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ORIGINAL ARTICLE

Nutrition

Relative validity and reproducibility of food frequency questionnaire for individuals on hemodialysis (NUGE-HD study)

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Abstract

Introduction: Adequate assessment of food intake is essential to establish the magnitude and direction of the relationship of food, nutrients, and bioactive compounds with clinical outcomes of individuals in hemodialysis. We evaluated the relative validity and reproducibility of a specific food frequency questionnaire for individuals on hemodialysis (FFQ-HD).

Methods: Eighty-two participants (57.3% male, 57.5 ± 14.4 years) from the open cohort Nutrition and Genetics in Hemodialysis Outcomes participated in this study. The relative validity of the FFQ-HD was assessed using the mean of two 24-h food recall (24hR) adjusted for within-subject variability as a reference method. We also performed Pearson correlations, and agreement between tertile, kappa statistics, and Bland–Altman scatter plots were validated. Reproducibility was assessed after 1 year using intraclass correlation coefficient (ICC).

Findings: Daily energy intake was not different between FFQ-HD and 24hR (mean difference of 50.1 kcal). Intake of protein, linolenic acid, fiber, phosphorus, potassium, sodium, calcium, and sugar showed a moderate correlation (r between 0.4 and 0.5) among instruments, while mean correlation coefficient was $r = 0.38$ to food group intake. Bland–Altman plots showed good agreement for micronutrients, phosphorus, sodium, and potassium and for the groups "flour, bread, and pasta" and "processed, canned meat, salts, and seasonings". The reproducibility of FFQ-HD for nutrients and food groups was satisfactory, reaching a maximum ICC of 0.72 and 0.59, respectively.

Discussion: The FFQ-HD showed moderate validity and reproducibility for calories, nutrients, and food groups of clinical and nutritional interest for HD subjects so that it can be a useful tool in epidemiological studies in this population.

KEYWORDS
end-stage renal disease, food intake, reliability and validity, validation studies

INTRODUCTION

The loss of renal function in humans is progressive and can lead to organ failure,[1] reaching about 8%–16% of people worldwide.[2] Hemodialysis (HD) is one of the essential renal replacement therapies for survival in individuals with chronic kidney disease (CKD).[3] However, this treatment requires time for HD sessions and health care, such as controlling nutrient and protein intake, which can lead to clinical and metabolic changes that affect nutritional and metabolic condition in this specific population.[3,4]In fact, evidence has reported dietary-nutritional control as one of the pillars for HD treatment[5] to prevent classic symptoms such as uremia, hyperkalemia, and hyperphosphatemia and avoid future complications.[6] Thus, an adequate assessment of food intake is essential to verify adherence to nutritional guidelines in the HD treatment.[7] Additionally, food intake assessment allows to know the magnitude and direction of the relationship of food, nutrients, and bioactive compounds with HD outcomes such as protein-energy malnutrition, obesity and inflammation, mineral and bone metabolism disorders, dyslipidemia, and cardiovascular diseases.[3,8,9]

In this context, the 24-h food recall (24hR) and the food record are tools that can be used to assess current and individual intake; however the wide; within-subject variability of these individuals implies the need for several days of application of these methods, making them unviable for epidemiological studies.[10] In turn, food frequency questionnaires (FFQ) assess intake over time (usual) and allow the establishment of associations between nutrients and clinical outcomes, being a more useful tool among HD subjects who suffer from chronic diseases[6,10,11] However, an FFQ to assess the usual food intake of Brazilian individuals on HD has not been reported, and researches with relative validation and reproducibility in HD are scarce in the literature. Thus, the aim of the study was to evaluate the relative validity and reproducibility of a specific FFQ for HD individuals (FFQ-HD).

