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RESEARCH ARTICLE

Reproducibility and validity ELSA-Brasil Food Frequency Questionnaire

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ABSTRACT

Introduction: To investigate the association between diet and health effects in population surveys, it is necessary to have precise tools that allow estimating the habitual consumption of the population. Aim: To evaluate the reproducibility and validity of the ELSA-Brasil food frequency questionnaire (FFQ) to assess macro and micronutrients intake.

Material and Methods: We collected dietary information of 281 participants which completed two ELSA-Brasil food frequency questionnaires over a year period and three records. To assess the reproducibility of the FFQ, we compared the macro and micronutrients intake from the two FFQ while to assess the validity, we compared the intakes of FFQ with the mean of three records. The intraclass correlation test (ICC) and agreement percentages of nutrient intake were calculated after categorization by tertiles.

Results: ICC coefficients for reproducibility ranged from 0.51 (polyunsaturated fat) to 0.70 (magnesium) while the ICC coefficients for validity ranged from 0.14 to 0.61 for omega 3 and magnesium, respectively. The exact concordances between methods ranged from 37% for omega 3 to 50.2% for magnesium (mean=44.6%). An average disagreement of 13.4% was found.

Conclusions: This study suggests that the ELSA-Brasil FFQ is suitable tool to assess dietary intake with a satisfactory reproducibility and relative validity.

> **Reproducibilidad y validez del cuestionario de frecuencia alimentaria ELSA-Brasil**

RESUMEN

Introducción: Para investigar la asociación entre dieta y efectos en salud en encuestas poblacionales, es necesario disponer de herramientas precisas que permitan estimar el consumo habitual de la población. Objetivo: Evaluar la reproducibilidad y validez del cuestionario de frecuencia alimentaria (FFQ) del ELSA-Brasil para evaluar la ingesta de macro y micronutrientes.

Material y Métodos: Recopilamos información dietética de 281 participantes que completaron dos cuestionarios de frecuencia alimentaria del ELSA-Brasil durante un período de un año y tres registros. Para evaluar la reproducibilidad del FFQ, comparamos la ingesta de macro y micronutrientes de los dos FFQ mientras que, para evaluar la validez, comparamos las ingestas de FFQ con la media de tres registros. La prueba de correlación intraclase (ICC) y los porcentajes de acuerdo de la ingesta de nutrientes se calcularon después de la categorización por tertiles.

Resultados: En la evaluación de la reproducibilidad, los coeficientes ICC variaron de 0,51-0,70 para magnesio de grasas poliinsaturadas, respectivamente; en la evaluación de la validez, oscilaron entre 0,14 y 0,61 para omega 3 y magnesio, respectivamente. Las concordancias exactas entre los métodos oscilaron entre el 37% para omega 3 y el 50,2% para magnesio (media=44,6%). Se encontró un desacuerdo promedio del 13,4%.

Conclusiones: Este estudio sugiere que ELSA-Brasil FFQ es una herramienta adecuada para evaluar la ingesta dietética con una reproducibilidad satisfactoria y validez relativa.

KEY MESSAGES

1. Precise and accurate dietary assessment studies are needed to find the relationship between diet and disease.

2. Elsa-Brasil is the largest cohort study in Latin America that needs validated questionnaires to make health and nutrition inferences.

3. The validation and reproducibility of the FFQ nutrients is an adequate tool for the assessment of dietary intake in ELSA-Brasil participants.

INTRODUCTION

In recent decades, nutritional epidemiology has improved the understanding of the complex relationship between diet and cardiometabolic diseases. Nowadays, it is already known that the food components affect either the risk of these diseases or prevention[1,2]. Therefore, it is essential to investigate food consumption to learn how the diet impacts the health-disease process. However, since the diet is an exposure that is difficult to measure, a significant challenge facing epidemiological studies of nutrition is dietary information inaccuracy[3].

Given these findings, to investigate the associations between diet (exposure) and health outcomes in population surveys, it is necessary to measure food consumption as accurately as possible, estimating habitual consumption and using the available dietary methods. For this reason, evaluating the quality of the measure is essential. Thus, to ensure greater accuracy and precision when determining the occurrence of possible measurement errors, specific to the methods, to minimize bias that may arise in scientific research, and to adding precision in the analyzes that involve research between diet/nutrients and outcomes, validation and reliability must be evaluated[4,5]. Therefore, the greater the number of nutrients evaluated through validation studies, the better the instrument's performance in the research.

