lower than 100%), demonstrating that the QFFQ underestimated consumption (Table 2). The mean agreement between the QFFQ and the 24HR ranged from 73% (folate) to 134% (vitamin A). The LOA indicated that the intakes reported by individuals could vary, on average, two-fold in either direction from one instrument to another. For example, a participant with a 24HR fiber intake of 20 g could have a QFFQ fiber estimate anywhere between 9 g (54%) and 44 g (266%). Particularly wide LOAs were found for vitamin C, vitamin A and trans fat. In evaluating the reproducibility of the QFFQ, the difference between the QFFQ was dependent on the magnitude of the intake only for vitamin C and calcium, and the mean agreement ranged from 95% (vitamin A) to 108% (folate) (Table 2).

With regards to the mean daily intakes (Table 1) and the LOA (Table 2), the QFFQ evaluated here underestimated nutrient intake. In general, food frequency questionnaires with groups of similar foods in a single question, as was the case of the QFFQ evaluated here, tend to underestimate food intake, particularly the intake of fat-rich foods. The quantification of food intake may be inaccurate because of the poor estimation of portions due to the aggregation of types of food, particularly for items containing three or more foods (44,45).

Choosing a reference method that accurately reproduces the habitual food intake is a major challenge in investigating the validity of an instrument (46). The instrument used here as the reference method is commonly used to evaluate diet in epidemiological studies (47-51). However, one of the limitations of the 24HR is that it presents high within-person variability (52).

The present study showed high ratios of within- to between-person variance, greater than 1.00 for energy and most of the nutrients, reaching 6.21 for vitamin A. The only nutrient that presented a ratio less than 1.00 was carbohydrates (ratio = 0.96) (Table 1). This data were comparable with the ratios in the study by Persson et al. (53) on pregnant women in Indonesia, which found very similar ratios for calcium and higher ratios for vitamin C, iron and thiamin.

Lack of accuracy in reference methods that are based on participants' reports may diminish the apparent performance of the questionnaire (30). Nonetheless, while food intake measurements of greater accuracy and acceptable costs for use in large-scale studies do not exist, QFFQ performance results based on 24HR estimates may be biased. In the present study, by considering the 24HR to be an error-free reference method, the validity results of the QFFQ used in the HIM Study may have been overestimated or underestimated.

Moreover, the three 24HRs collected over a year may not represent differences due to seasonality. There was an attempt to minimize the effects of seasonality with the deattenuation of the 24HR. Furthermore, during the interview of the HIM Study, participants were asked to report what they had habitually consumed over the past year when completing the QFFQ. This provided coverage for a complete cycle of seasons and, in theory, generated similar responses independent of the time of year (10).

CONCLUSIONS

The results of the present validation and reproducibility study support the use of the QFFQ in the HIM Study. Moreover, this food frequency questionnaire, developed with a representative sample of the city of São Paulo, can be utilized in future studies in Brazil, taking into account the strengths and limitations presented.

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Table 1

Estimates of mean (SD) daily intakes of energy and nutrients reported on the QFFQ and 24HR in the validation sub-sample, correlation coefficients for crude, deattenuated and energy-adjusted values, and variability of nutrient intake according to the 24HR: HIM Study, Brazil, 2007-2008.