METHODS

Study population

Eighty-two individuals (57.3% male, 57.5 ± 14.4 years) undergoing on HD participated in this study from the cohort Nutrition and Genetics in Hemodialysis Outcomes (NUGE-HD study), between September 2017 and October 2018, at the Nephrology Center of a public hospital in Minas Gerais, Brazil. The sample comprised individuals over the age of 18, with treatment period longer than 1 month. Individuals with hearing and/or visual impairment and hemodynamic instability were not included due to communication difficulties and unreliability of data. This study was approved by the Research Ethics Committee of the Universidade Federal de Viçosa (Protocol number 1.956.089/2017) and by the Nephrology Center. All patients read and signed informed consent before participating in the study, in accordance with the principles of the Declaration of Helsinki.

FFQ-HD and data collection

Our FFQ-HD was specially constructed for HD individuals, based on a questionnaire developed for Australian patients with CKD on the consumption information obtained from previous data collections of NUGE-HD study using 24hR.[12]

The FFQ-HD has 135 food items, ate in the following food groups: sugars and confectionery; non-alcoholic beverages and infusion; processed meat, canned, salts, and seasonings; meat, fish, and eggs; cereals and tubers; flour, bread, and pasta; dairy products; legumes; miscellaneous; fruits and leafy vegetables; and oils and fats. Additionally, we categorized the vegetables according to potassium content. Thus, the participants informed their usual intake over the last year, concerning the portion (using open questions—without amount of predefined portions) and the frequency (daily, weekly, monthly, or yearly) of each FFQ-HD food item. Usual home measures were entered into the FFQ-HD to standardize and facilitate data collection; however, if other home measures were reported, they were recorded and used to calculate food intake. Furthermore, a photo album was used during the interview[13] to assist individuals in choosing portions that correspond to their usual intake. During routine HD sessions in the dialysis unit, the FFQ was used by dietitians to interview patients. For patients with any sign of cognitive impairment, the responses were confirmed with caretakers. Data related to underlying kidney disease or other comorbidities were collected from medical records.

Food intake assessment

Daily food, energy, and nutrient intake was estimated for each FFQ-HD food item using a Microsoft Excel 2016 (Chicago, Illinois, version 2016) spreadsheet specifically designed for this purpose. First, we conversed reported home measures to gram or milliliter per day to each participant. Then, the daily intake was calculated by dividing the value found by 1 if the reported frequency of consumption is daily, by 7 if weekly, by 30 if monthly, and by 365 if annual, and subsequently, the daily amount of consumption was converted into nutrients through mathematical formulas (syntaxes) developed for this purpose.

Foods reported at 24hR were recorded in the ERICA software (Rio de Janeiro, Brazil).[14] In both instruments (FFQ and 24hR), the conversion of food in grams or milliliters was standardized from the Table of Measures Referred to the Foods Consumed in Brazil,[15] and energy and nutrient intake was estimated using the Nutritional Composition Table of Foods Consumed in Brazil.[16] The foods mentioned in the 24hR were grouped according to the chemical similarity and inserted in one of the 11 groups previously mentioned (Supplementary Table 1). We did not consider the use of dietary supplements due to the large amount of medication, which difficult the reliable information about the supplementation. We neither consider water intake because our sample is mostly anuric with water restriction.

FFQ-HD relative validation

We used the average food and nutrient intake of two 24hR as a reference method for food intake. First, the FFQ-HD was applied, followed by the first 24hR (same time), and a second 24hR (after 6 months). Both 24hR were performed using the five-step multistep method to increase the accuracy of the information obtained and cover the dietary changes that occur at different times of the year due to the Brazilian climatic seasonality opted for a longer period between applications (Figure 1). Foods, reported at 24hR and FFQ-HD, were grouped according to similar nutritional composition (Supplementary Table 1). During FFQ-HD application, the interviewer repeated to each food group that responses should be based on the last 12 months.

The validity was evaluated by comparing the mean reports of nutrient intake and food groups obtained by applying the two FFQ-HD and the mean of the two 24hR[17] adjusted for within-subject variability according to the design presented in Figure 1.

