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Validation of a food frequency questionnaire for assessing the intake of food groups and nutrients in adults

Validação de um questionário de frequência alimentar para avaliação do consumo de grupos de alimentos e nutrientes em adultos

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Article based on the dissertation of SCRS MUNIZ, entitled "*Validação relativa de um questionário de frequência alimentar e associação de padrões alimentares com excesso de peso e porcentagem de gordura corporal em adultos de uma coorte brasileira*". Universidade de São Paulo; 2021.

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ABSTRACT

Objective
To validate a food frequency questionnaire used to assess food consumption among adults in a Brazilian cohort.

Methods
Cross-sectional study conducted on 100 adults. Food intake was assessed by the food frequency questionnaire and by two 24-hour recalls. Validation was performed for nutrients (n=19) and food groups (n=21).

Results
Moderate deattenuated Pearson's correlation coefficients (>0.4) were observed for the consumption of dairy products, breads and crackers, rice, pasta and tubers, leafy vegetables, other vegetables, fats, sweetened drinks, sandwiches and savory snacks, and nuts, and for the following nutrients (deattenuated and adjusted for energy intake): fiber, calcium, and vitamins A, B2, and C. Based on almost all food groups and nutrients assessed, ≥70% of the individuals were classified into the same or adjacent quartile for both methods, except for red and pork meat, snacks, nuts, phosphorus, potassium, and vitamin B3. The food groups and nutrients

with fair kappa agreement (>0.2) were: dairy products, other vegetables, sweetened drinks, breakfast cereals, energy, carbohydrate, iron, and vitamin A.

Conclusion
The food frequency questionnaire has proven useful for estimating the intake of some nutrients and food groups of the subjects evaluated. Only the intake of red and pork meat, snacks, nuts, vitamin B3, phosphorus and potassium were estimated with less accuracy.

Keywords: Adults. Nutrient intake. Validation studies.

RESUMO

Objetivo
Validar um questionário de frequência alimentar para avaliar o consumo alimentar de adultos em uma coorte brasileira.

Métodos
Estudo transversal realizado com 100 adultos. A ingestão alimentar foi avaliada pelo questionário de frequência alimentar e por dois recordatórios de 24 horas. A validação foi realizada para nutrientes (n=19) e grupos de alimentos (n=21).

Resultados
Coeficientes de correlação de Pearson deatenuados moderados (>0,4) foram observados para o consumo de laticínios, pães e biscoitos, arroz, macarrão e tubérculos, vegetais folhosos, outros vegetais, gorduras, bebidas adoçadas, sanduíches e salgadinhos, e nozes, e para os seguintes nutrientes (deatenuados e ajustados para ingestão de energia): fibra, cálcio e vitaminas A, B2 e C. Com base em quase todos os grupos de alimentos e nutrientes avaliados, ≥70% dos indivíduos foram classificados no mesmo quartil ou quartil adjacente para ambos os métodos, exceto para carnes vermelhas e suínas, salgadinhos, nozes, fósforo, potássio e vitamina B3. Os grupos de alimentos e nutrientes com concordância kappa justa (>0,2) foram: laticínios, outras verduras, bebidas açucaradas, cereais matinais, energia, carboidratos, ferro e vitamina A.

Conclusão
O questionário de frequência alimentar mostrou-se útil para estimar a ingestão de alguns nutrientes e grupos de alimentos dos sujeitos avaliados. Apenas o consumo de carnes vermelhas e suínas, salgadinhos, nozes, vitamina B3, fósforo e potássio foi estimado com menor precisão.