The instrument of collection of dietary data considered most appropriate and used in epidemiological studies is the Food Frequency Questionnaire (FFQ), mainly for reasonably estimating the individual's usual diet and for being a simple, low-cost, and highly applicable instrument. The FFQ must be specific for each population, presenting a list of foods that reflect the place's dietary pattern being studied and identifying the portions commonly consumed[3,4].

However, it is considered that the FFQ has less accuracy when compared to other methods of assessing consumption that present specific measures[3,6]. Thus, since it is a method with the characteristics mentioned and used in a specific population, it is necessary to validate the FFQ to assess its performance compared to a reference method, making it more accurate and precise[6,7]. In this sense, there is no ideal instrument for comparison since all have limitations. However, the 24-hour Food Record or Recall has been suggested as reference methods for validating FFQ, as it presents different systematic errors[6,8]. Besides, it is also crucial to evaluate reproducibility, as certifying that the consumption values found are similar between two applications of the instrument at different times[9].

ELSA-Brasil developed its own FFQ (114 food items) and tested its reproducibility and validity for twelve nutrients[10]. It is relevant to highlight that ELSA-Brasil is a follow-up study covering a wide range of health variables. It has increasingly sought to understand and expand the analysis of the diet and its different components on health outcomes. Whereas that diet can be one of the leading modifiable determinants of the risk of chronic diseases, it is essential to validate other nutrients from the FFQ-ELSA-Brasil. Thus, the validation will estimate the measurement errors inherent to the method, which are seen as the primary source of bias in epidemiological studies.
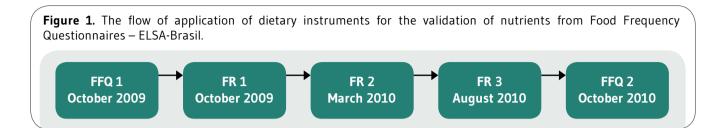
Therefore, the objective of this study is to evaluate the reproducibility and validity of the FFQ applied in the ELSA-Brasil study for selected macro and micronutrients: (Animal and vegetable protein, fructose, Total Conjugated Linoleic Acid, Saturated Fat, Mono and Polyunsaturated, Omega 3, Magnesium, Vitamin D, and B vitamins [B_6, B_9, and B_{12}]). The reference method adopted was the food register applied in a subsample of ELSA-Brasil.

MATERIAL AND METHODS

The Longitudinal Study on Adult Health (ELSA-Brasil) is a cohort of 15,105 public servants, active and retired, of both sexes, aged 35 to 74 years old, started in 2008. It has been conducted in six Health Centers Research (USP, UFMG, UFBA, UFRGS, and UFES) and a research institution of the Ministry of Health, FIOCRUZ / RJ[11].

For the FFQ ELSA-Brasil validation study, a random subsample consisting of 150 men and 150 women was selected. The FFQ-ELSA-Brasil was applied in two moments, in the first contact with the participant (FFQ1) and one year later (FFQ2); In the interval between the application of the FFQs, three food registers (FR) were applied (Figure 1).

The ELSA-Brasil FFQ is a semi-quantitative questionnaire containing 114 food items and aims to assess the participants' regular consumption in the last 12 months[12]. The instrument was validated by Molina et al.[10] for the following nutrients: carbohydrates (g), proteins (g), lipids (g), fiber (mg), calcium (mg), iron (mg), potassium (mg), selenium (µg), zinc (mg), vitamin A (IU), vitamin C (mg) and vitamin E (mg). This study will validate selected macro and micronutrients (animal and vegetable protein, fructose, total conjugated linoleic acid, saturated fat, mono and polyunsaturated fat, omega 3, magnesium vitamin D, and B vitamins [B_6, B_9, and B_{12}]).

Figure 1. The flow of application of dietary instruments for the validation of nutrients from Food Frequency Questionnaires – ELSA-Brasil.

FFQ 1 October 2009	→	FR 1 October 2009	→	FR 2 March 2010	→	FR 3 August 2010	→	FFQ 2 October 2010

The ELSA-Brasil FFQ is structured in three sections: (1) food/preparations, (2) measures of consumption portions and (3) frequency of consumption, with eight response options: "more than 3 times/day" , "2-3 times/day" , "1 time/day" , "5-6 times/week" , "2-4 times/week" , "1 time/week" , "1-3 times/month" and "never/almost never"[12]. For the application of the FFQ-ELSA-Brasil, the interviewer used a standardized kit of utensils to facilitate the understanding of home measurements. The participant had an answer card in hand with the frequency of consumption options to ease the interview.