FFQ-HD reproducibility

After 12 months, we applied a second FFQ-HD (Figure 1). The same photo album used for FFQ application was used to assist individuals in choosing portions that correspond to their intake during 24hR application reproducibility of the FFQ-HD that was determined by retesting the instrument 1 year after the first application (Figure 1). In order to improve reliability, the same interviewers applied both questionnaires, standardizing the application.

Statistical analyses

Food intake values obtained from 24hR were corrected by intrapersonal variance using statistical modeling technique "Multiple Source Method" (MSM); in addition, the MSM also calculated the ratio of between-subjects and within-subject variance.

The variable normalities were analyzed by the Shapiro–Wilk test. The agreement between the mean FFQ-HD and 24hR was analyzed using Pearson's

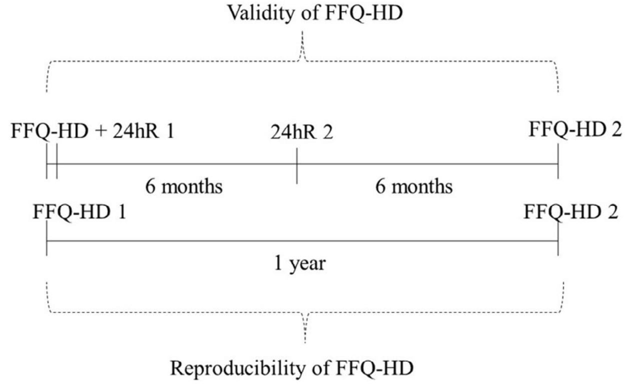

FIGURE 1 Design of the validity and reproducibility study to assess FFQ-HD among HD subjects. FFQ 1 and FFQ 2 are first and second application of FFQ, respectively. 24hR1 and 24hR2 are first and second application of 24-h recall, respectively. 24hR, 24-h food recall; FFQ-HD, food frequency questionnaire for individuals on hemodialysis

TABLE 1 Characteristics of the individuals evaluated in the study

Characteristics	*N* (%) or median (IQR)
Gender	
Female	35 (42.7)
Male	47 (57.3)
Age (years)	60 (20–88)
BMI (kg/m^2)	23.9 (17.3–38.8)
Time in HD (months)	36 (1–292)
Low education level	50 (60.2)
Etiology of CKD	
Hypertensive nephropathy	31 (37.8)
Diabetic nephropathy	27 (32.9)
Polycystic kidney	6 (7.3)
Other causes[a]	18 (21.9)

Note: $n = 82$.

Abbreviations: BMI, Body mass index; CKD, Chronic kidney disease; HD, hemodialysis; IQR, interquartile range.

[a]Other causes are glomerulonephritis, lupus erythematosus, pyelonephritis, and transplant loss.

TABLE 2 Daily intake of calories, nutrients, and food groups, according to the average of two FFQ-HD and two 24hR, 24hR variance ratio, and Pearson's correlation coefficient (r) between the instruments (FFQ-HD and 24hR)