Palavras-chave: *Adulto. Ingestão de alimentos. Estudo de validação.*

INTRODUCTION

Food consumption is considered a modifiable risk factor for the development of overweight, and has proved to be one of the greatest current determinants of health [1-4]. Several studies have pointed out that the improvement of eating habits also tends to improve health by preventing chronic non-communicable diseases [2,4-6]. Thus, estimating food consumption is an important step in assessing the health of individuals or populations. One of the most used instruments for assessing food consumption in epidemiological studies are Food Frequency Questionnaires (FFQ), whose main objective is to measure the frequency of consumption of foods or food groups over a long period of time and to classify individuals according to food or nutrient intake [7-10]. Several studies have pointed out the need for accurate food consumption assessment methods to estimate the food consumption of adults in order to relate them to health outcomes [7,11,12].

Cardoso and Stocco [13] developed an FFQ to assess the habitual diet of Japanese immigrants and descendants residing in São Paulo for use in epidemiological studies. This questionnaire was later adapted for use in programs for the prevention of non-communicable diseases among adults, excluding food of Japanese origin. Several validation studies have been previously conducted to

test the accuracy of the FFQ developed by Cardoso et al. [14], which proved to be suitable for estimating energy, protein, total lipids, carbohydrates, saturated fatty acids, cholesterol, fiber, calcium, phosphorus, potassium, iron, vitamin C, vitamin A, riboflavin, niacin, and folate.

This adapted FFQ was used to estimate the habitual diet in the first assessment of adults belonging to the birth cohort started in 1978/79 in Ribeirão Preto, São Paulo, Brazil. This FFQ was then readapted for the second assessment of adults of this cohort and also for the first assessment of adults of the 1994 birth cohort from the same city [15]. The main purpose was to consider particularities of food consumption and changes that had occurred in the population's eating habits since the period when the original FFQ was developed.

Thus, it is important to evaluate the performance of the instrument used for assessment of food consumption and to determine its accuracy because valid information about food consumption is essential for the interpretation of studies in nutritional epidemiology [16]. Since the questionnaire was adapted, its accuracy needs to be evaluated [15]. On this basis, the objective of the study will be to validate an FFQ that will be employed in two Brazilian birth cohorts (1978-79 and 1994) from Ribeirão Preto, São Paulo, Brazil. We hypothesized that the FFQ is useful to estimate food and nutrient intake of the adults evaluated.

MATERIAL AND METHODS

This was a cross-sectional study which used a convenience sample. The sample size of the present study (n=100) was based on the recommendation that 100 subjects are sufficient to test the agreement between the methods for the assessment of food consumption [10,16-18]. The inclusion criteria were adults aged between ≥20 and ≤40 years, living in the city of Ribeirão Preto (São Paulo, Brazil), people without illnesses that require a special diet, and individuals who are not on a weight reduction diet. Individuals aged between 20 and 40 years were included, as this is the age range of the adults belonging to the cohorts in which the FFQ will be employed. The subjects included in the validation study were recruited from February to May 2018. These subjects did not belong to the mentioned cohorts and were mostly students and/or employees of the University of São Paulo, Ribeirão Preto Campus, of all levels of education and income, with age and sex proportional to the participants in both cohorts.

The study was approved by the Research Ethics Committee of the University Hospital, Ribeirão Preto Medical School, University of São Paulo, Brazil (nº 3.454.618). All subjects gave written informed consent prior to their inclusion in the study.

The Food Frequency Questionnaire (FFQ)

The FFQ consists of 97 food items with questions about frequency and amount consumed, with a reference period of one year [13]. The questionnaire contains photographs of the average portion of reference in order to assist in the estimation of the portions consumed. The mean reference portion shown for each food item represents the 50th percentile, and the small and large portions represent the 25th and 75th percentiles, respectively [13]. Thus, the subjects were able to estimate whether the usual portion consumed was small (less than the reference), medium (equal to the reference), or large (greater than the reference). The FFQ included the following frequency of consumption options: "never or less than once a month", "1-3 times a month", "once a week", "2-4 times a week", "5-6 times a week", "once a day", "2-4 times a day", and "5 or more times a day".