Considering the application of the FR-24h, to support the registration of the information was delivered to the participant an instruction manual and a photographic life-size food utensils album. The FRs showed representativeness regarding weekdays (Monday to Friday) and weekend days (Saturday or Sunday).

As it is a multicenter study, the procedures were standardized, and all research centers performed data collection in the same period. Participants were scheduled to confirm the date for holding the FRs and the date on which the completed record would be checked and collected.

After applying the FFQ and FR, the data was inserted into the Nutrition Data System for Research (NDSR) software[13] from the University of Minnesota (NCC) to quantify the nutrients. For a single food, "cassava flour," information from the Brazilian Food Composition Table (TACO)[14] from the State University of Campinas – UNICAMP was used.

For the correction of intra-individual variability in food consumption, the values obtained in the FRs were attenuated (ratio between intra-individual variability and among individuals), using the PC-SIDE program (Department of Statistics, Iowa State University, Iowa, United States)[15,16]. This process resulted in an estimate of the individual values of energy and nutrients. Adjustment for energy was performed using the residual method to correct nutrient estimates by total energy intake[17].

The normality of nutrients was verified, and the means and standard deviations were estimated using appropriate statistical tests. For the analyzes of reproducibility and validity of the FFQ, the correlation coefficients were calculated intraclass (CCI) between FFQ1 and FFQ2 and between FRs and FFQ2. The nutrient intake by all participants was categorized into tertiles, calculating the percentage of exact agreement (even tertile), adjacent (adjacent tertiles), and discordant (opposite tertiles) to assess the degree of misclassification error. The statistical analyzes were performed using the SPSS program, version 18.0 (SPSS Inc., Chicago, United States).

As a multicenter study, the ELSA-Brasil project was approved by the National Research Ethics Committee and each institution's committees involved[11]; all participants signed the Free and Informed Consent Form.

RESULTS

Of the initial sample of three hundred participants, seven did not complete the third registration, and 12 did not respond to the second FFQ. Therefore, the final sample was composed of 281 participants, 136 (48.4%) men, and 145 (51.6%) women; 154 (54.8%) aged 35-54 years and 127 (45.2%) between 55 to 74 years old; with approximately 40% belonging to the functional category of technical level. The percentage of participants in each research center ranged from 15.3% to 18.9% (data not shown in table).

Table 1 shows the crude means and standard deviations and adjusted variables (energy and nutrients) obtained in FFQ1 and FF2, in addition to the ICC and the agreement between energy and nutrients measured in the FFQ at both times. High variability is observed in the consumption of energy and nutrients in the two measurements. The average energy consumption and all analyzed nutrients were lower in FFQ2 when compared to FFQ1. The energy-adjusted ICC values ranged from 0.51 (polyunsaturated fat)

Table 1. Mean intake and standard deviation (SD) of energy and nutrients in the FFQ1 and FFQ2, intraclass correlation coefficient (ICC) and percentage (%) of agreement between FFQ1 and FFQ2.