	Daily intake estimates			*Correlation coefficients*					*Variability of nutrient intake (24HR)*
				QFFQ2 vs. QFFQ3 (reproducibility)		QFFQ3 vs. 24HR (validity)			
	QFFQ2[a]	QFFQ3	24HR[b] Deatenuatted[c]	Crude	Energy Adjusted	Crude	Deattenuated	Deattenuated and energy-adjusted	Ratio ($V_{within}/V_{between}$)
Energy (kcal)	2245 (671)	2229 (693)	2399 (519)*	0.53*	-	0.38*	0.40*	-	1.66
Nutrients									
Protein (g)	83.3 (25.8)	83.1 (27.7)	97.8 (15.5)*	0.50*	0.45*	0.33*	0.34*	0.29*	4.83
Carbohydrate (g)	280.3 (95.1)	277.4 (94.4)	300.9 (84.7)*	0.59*	0.49*	0.45*	0.42*	0.32*	0.96
Fiber (g)	25.5 (9.3)*	25.0 (10.0)	20.2 (7.2)*	0.59*	0.63*	0.44*	0.46*	0.45*	1.26
Total fat (g)	86.6 (28.9)	86.6 (29.3)	87.8 (19.0)	0.51*	0.38*	0.28*	0.30*	0.05	3.18
Saturated fat (g)	30.0 (10.9)	30.5 (11.2)	29.7 (6.9)	0.51*	0.41*	0.24*	0.33*	0.17	3.41
Monounsat. fat (g)	29.9 (10.5)	29.9 (10.4)	29.9 (5.2)	0.55*	0.51*	0.22*	0.25*	0.13	5.52
Polyunsat. fat (g)	19.2 (6.2)	18.8 (6.2)	20.9 (6.8)*	0.57*	0.46*	0.32*	0.27*	0.13	1.88
Trans fat (g)	4.2 (1.8)	4.5 (2.3)	3.9 (1.1)	0.49*	0.29*	0.27*	0.34*	0.22*	4.79
Cholesterol (g)	272.6 (123.8)	269.3 (117.7)	281.6 (82.3)	0.51*	0.36*	0.29*	0.29*	0.27*	3.45
Vitamin A (UI)	10039.6 (7084.5)	10323.9 (7207.9)	6794.6 (2436.5)*	0.58*	0.63*	0.28*	0.32*	0.34*	6.21
Thiamin (mg)	1.7 (0.6)*	1.7 (0.5)	1.9 (0.5)*	0.53*	0.41*	0.38*	0.40*	0.16	1.61
Riboflavin (mg)	1.8 (0.6)	1.8 (0.6)	1.9 (0.4)	0.58*	0.59*	0.29*	0.30*	0.41*	2.99
Niacin (mg)	19.6 (6.4)	19.0 (6.2)	22.6 (3.8)*	0.50*	0.49*	0.28*	0.28*	0.23*	4.35
Folate (mg)	435.9 (140.9)*	418.0 (136.6)	558.8 (150.4)*	0.58*	0.55*	0.46*	0.41*	0.34*	1.33
Vitamin C (mg)	135.1 (125.6)	124.4 (84.0)	103.7 (67.3)	0.60*	0.65*	0.26*	0.29*	0.32*	3.53
Vitamin E (mg)	6.2 (1.9)	6.1 (1.9)	7.6 (2.1)*	0.51*	0.62*	0.29*	0.31*	0.30*	2.53
Calcium (mg)	815.3 (315.4)	849.4 (369.5)	829.8 (240.0)	0.54*	0.58*	0.51*	0.49*	0.57*	2.51
Phosphorous (mg)	1291.7 (397.3)	1308.9 (437.0)	1355.4 (272.6)	0.53*	0.55*	0.34*	0.36*	0.54*	2.79

	Daily intake estimates			Correlation coefficients					Variability of nutrient intake (24HR)
				QFFQ2 vs. QFFQ3 (reproducibility)		QFFQ3 vs. 24HR (validity)			
	QFFQ2[a]	QFFQ3	24HR[b] Deatenuatted[c]	Crude	Energy Adjusted	Crude	Deattenuated	Deattenuated and energy-adjusted	Ratio ($V_{within}/V_{between}$)
Iron (mg)	14.6 (4.2) *	14.3 (4.9)	18.3 (4.3) *	0.55 *	0.47 *	0.44 *	0.37 *	0.39 *	1.69

SD – standard deviation; QFFQ – quantitative food frequency questionnaire; 24HR – 24-hour recall; V_{within} - within-person variance; $V_{between}$ - between-person variance

[a]Paired Student's t-test or Wilcoxon test were used to investigated difference between QFFQ2 and QFFQ3.

[b]Student's t-test or Mann-Whitney U-test were used to investigated difference between QFFQ3 and 24HR.

[c]Data adjusted for within-person variability.

*p < 0.05.

Table 2

Agreement between energy and nutrient intakes estimated by the QFFQ and the 24HR: HIM Study, Brazil, 2007-2008.