This questionnaire was readapted as a result of changes in the dietary pattern observed in the population over the years. There was a separation of biscuits due to their sugar content (with/without filling, sweet/salty), separation of leafy vegetables according to color (dark/light green) and predominant preparation method (sautéed/raw), separation of honey and jelly, and popcorn and salty chips. The following items were included: breakfast cereal, cereal bar, canned fish, sashimi, sushi, shoyu (conventional/light), burger, nuggets, wine, "bauru" sandwich, cheeseburger, hot dog, fried snacks, canned food, powdered chocolate, candy, and lollipops. The following items were excluded: semi-skimmed milk, skimmed milk, skimmed yoghurt, and yoghurt with fruit (questions about the type of milk and yoghurt consumed were included) [15].

Validation of the FFQ for food groups and nutrients

The 24-hour recall (24HRs) was selected as the reference method, which is extensively used in studies of FFQ validation [12,18]. For the validation of the FFQ, two 24HRs were obtained from each participant [17,19,20]. The first was obtained in a face-to-face interview when the subject received the FFQ. The second 24HRs was obtained by telephone contact, when the subject had already had the experience of answering the questionnaire and was aware of the portions, after 6 to 8 days, on a different week day than that of the first interview. The interviews were carried out by nutritionists trained for the function.

During application of the 24HRs, the participants were asked about their food consumption on the previous day, and whether this consumption was the usual one. The interviews were conducted in three main stages, with a quick listing of the food and drinks consumed on the previous day, followed by a detailed description of each item, and finally by the review [21,22]. A photographic record album with the photo of the utensils and also of the food portion size was used to help the participants to answer the 24HRs. A manual of homemade measures was created for the foods and portions of the FFQ to convert these measures to grams of food. The weight references (in grams) for the home measurements were taken from the photo album used in the interviews and from a table of home measurements for assessing food consumption.

The 97 food items of the FFQ were divided into 21 food groups according to their nutritional characteristics, as shown in Chart 1.

Chart 1 – Food groups examined in the validation of the Food Frequency Questionnaire for adults. Ribeirão Preto (SP), Brazil.

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Food group	Food item
Milk and dairy products	Milk, yogurt, cheese, cream cheese (light/regular)
Breads and cracker	Whole wheat bread, white bread, crackers
Rice, pasta and tubers	Rice, ramen noodles, pasta, manioc flour, crumbs, potato, manioc, tapioca
Fruits	Orange, tangerine, banana, papaya, apple, pear, açaí, watermelon, melon, pineapple, grape, pine cone, avocado, mango, strawberry, cashew, guava
Leafy vegetables	Lettuce, chard, arugula, kale, cabbage
Other vegetables	Tomato, chayote, okra, pumpkin, squash, cucumber, green pod, carrot, beetroot, broccoli, cauliflower, bell pepper, onion, garlic
Red and pork meat	Beef, pork, bacon, smoked bacon
White meat	Chicken, fish, canned fish (sardines/tuna), sashimi, sushi
Processed meats	Hamburger, nuggets, sausage, mortadella, ham, salami
Eggs	Eggs
Fats	Butter, margarine, mayonnaise
Sweets, cakes and similar	Cake without filling, ice cream, popsicle, candy, lollipops, milk-based sweet, cake with filling, fruit-based sweets, chocolate milk, chocolate bar, bonbon, sweet cookies, cookies with filling, corn porridge, hominy, pamonha corn
Sweetened drinks	Cola soft drink, other soft drinks, box juice, powder juice

Chart 1 – Food groups examined in the validation of the Food Frequency Questionnaire for adults. Ribeirão Preto (SP), Brazil.