Daily nutrient intake	FFQ-HD (mean ± SD)	24hR[a] (mean ± SD)	Variance ratio 24hR[b]	Pearson correlation (r)[c]
Energy (kcal)	1066.1 ± 400.7	1116.2 ± 279.4	0.98	—
Carbohydrate (g)	140.7 ± 50.7	154.7 ± 39.1	1.19	0.26
Protein (g)	40.0 ± 13.8	50.4 ± 15.6	1.04	0.50
Total fat (g)	37.3 ± 16.7	33.4 ± 9.5	1.73	0.31
Saturated fat (g)	12.6 ± 5.9	11.9 ± 3.7	2.07	0.35
MUFA (g)	12.5 ± 5.8	10.7 ± 2.9	2.74	0.26
PUFA (g)	7.4 ± 2.9	7.1 ± 2.1	2.12	0.33
Omega 3 (g)	0.8 ± 0.3	0.3 ± 0.5	0.38	0.41
Omega 6 (g)	6.4 ± 2.6	6.3 ± 1.7	2.36	0.32
Cholesterol (mg)	131.2 ± 59.3	153.5 ± 53.4	3.24	0.05
Fiber (g)	13.7 ± 4.9	11.4 ± 4.0	1.27	0.43
Phosphorus (mg)	551.4 ± 213.2	598.5 ± 181.6	1.22	0.46
Potassium (mg)	1467.9 ± 507.7	1583.7 ± 564.5	0.14	0.40
Sodium (mg)	897.1 ± 452.6	952.4 ± 335.5	1.59	0.35
Adding sodium (mg)	913.7 ± 285.4	1255.6 ± 439.2	0.85	0.44
Calcium (mg)	434.0 ± 206.1	359.4 ± 126.9	1.51	0.48
Iron (mg)	6.4 ± 2.1	7.5 ± 2.5	0.95	0.27
Selenium (mg)	44.2 ± 17.4	45.3 ± 15.5	1.86	0.31
Vitamin C (mg)	82.2 ± 21.9	106.7 ± 117.5	4.08	0.32
Total sugar (g)	37.9 ± 21.4	25.3 ± 58.4	2.82	0.46
Mean				0.33
Daily foods group intake (g or ml)[d]	**FFQ-HD (mean ± SD)**	**24hR[a] (mean ± SD)**	**Variance ratio 24hR[b]**	**Pearson correlation (r)**
Sugars and confectionery	12.9 ± 12.3	6.2 ± 15.6	—	0.29
Nonalcoholic beverages and infusion	193.6 ± 110.6	259.2 ± 130.3	—	0.28
Processed meat, canned, salts, and seasonings	6.7 ± 5.3	7.0 ± 29.3	—	0.47
Meat, fish, and eggs	50.3 ± 24	78.3 ± 51.8	—	0.46
Cereals and tubers	163.8 ± 72.9	227.9 ± 120.2	—	0.49
Flour, bread, and pasta	90.2 ± 61.4	86.7 ± 48.5	—	0.19
Fruits and leafy vegetables	205.9 ± 128.6	161.4 ± 115.2	—	0.51
Dairy products	116.8 ± 88.2	37.8 ± 66.0	—	0.38
Legumes	86.9 ± 42.7	136.2 ± 93.9	—	0.50
Miscellaneous	31.53 ± 36.5	23.3 ± 88.7	—	0.27
Oils and fats	10.8 ± 10.4	6.1 ± 6.3	—	0.44
Mean				0.38

Note: $n = 82$.

Abbreviations: 24hR, 24-h food recall; FFQ-HD, food frequency questionnaire for individuals on hemodialysis; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

[a]Values corrected for intraindividual variation over 2 days of 24hR.

[b]Between-subjects/within-subject.

[c]Adjusted for caloric density (per 1000 kcal).

[d]Deattenuated values and adjusted for caloric density.

TABLE 3 Frequency (%) of study participants ($n = 82$) in the exact + adjacent and opposite tertiles according to daily calorie, nutrient, and food group intake estimated by FFQ-HD and 24hR