Energy and nutrients	FFQ1 Mean (SD)		FFQ2 Mean (SD)		ICC* Mean (SD)			% of Agreement	
	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted	Exact	Exact + Adjacent	Discordant
Energy (kcal)	3228 (1464)	-	2982 (1456)	-	0.73*	-	-	-	-
Animal protein (g)	99 (68)	92 (39)	90 (64)	81 (30)	0.47*	0.53*	49.8	89.6	10.3
Vegetable protein (g)	50 (24)	46 (11)	45 (20)	43 (10)	0.69*	0.57*	45.2	87.9	12.1
Fructose (g)	41 (30)	37 (19)	38 (27)	35 (18)	0.67*	0.65*	47.3	90.0	9.9
TCLA (g)	0.2 (0.12)	0.18 (0.08)	0.18 (0.12)	0.17 (0.07)	0.64*	0.67*	50.9	92.2	7.9
Saturated fat (g)	33 (18)	30 (9)	31 (17)	28 (8)	0.61*	0.67*	54.4	92.1	7.9
Monounsaturated fat (g)	31 (17)	28 (7)	29 (16)	26 (6)	0.59*	0.57*	50.2	89.4	10.6
Polyunsaturated fat (g)	24 (13)	22 (5)	22 (12)	20 (5)	0.64*	0.51*	51.6	86.4	13.5
Omega 3 (g)	4.3 (2.6)	3.9 (1.7)	3.9 (2.8)	3.5 (1.3)	0.64*	0.59*	44.8	90.4	9.6
Magnesium (mg)	532.3 (234)	494.4 (94)	501.2 (215)	469 (86)	0.66*	0.70*	51.6	92.2	7.8
Vitamin D Calciferol (µg)	20.7 (21)	19.5 (19)	19.7 (24)	17 (14)	0.59*	0.62*	50.5	90.4	9.6
Vitamin B$_6$ (mg)	3.85 (1.97)	3.56 (0.85)	3.54 (2.06)	3.21 (0.70)	0.62*	0.68*	54.10	91.8	8.2
Vitamin B$_9$ (µg)	829.82 (386.07)	768.05 (173.53)	740.04 (328.26)	689.98 (143.01)	0.70*	0.59*	47.00	86.8	13.2
Vitamin B$_{12}$ (µg)	7.83 (5.16)	7.34 (3.83)	7.89 (6.07)	7.22 (3.75)	0.70*	0.68*	51.60	89.3	10.7

*p-valor <0,05; FFQ1: Food frequency questionnaire 1; **FFQ2:** Food frequency questionnaire 2; **SD:** Standard deviation; **ICC:** Intraclass correlation coefficient. [a]: Log-transformed fructose; **TCLA:** Total conjugated linoleic acid.

to 0.70 (magnesium). The mean of the exact agreement was 49.9%, with a variation from 44.8% for omega 3 to 54.4% for saturated fat, and the average percentage of disagreement between the methods was 10.1%, with a minimum of 7.8% (magnesium) and a maximum of 13.5% (polyunsaturated fat).

Table 2 shows the means and standard deviations of energy and nutrient intake for FFQ2 and RA, as well as the correlations between the two methods. The ICC values between nutrients related to the adjusted data ranged from 0.14 (omega 3) to 0.61 (magnesium). Checking the values of the percentages of agreement between the QFA2 and the RA, we observed an average value of exact agreement of 44.7%, varying between 37% and 50.2%, of omega 3 and magnesium, respectively; these nutrients also showed the highest and lowest percentage disagreement, 18.9% and 8.5%, and an average disagreement of 13.4% was found.

DISCUSSION

This study presents good reproducibility and validity of some nutrients, which will help us better understand the ELSA-Brasil population's food compartment. The nutrients evaluated in this study show good reproducibility, finding ICC values (0.51-0.70); these values were similar and comparable to other FFQs[18–22]. In Moroccan adults with an average age of 23.7 years, the reproducibility of a FFQ was evaluated, finding an agreement for macro (between 0.69-0.75 for fat and protein, respectively) and micronutrients (above 0,7 for majority micronutrients)[23]. In the same way, was found in the Japanese community, the mean correlation of 0.79, for fiber (0.85) and vitamin B_1 (0.67), besides not showing significant difference as stratified by sex[24].

Looking at this study's results, we consider fructose, TCLA, saturated fat, magnesium, vitamin B_6, and vitamin B_9 had relative validity. The others had lower ICC values, such as animal and vegetal protein, monounsaturated fat, polyunsaturated fat, omega 3, vitamin D, and vitamin B_{12}. There are different analysis methodologies in the validation studies that make the comparison of results difficult[9,10,19]; however, some studies support our findings. In a French study with adults, finding correlation coefficients less than 0.3 in 8 nutrients, among these vitamin B_{12}[25], low correlations for vitamins can be attributed to implicit bias of the FFQ[26]. In the literature,

the validity has been reached for most macronutrients, but micronutrients, in general, have the lowest values of correlation coefficient[9,10,19], other studies also show low correlation for protein[27], data likewise found in our study.

When we analyze the agreement values, we observe that reproducibility presents higher percentages when compared to the validity analysis, varying from 44.8% omega 3 and 54.4 sutured fat for reproducibility and 37% Omega 3 and 50% magnesium for validity. It can be explained because the reproducibility compares the same instruments (FFQ), and the validity compares two different methods FFQ and RA. Our data report concordance similarities with other studies of the same nature[28,29]; the discordant data presented low percentages, showing for reproducibility 13.5% for polyunsaturated fat and 7.8% for magnesium and validity of 18.9% for omega 3 and 8.5% for magnesium.