Food group	Food item
Natural fruit juice	Natural fruit juices
Energy drinks	Coffee, tea, energy drinks, powdered guarana from Amazonia
Alcoholic drinks	Beer, draft beer, wine, liquor, whiskey, vodka, shake
Sandwiches and savory snacks	Pizza, "bauru" sandwich, cheeseburger, hot dog, savory snacks
Snacks	Packet snack, potato chips, popcorn
Beans	Bean
Nuts	Chestnuts, peanut, almond, walnuts
Breakfast cereals	Breakfast cereal, granola, cereal bar

The nutritional composition of all foods of the FFQ and the 24HRs was examined using the following nutritional composition tables: Brazilian Food Composition Table [23], Table of Personal Food Consumption in Brazil from the Household Budget Survey [24]. Validation was performed to test the accuracy of the questionnaire regarding 19 nutrients and 21 food groups.

All frequencies of the FFQ were transformed into daily frequencies and multiplied by the portion size to express their values in grams (g) or milliliters (ml). All consumption frequencies were transformed into daily frequencies as follows: the number of times consumed per day × frequency of consumption (daily = 1; weekly = 1/7; monthly = 1/30) × amount of food consumed (g). When the food was not consumed by the subject, a value of zero was assigned. Energy intake was evaluated in kilocalories per day (kcal/day).

Some fruits are considered to be seasonal. The frequency of consumption of seasonal fruits was transformed into daily consumption according to the number of months of the year in which the availability of these fruits is highest. To transform the consumption of seasonal fruits, the first step was to multiply the number of months in which these fruits are available during the year by 30 (average number of days per month) in order to obtain the number of days per year. In the second step, daily availability was divided by the number of days in the year (365 days on average). In the third step, the result of the second step was multiplied by the frequency of consumption reported by the individual transformed into daily frequency, thus obtaining the daily frequency corrected by seasonality.

Statistical Analysis

To correct for within-individual errors in the measurement of the average of the two 24HRs, the Multiple Source Method (MSM) online program was used to estimate the habitual nutrient intake and consumption of food groups. Therefore, deattenuated correlations represent values after within-individual variance correction. Food groups and nutrients were tested for normality using the Kolmogorov-Smirnov test. Since none of the food groups or nutrients showed a normal distribution, all of them were transformed into a natural logarithm before statistical analysis [12]. The nutrients of the FFQ and 24HRs were adjusted for energy by the residual method [12]. The median (P50) and interquartile range (P25-P75) values were used to describe the dietary data. Pearson's correlation coefficients were used to validate the FFQ, where a value >0.4 was considered moderate [25]. This analysis also included assessments of the degree of agreement between the methods: joint classification of estimated food group/nutrient intake into quartiles (≥70% of subjects in the same or adjacent quartiles) and weighted quadratic kappa (fair agreement >0.2) [26]. All statistical calculations were performed using the Stata software 14.0.

RESULTS

Of the 100 individuals assessed in the validation study, 61% were females. The mean age was 28.6±5.1 years.

Table 1 shows the median and interquartile range of food group consumption, as well as Pearson's correlation coefficients (*r*) corresponding to each group. The food groups that showed adequate correlation (≥0.4) [25] were: milk and dairy products; breads and crackers; rice, pasta and tubers; leafy vegetables; other vegetables; fats; sweetened drinks; sandwiches and savory snacks; and nuts. The cross-classification of food groups in consumption quartiles for both methods and the quadratic kappa coefficient are shown in Table 2. For almost all food groups, 70% or more of the subjects were classified into the same or adjacent quartiles by both methods, except for red and pork meat, snacks, and nuts. The quadratic kappa coefficient showed fair agreement (>0.2) for milk and dairy products, other vegetables, sweetened drinks, and breakfast cereals [26].

Table 1 – Food consumption (grams) estimated for the food groups by the Food Frequency Questionnaire and 24-hour recall, Pearson's correlation coefficients (*r*) obtained with the two methods for the participants in the validation study. Ribeirão Pret (SP), Brazil, 201.8 (n=100).