Daily nutrient intake	Exact tertile + adjacent	Opposite tertiles	κw [95% CI]
	%		
Energy (kcal)	89.2	10.8	0.22 [0.38, 0.06]
Carbohydrate (g)	88	12	0.24 [0.40, 0.08]
Protein (g)	84.4	15.6	0.17 [0.32, 0.00]
Total fat (g)	88	12	0.15 [0.91, 0.06]
Saturated fat (g)	88	12	0.24 [0.40, 0.08]
MUFA (g)	84.1	15.8	0.09 [−0.07, 0.24]
PUFA (g)	85.6	14.4	0.18 [0.34, 0.02]
Omega 3 (g)	74.7	25.3	0.08 [−0.05, 0.21]
Omega 6 (g)	85.6	14.4	0.17 [0.32, 0.00]
Cholesterol (mg)	87.8	12.2	0.19 [0.35, 0.03]
Fiber (g)	84.4	15.6	0.17 [0.32, 0.01]
Phosphorus (mg)	89.2	10.8	0.13 [0.28, −0.02]
Potassium (mg)	92.8	6.1	0.16 [0.32, 0.00]
Sodium (mg)	82	18	0.07 [0.23, −0.07]
Adding sodium (mg)	89.2	10.8	0.13 [0.29, −0.02]
Calcium (mg)	91.6	8.4	0.15 [0.30, −0.00]
Iron (mg)	89.2	10.8	0.15 [0.31, −0.01]
Selenium (mg)	88	12	0.18 [0.34, 0.02]
Vitamin C (mg)	81.7	18.3	0.14 [0.30, −0.02]
Total sugar (g)	88	12	0.26 [0.41, 0.09]
Mean	86.5	13.3	0.16
Daily foods group intake (g or ml)	**Exact tertile + adjacent**	**Opposite tertiles**	**κw (95% CI)**
Sugars and confectionery	100	0	0.04 (0.16, −0.08)
Nonalcoholic beverages and infusion	86.6	13.4	0.08 (0.25, −0.08)
Processed meat, canned, salts, and seasonings	97.6	2.7	0.02 (0.13, −0.09)
Meat, fish, and eggs	86.6	13.4	0.10 (0.26, −0.05)
Cereals and tubers	91.4	8.6	0.17 (0.33, 0.016)
Flour, bread, and pasta	82.9	17.1	0.12 (0.39, 0.06)
Fruits and leafy vegetables	91.5	8.5	0.21 (0.037, 0.05)
Dairy products	80.5	19.5	0.10 (0.31, 0.02)
Legumes	91.5	8.5	0.23 (0.39, 0.06)
Miscellaneous	96.3	3.7	0.06 (−0.04, 0.16)
Oils and fats	92.7	7.3	0.21 (0.37, 0.04)
Mean	90.7	9.3	0.12

Abbreviations: 24hR, 24-h food recall; CI, confidence interval; FFQ-HD, food frequency questionnaire for individuals on hemodialysis; κw, weighted kappa statistic; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

correlation coefficients (r), with $r > 0.4$ acceptable correlation. Nonparametric variables were logarithmically transformed. We evaluated the agreement between the mean FFQ-HD and 24hR by the distribution of participants according to the consumption tertiles of the two instruments. The cutoff points are the values of the 25th, 50th, and 75th percentiles of the distribution of nutrients and foods groups for the FFQ-HD and for the average of the 24hR separately. Weighted kappa statistics (κw) was used for tertiles classification analysis. The graphs proposed by Bland and Altman (1999)[18] were also constructed to evaluate the agreement and magnitude of the differences between the information obtained by FFQ-HD and 24hR. For reproducibility analyses, the intraclass correlation coefficient (ICC) was used and values between 0.4 and 0.7 were considered indicative of good reproducibility.[19]

The evaluated nutrients were adjusted for energy density before statistical analyses, multiplying the amount of nutrient ingested by 1000 kcal, and then dividing by the total energy intake.[20] This correction of energy effect was also applied on food groups since these also were analyzed in the FFQ-HD validation and reproducibility.[20,21]

Finally, statistical analyzes were performed using Statistical Package for the Social Sciences software (IBM, New York, version 21.0). For analyses of Bland–Altman, we considered a significance level of 5% ($\alpha = 0.05$).

RESULTS

Of the 137 individuals began this study, 100 met the inclusion criteria. In 1 year of follow-up, 17.8% (18) died, transplanted, or could not respond to the second application of FFQ-HD or 24hR, totaling a sample of 82 individuals. The sample individuals were mostly male, elderly, and have hypertension nephrosclerosis as the main cause of CKD (Table 1).

Regarding food intake (Table 2), energy intake was very close in both methods (FFQ-HD and 24hR). Among the macronutrients, carbohydrate and protein presented the highest estimated consumption by the 24hR average, as for all micronutrients, except for total sugar.