	QFFQ2 vs. QFFQ3 (reproducibility)						*QFFQ3 vs. 24HR (validity)*					
	Concord.[a] (%)	**Opposing terciles[a] (%)**	**Kappa[a]**	**Mean Agreement[b] (%) (95% CI)**	**LOA[c] (%)**	**β_1 [d]**	**Concord.[a] (%)**	**Opposing quartiles[a] (%)**	**Kappa[a]**	**Mean Agreement[b] (%) (95% CI)**	**LOA[c] (%)**	**β_1 [d]**
Energy (kcal)	47	5	0.51 *	103 (97-110)	57-186	0.021	30	5	0.25 *	90 (85-96)	48-168	0.509 *
Nutrients												
Protein (g)	37	2	0.44 *	102 (96-109)	54-194	−0.164	33	9	0.14	81 (76-86)	42-157	1.055 *
Carbohydrate (g)	41	3	0.45 *	104 (97-111)	55-194	0.112	37	6	0.26 *	90 (84-97)	47-175	0.231
Fiber (g)	48	0	0.64 *	107 (100-115)	54-210	0.008	50	4	0.46 *	120 (111-130)	54-266	0.177
Total fat (g)	34	5	0.35 *	102 (95-109)	52-201	−0.051	32	14	0.01	95 (88-102)	46-195	0.720 *
Saturated fat (g)	35	4	0.40 *	101 (93-110)	45-226	−0.157	24	5	0.24 *	97 (90-106)	43-219	0.801 *
Monounsaturated fat (g)	32	3	0.34 *	102 (95-109)	50-205	−0.013	27	11	0.08	95 (88-102)	45-198	1.030 *
Polyunsaturated fat (g)	44	5	0.39 *	104 (98-111)	57-189	0.064	24	7	0.13	90 (83-97)	42-195	−0.083
Trans fat (g)	32	5	0.27 *	103 (93-114)	38-280	−0.180	32	8	0.13	106 (95-118)	37-309	0.872 *
Cholesterol (g)	31	4	0.38 *	103 (94-113)	41-257	−0.118	43	10	0.30 *	89 (81-98)	34-233	0.784 *
Vitamin A (UI)	43	2	0.51 *	95 (84-107)	29-311	0.171	33	6	0.31 *	134 (119-152)	39-459	0.819 *
Thiamin (mg)	38	5	0.42 *	106 (99-113)	58-194	0.120	27	9	0.14	83 (78-89)	44-157	0.348 *
Riboflavin (mg)	49	4	0.54 *	101 (95-108)	52-196	−0.137	36	7	0.36 *	91 (84-98)	44-186	0.742 *
Niacin (mg)	49	6	0.37 *	105 (98-112)	57-195	−0.020	31	9	0.13	81 (76-87)	43-153	0.925 *
Folate (mg)	49	3	0.50 *	108 (102-115)	62-189	0.096	27	4	0.38 *	73 (69-78)	39-138	0.260 *
Vitamin C (mg)	42	1	0.56 *	99 (86-114)	25-388	0.234 *	37	9	0.26 *	117 (100-136)	26-535	0.187
Vitamin E (mg)	46	1	0.57 *	104 (98-111)	56-194	0.038	29	8	0.18 *	79 (74-85)	39-160	0.178
Calcium (mg)	53	2	0.59 *	101 (93-110)	45-227	−0.289 *	39	6	0.44 *	97 (89-106)	42-226	0.595 *
Phosphorous (mg)	46	4	0.53 *	102 (95-108)	54-191	−0.147	40	3	0.48 *	93 (87-99)	47-183	0.740 *
Iron (mg)	44	3	0.50 *	106 (100-113)	59-192	−0.088	39	4	0.43 *	75 (70-80)	40-142	0.533 *

QFFQ – quantitative food frequency questionnaire; 24HR – 24-hour recall; Concord. – percentage concordance; 95% CI - 95% confidence interval; LOA – limits of agreement.

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[a] Dietary intake, estimated from the QFFQ and the 24HR, was categorized into quartiles before analysis of percentage concordance and weighted kappa.

[b] Mean Agreement = exponential (mean of the differences) * 100; 95% CI for mean agreement

[c] LOA = exponential (agreement limits of the differences) * 100; 95% limits of agreement.

[d] Regression slope. Reproducibility = (QFFQ2 - QFFQ3) = $\beta 0 + \beta 1((QFFQ2 + QFFQ3)/2)$; Validity = (QFFQ3 - R24h) = $\beta 0 + \beta 1((QFFQ3 + R24h)/2)$.

* $p < 0.05$.