Food group	Food Frequency Questionnaire		24HRs		Deattenuated (*r*)
	Median	Interquartile range	Median	Interquartile range	
Milk and dairy products	179.3	70.0–276.0	103.0	48.0–222.0	0.45
Breads and cracker	50.0	24.8–57.8	53.6	29.2–71.1	0.47
Rice, pasta and tubers	219.1	135.0–306.1	174.3	125.4–232.9	0.41
Fruits	145.4	96.6–221.1	85.4	29.3–167.3	0.35
Leafy vegetables	20.6	10.0–36.7	25.4	5.1–43.1	0.40
Other vegetables	143.1	94.9–206.6	77.0	44.2–121.6	0.61
Red and pork meat	44.0	28.0–75.7	67.3	34.1–89.6	0.35
White meat	70.6	47.1–108.4	69.0	47.1–106.2	0.12
Processed meats	4.8	1.4–14.7	5.6	3.0–25.0	0.36
Eggs	14.0	9.8–21.0	4.3	2.4–50.6	0.31
Fats	4.5	0–16.0	2.2	0.6–7.7	0.45
Sweets, cakes and similar	44.1	22.8–83.3	39.0	14.1–73.8	0.32
Sweetened drinks	57.6	0–168.0	9.1	6.0–272.2	0.62
Natural fruit juice	67.2	18.0–100.8	14.1	12.3–131.0	0.38
Energy drinks	100.0	50.0–200.0	61.5	31.3–124.6	0.33
Alcoholic drinks	3.5	0–148.1	0.0	0.0	0.06
Sandwiches and savory snacks	14.1	9.5–29.5	31.9	18.1–91.1	0.41
Snacks	1.8	0–3.9	0.4	0.3–0.5	0.07
Beans	88.2	44.1–210.0	35.0	16.0–125.4	0.19
Nuts	0.0	0–2.5	0.0009	0.0007–0.0015	0.47
Breakfast cereals	0.0	0–2.0	0.0	0.0	0.35
Mean	–	–	–	–	0.36

Table 2 – Food consumption (grams) estimated for the food groups by the Food Frequency Questionnaire and 24-hour recall, Joint classification into quartiles for food group consumption, and quadratic kappa statistic obtained with the two methods for the participants in the validation study. Ribeirão Preto (SP), Brazil, 2018. (n=100).

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Food groups	Classification into quartiles (%)				Quadratic kappa
	Same	Adjacent	Same and adjacent	Opposite	
Milk and dairy products	43	39	82	4	0.24
Breads and cracker	39	45	84	1	0.18
Rice, pasta and tubers	34	48	82	4	0.12
Fruits	27	44	71	5	0.03
Leafy vegetables	34	46	80	5	0.12
Other vegetables	45	41	86	3	0.27
Red and pork meat	33	35	68	6	0.11

Table 2 – Food consumption (grams) estimated for the food groups by the Food Frequency Questionnaire and 24-hour recall, Joint classification into quartiles for food group consumption, and quadratic kappa statistic obtained with the two methods for the participants in the validation study. Ribeirão Preto (SP), Brazil, 2018. (n=100).

Food groups	Classification into quartiles (%)				Quadratic kappa
	Same	Adjacent	Same and adjacent	Opposite	
White meat	34	44	78	2	0.12
Processed meats	31	41	72	6	0.08
Eggs	27	51	78	5	0.03
Fats	40	43	83	6	0.20
Sweets, cakes and similar	32	49	81	4	0.09
Sweetened drinks	45	40	85	1	0.27
Natural fruit juice	25	57	82	1	0.01
Energy drinks	39	34	73	10	0.18
Alcoholic drinks	50	25	75	0	0.03
Sandwiches and savory snacks	37	44	81	3	0.16
Snacks	26	34	60	13	0.01
Beans	39	37	76	6	0.16
Nuts	31	26	57	16	0.08
Breakfast cereals	73	2	75	0	0.22
Mean	37	39	77	5	0.13