The low ICC values for some nutrients may be associated with the vast number of food items in the FFQ ELSA-Brasil. Overestimation may occur due to the induction of the response[5], a fact that does not occur in the RA since, in this method, the individual registers their food consumption.

The time between the completion of one FFQ and the other, of one year in this study, makes spurious correlations difficult, which can occur when the interval between the FFQs is very short (a few days or weeks), favoring that the interviewees remember the answers given in the first FFQ, thus being able to overestimate reproducibility[9,19].

Not all nutrients have been validated because a number of major recalls have been applied in this studio to have a better correlation; theoretically, some micronutrients have been reported to require a minimum of 7 recalls to have a better validation analysis[3]. It is important to carry out validation studies, mainly those analyzed in this article, that will help associate with chronic diseases.

CONCLUSIONS

It is concluded that the ELSA-Brasil FFQ presents satisfactory reproducibility for all analyzed nutrients and relative validity for fructose, TCLA, saturated fat, magnesium, vitamin B_6, and vitamin B_9.

Table 2. Means and standard deviations (SD) of energy and nutrient consumption, intraclass correlation coefficient (ICC) and percentage (%) of agreement between FFQ2 and food records (n=281).

Energy and nutrients	Crude Mean (SD)		Adjusted Mean (SD)		ICC* Adjusted		% of Agreement		
	FFQ2	Food records	FFQ2	Food records	Crude	de-attenuated and adjusted	Exact	Exact + Adjacent	Discordant
Energy (kcal)	2982 (1456)	2189 (611)	-	-	0.51	-	-	-	-
Animal protein (g)	90 (64)	66 (24)	81 (30)	66 (8)	0.18	0.29*	48.8	87.3	12.8
Vegetable protein (g)	45 (20)	31 (12)	43 (10)	30 (3)	0.32*	0.36*	40.2	85.1	14.9
Fructose (g)	38 (27)	25 (17)	35 (18)	24 (5.6)	0.31	0.46*	44.1	86.8	13.1
TCLA (g)	0.18 (0.12)	0.16 (0.04)	0.17 (0.07)	0.16 (0.03)	0.37*	0.48*	49.1	89.7	10.3
Saturated fat (g)	31 (17)	25 (14)	28 (8)	25 (3)	0.33*	0.48*	47.0	89.7	10.3
Monounsaturated fat (g)	29 (16)	24 (13)	26 (6)	24 (3)	0.31*	0.35*	40.9	85.7	14.3
Polyunsaturated fat (g)	22 (12)	15 (8)	20 (4)	15 (2)	0.26*	0.36*	48.6	86.3	14.3
Omega 3 (g)	4 (3)	2 (0.6)	3.5 (1.3)	2.3 (0.5)	0.10	0.14	37.0	81.1	18.9
Magnesium (mg)	501 (215)	329 (56)	469 (86)	326 (42)	0.25	0.61*	50.2	91.5	8.5
Vitamin D Calciferol (µg)	20 (24)	9 (3.87)	17 (14)	9 (3.82)	0.10	0.16	40.6	83.3	16.8
Vitamin B$_6$ (mg)	3.54 (2.06)	2.14 (0.35)	3.21 (0.70)	(0.25)	0.19*	0.41*	47.3	87.9	12.2
c (µg)	740.0 (328.2)	455.62 (80.26)	689.98 (143.01)	451.11 (59.38)	0.27*	0.40*	45.2	87.9	12.1
Vitamin B$_{12}$ (µg)	7.89 (6.07)	7.41 (2.18)	7.22 (3.75)	7.35 (1.96)	0.18*	0.21*	41.6	85.8	14.2

*p-valor <0,05; FFQ1: Food frequency questionnaire 1; **FFQ2:** Food frequency questionnaire 2; **SD:** Standard deviation; **ICC:** Intraclass correlation coefficient.
a: Log-transformed fructose; **TCLA:** Total conjugated linoleic acid.

AUTHORS' CONTRIBUTIONS

All authors participated in the study conception and design; OGEM, CMOA, TKBM, SAAA, TSSP. JHS and LOF conducted the analysis and interpretation of the results and draft manuscript preparation; all authors discussed the results, reviewed the manuscript, and approved the final version.

COMPETING INTERESTS

Authors state that there are no conflicts of interest in preparing the manuscript.

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