The Pearson's correlation coefficient (*r*) deattenuated and adjusted for caloric density nutrients and for protein, linolenic acid, fiber, phosphorus, potassium, sodium, calcium, and total sugar showed a moderate correlation ($r > 0.4$), and the other nutrients showed weak correlations (Table 2). Of the 11 food groups, the average consumption by FFQ-HD was higher for six food groups and the correlation coefficients ranged from 0.19 for "flour, bread, and pasta" to 0.51 for vegetables including fruits and leafy vegetables (Table 2).

In the agreement analysis between tertiles of calorie and nutrient intake, we found an average of 86.5% of individuals in the exact and adjacent tertile and 13.3% of individuals in the opposite tertile. Potassium and calcium nutrients stand out for presenting only 6.1% and 8.4% of individuals, respectively, classified in the opposite tertile (Table 3), indicating that the method is appropriate for the classification of individuals with

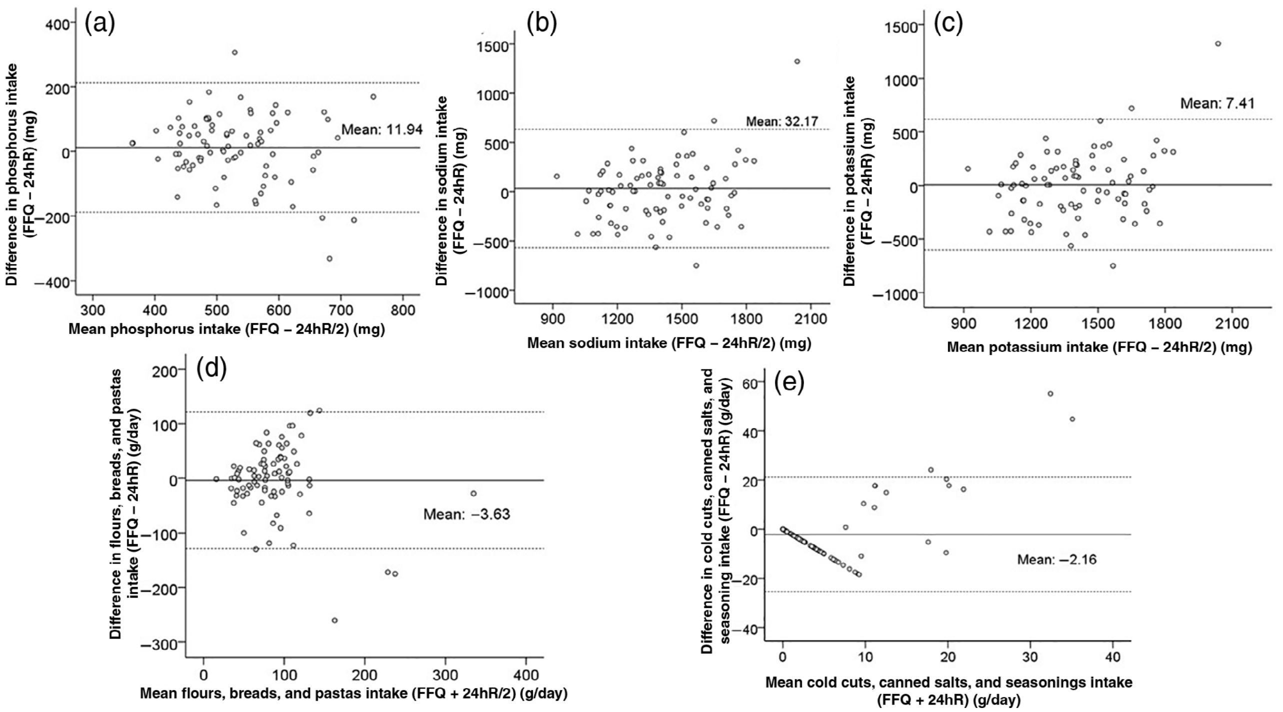

FIGURE 2 FFQ-HD validity evaluation by Bland–Altman graphics. Difference between two mean FFQ and two mean 24hR for: (a) phosphorus; (b) sodium; (c) potassium; (d) flours, breads, and pastas; (e) processed meat, canned, salts, and seasonings. ——, Mean difference (bias); -----, limits of agreement (±2dp); 24hR, 24-h food recall; FFQ-HD, food frequency questionnaire for individuals on hemodialysis