The Table 3 shows the median and interquartile range of nutrient intake, as well as the deattenuated and energy-adjusted Pearson's correlation coefficient (*r*) for each nutrient. The deattenuated and energy-adjusted correlation coefficients show an adequate correlation for fiber, calcium, vitamin A, vitamin B2, and vitamin C. It is noted that the correlation coefficients decreased for most nutrients after adjustment for energy. The Table 4 shows the values for the cross-classification of nutrients into intake quartiles for both methods and the quadratic kappa coefficient. For almost all nutrients, 70% or more of the subjects were classified into the same or adjacent quartiles by both methods, except for phosphorus, potassium, and vitamin B3. The quadratic kappa coefficient showed fair agreement (>0.2) for energy, carbohydrate, iron, and vitamin A [26].

Table 3 – Nutrient intake estimated by the Food Frequency Questionnaire and 24-hour recall, deattenuated and energy-adjusted Pearson's correlation coefficients (*r*), obtained with the two methods for the participants in the Food Frequency Questionnaire validation study. Ribeirão Preto (SP), Brazil, 2018. (n=100).

Nutrients	FFQ		24-hour recall		*r*	
	Median	Interquartile range	Median	Interquartile range	Deattenuated	Deattenuated and energy adjusted
Energy (kcal)	1771.8	1515.4–2456.4	1761.0	1438.8–2115.1	0.61	–
Protein (g)	76.0	60.3–100.1	84.9	72.1–97.6	0.34	0.32
Lipids (g)	57.5	44.3–77.7	63.6	54.2–75.0	0.48	0.09
Cholesterol (mg)	271.9	204.0–333.8	298.0	231.9–448.3	0.26	0.33
Carbohydrates (g)	248.0	198.5–346.4	204.6	156.0–270.0	0.62	0.19
Fiber (g)	29.6	21.8–45.4	19.4	12.6–27.0	0.50	0.57
Calcium (mg)	581.8	481.4–777.6	592.2	415.5–751.5	0.49	0.55
Phosphorus (mg)	20.9	12.5–30.9	11.1	7.6–18.7	0.16	0.16
Iron (mg)	6.6	5.5–8.3	7.9	6.6–9.8	0.55	0.17
Sodium (mg)	1298.3	916.8–1951.3	1642.1	1279.0–1925.3	0.40	-0.02
Potassium (mg)	23.9	16.2–42.3	25.7	17.3–38.2	-0.03	-0.03
Vitamin A (µg)	235.2	124.8–790.5	296.0	198.0–454.1	0.51	0.51
Vitamin B1 (mg)	1.4	0.9–2.3	1.2	0.9–1.7	0.36	0.35
Vitamin B2 (mg)	1.1	0.8–1.5	1.2	0.9–1.4	0.54	0.52
Vitamin B3 (mg)	15.1	10.8–23.4	15.0	13.3–17.3	0.23	0.12
Vitamin C (mg)	120.6	68.4–177.4	83.1	52.2–124.9	0.40	0.41
Saturated fatty acid (g)	23.4	17.1–31.1	25.2	20.6–30.0	0.38	0.05
Monounsaturated fatty acid (g)	20.2	15.5–27.0	23.1	19.1–29.3	0.37	0.14
Polyunsaturated fatty acid (g)	9.5	7.5–12.9	12.1	9.7–14.6	0.50	0.25
Mean	–	–	–	–	0.40	0.26

Note: FFQ: Food Frequency Questionnaire.

Table 4 – Nutrient intake estimated by the Food Frequency Questionnaire and 24-hour recall, joint classification into quartiles for nutrient intake, and quadratic kappa statistic obtained with the two methods for the participants in the Food Frequency Questionnaire validation study. Ribeirão Preto (SP), Brazil, 2018. (n=100).

Nutrients	Classification into quartiles (%)				Quadratic kappa
	Same	Adjacent	Same and adjacent	Opposite	
Energy (kcal)	45	42	87	0	0.27
Protein (g)	27	49	76	3	0.03
Lipids (g)	36	43	78	1	0.15
Cholesterol (mg)	37	35	72	8	0.16
Carbohydrates (g)	46	44	90	0	0.28
Fiber (g)	40	42	85	4	0.19
Calcium (mg)	38	41	78	7	0.15
Phosphorus (mg)	32	35	68	10	0.04
Iron (mg)	40	43	83	0	0.21
Sodium (mg)	34	43	77	5	0.12
Potassium (mg)	22	37	59	11	-0.04
Vitamin A (µg)	43	40	83	6	0.24
Vitamin B1 (mg)	35	43	78	3	0.13
Vitamin B2 (mg)	37	44	81	2	0.15
Vitamin B3 (mg)	33	35	68	7	0.11
Vitamin C (mg)	39	43	82	6	0.19
Saturated fatty acid (g)	38	39	77	3	0.17
Monounsaturated fatty acid (g)	34	43	77	4	0.11
Polyunsaturated fatty acid (g)	39	39	78	4	0.17
Mean	37	41	78	4	0.15

DISCUSSION

The present study examined the relative validity of a 97-item semi-quantitative FFQ, adapted to assess the habitual diet of adults. 24HRs were used as a reference method. Participants answered an FFQ and two 24HRs, administered exclusively by nutritionists. Validation of the FFQ was tested for nutrients and also for food groups. As it was hypothesized, the FFQ proved to be useful to estimate the intake of some nutrients and food groups of the subjects evaluated. For food groups, less than 70% of individuals were classified into the same or adjacent quartile only for red and pork meat, snacks, and nuts. Groups such as milk and dairy products, breads and crackers, rice, pasta and tubers, leafy vegetables, other vegetables, fats, sweetened drinks, sandwiches and savory snacks, and nuts showed moderate correlations (>0.4) [25]. For nutrients, less than 70% of individuals were classified into the same or adjacent quartile only for phosphorus, potassium, and vitamin B3. Furthermore, there was a decrease in the correlation coefficients for most nutrients after adjustment for energy.

Regarding the "Red and pork meat" food group, 68% of the subjects were classified into the same and adjacent quartile. The food items of this group were beef, pork, bacon, and smoked bacon. In the FFQ, beef is presented as "Steak, cubed beef or others", with the reference portion defined as "one piece, one steak or four tablespoons (beef stew)". Differences in the size of the reference portion of the same food item can make it difficult to report consumption, leading the subjects to report their consumption incorrectly. Regarding the "Snacks" food group (packet snack, potato chips, and popcorn), 60% of the subjects were classified into the same or adjacent quartile, while regarding the "Nuts" group (chestnuts, peanuts, almonds, and walnuts), 57% were similarly classified. The low concordances between consumption quartiles for these food groups can be explained by the administration of only two 24HRs since these foods may not have appeared in the food recalls, but only in the FFQ.

In the present study, only 67%, 59% and 68% of the individuals were classified into the same or adjacent quartile, respectively, regarding the nutrients phosphorus, potassium, and vitamin B3.

These nutrients are present in red meats, a food item that belongs to the "Red and pork meat" group, for which low agreement was also obtained between consumption quartiles. However, these nutrients are also present in other foods that are sources of protein such as milk and dairy products, oilseeds and grains.

Some validation studies have reported that their FFQ overestimated the consumption of food groups and the intake of nutrients [7,10,17,20,27-29]. However, if the FFQ obtains an adequate classification of the level of food consumption, there are no problems regarding the overestimation in epidemiological studies [7,9,30,31]. The quantile classification shows that the two methods are able to allocate subjects according to the level of nutrient intake or food consumption, thus being useful for the estimation of the risk of diseases [9,16,22,31]. Since one of the main objectives of the FFQ is to classify individuals according to their food consumption, the agreement between the consumption quartiles was the most relevant result of the present study, as also reported in previous investigations [7,16,31].

The correlation coefficients decreased for most of the investigated nutrients after adjustment for energy, showing an adequate correlation (>0.4) for fiber, calcium, vitamin A, vitamin B2, and vitamin C. The reduction in the correlation coefficients after adjustment for energy has also been observed in other validation studies [7,27,28,32]. The adjustment for energy assumes that the description of food intake is similar in both methods; therefore, the correlation coefficients tend to increase when the variability of nutrient intake estimates is related to energy consumption, or tend to decrease when the variability is related to under- or overestimation of food intake [12,32].

On the other hand, Zaragoza-Martí et al. [33] found strong correlations (r >0.7) for most nutrients even after adjusting for energy. More than 80% of the subjects were classified into the same quartile in the FFQ and the 24HRs, with the kappa statistic showing a moderate to high level of agreement (0.70-0.95) between the two. The authors explain that the high correlations found could be related to the number of administrations of the 24HRs (nine), and also to the fact that a photo album was produced with the exact size of the portions included in their FFQ, in addition to the use of food replicas of actual size and weight of each serving [33].

Perhaps, a greater number of administrations of the reference method (24HRs) might have improved the values of correlation and agreement between methods in the present study [34]. Indeed, other validation studies have detected even higher accuracy of the FFQ that used as a reference method a greater number of 24HRs replications [11,33]. However, in the present study, the data were adjusted by the MSM, which replaces the need for a large number of replications of the reference method, considering the within-person variance of food consumption [20,34].

Results more similar to those of the present study were reported in a study carried out in Morocco, which validated an FFQ for adults, with three administrations of the 24HRs [28]. Pearson's correlation coefficients adjusted for energy showed that the findings of relative validity were moderately consistent for most nutrients, ranging from 0.19 for fats to 0.86 for monounsaturated fatty acids [28]. The lowest correlations may be due to incorrect reports, i.e., individuals with high food consumption tend to underestimate their consumption; they may also be due to bias of the reference method, to variations in food intake during the study period, and to difficulties in remembering food intake and correctly estimating portions [20]. Nevertheless, the limitations reported in food consumption studies are inherent to the application of these instruments.

The strength of the present study concerns the structure of the validated FFQ, which was adapted from an FFQ developed to assess the habitual diet for use in epidemiological studies, and also validated for use in programs for the prevention of non-communicable diseases in adults [13,14].

The 24HRs and the FFQ have as a limitation the memory bias, which is inherent to these methods [27,32]. To reduce the error of the estimate, all the questionnaires in this study were applied by only two trained professionals (nutritionists) with a photographic guide of food portions [27]. However, studies in the field of FFQ validation have revealed the lack of a gold standard method for food consumption assessment. Also, the 24HRs is less demanding for the participant when compared to food records, for example, in addition to being more appropriate when the literacy and cooperation of the participants is limited. Nevertheless, the 24HRs has been one of the instruments most frequently used to assess food consumption in validation studies [12,22]. A second limitation was the application of only two 24HRs because, according to Haubrock et al. [34], the ideal is the use of repeated short-term information, so that the MSM can more accurately estimate the usual intake of nutrients and the consumption of foods in a population, together with information on the frequency of consumption. However, it is recommended to use at least two non-consecutive days of short-term consumption information, such as 24HRs [34], as done in the present study.

It is emphasized that both the development and the validation of FFQ should consider the objectives of the study. The present FFQ was not adapted and validated for the estimation of the NOVA classification of foods, recommended by the Food Guide for the Brazilian Population [35].

CONCLUSION

In this validation study of an FFQ used to assess the food consumption of adults from two Brazilian birth cohorts, the instrument proved to be useful to estimate the intake of some nutrients and food groups of the subjects evaluated. However, the consumption of the food groups Red and pork meat, Nuts and Snacks was estimated with less accuracy, as was also the case for the nutrients vitamin B3, phosphorus, and potassium.

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CONTRIBUTORS

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