TABLE 4 Values of crude and adjusted intraclass correlation coefficients (ICC; per 1000 kcal) for FFQ-HD reproducibility of 1 year

	FFQ-HD 1 vs. FFQ-HD 2			
	Unadjusted		Adjusted[a]	
Daily nutrient intake	**ICC**	**95% CI**	**ICC**	**95% CI**
Energy (kcal)	0.70	0.54, 0.80	—	—
Carbohydrate (g)	0.67	0.50, 0.79	0.44	0.14, 0.64
Protein (g)	0.58	0.36, 0.73	0.70	0.55, 0.81
Total fat (g)	0.67	0.50, 0.79	0.48	0.20, 0.66
Saturated fat (g)	0.65	0.46, 0.77	0.49	0.22, 0.67
MUFA (g)	0.61	0.41, 0.75	0.39	0.06, 0.60
PUFA (g)	0.63	0.44, 0.76	0.40	0.08, 0.61
Omega 3 (g)	0.61	0.40, 0.75	0.26	−0.13, 0.52
Omega 6 (g)	0.63	0.44, 0.76	0.43	0.12, 0.63
Cholesterol (mg)	0.49	0.21, 0.67	0.45	0.15, 0.64
Fiber (g)	0.55	0.30, 0.70	0.59	0.38, 0.74
Phosphorus (mg)	0.60	0.39, 0.74	0.61	0.40, 0.75
Potassium (mg)	0.43	0.13, 0.63	0.40	0.08, 0.61
Sodium (mg)	0.72	0.57, 0.82	0.38	0.05, 0.60
Adding sodium (mg)	0.51	0.25, 0.68	0.55	0.30, 0.70
Calcium (mg)	0.63	0.44, 0.76	0.68	0.51, 0.79
Iron (mg)	0.61	0.40, 0.75	0.63	0.43, 0.76
Selenium (mg)	0.66	0.48, 0.78	0.64	0.45, 0.77
Vitamin C (mg)	0.21	−0.20, 0.49	0.06	−0.44, 0.39
Total sugar (g)	0.61	0.40, 0.75	0.50	0.23, 0.68
Mean	0.60		0.50	
Daily foods group intake (g or ml)				
Sugars and confectionery	0.38	0.04, 0.60	0.17	−0.27, 0.46
Nonalcoholic beverages and infusion	−0.06	−0.64, 0.31	0.21	−0.22, 0.49
Processed meat, canned, salts, and seasonings	0.17	−0.27, 0.46	0.13	−0.34, 0.44
Meat, fish, and eggs	0.31	−0.05, 0.56	0.59	0.37, 0.74
Cereals and tubers	0.54	0.29, 0.70	0.40	0.07, 0.61
Flour, bread, and pasta	0.57	0.34, 0.72	0.09	−0.40, 0.41
Fruits and leafy vegetables	0.50	0.23, 0.68	0.53	0.27, 0.69
Dairy products	0.35	−0.00, 0.58	0.51	0.25, 0.68
Legumes	0.37	0.03, 059	0.56	0.32, 0.71
Miscellaneous	0.26	−0.14, 0.52	0.18	−0.26, 0.47
Oils and fats	0.48	0.20, 0.66	0.44	0.14, 0.64
Mean	0.35		0.34	

Note: $n = 82$.

Abbreviations: CI, Confidence interval; FFQ-HD, food frequency questionnaire for individuals on hemodialysis; CI, confidence interval; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

[a]Adjusted for caloric density (1000 kcal).

low and high consumption. Kappa values were poor for 80% of the evaluated nutrients ($\kappa w < 0.2$) and reasonable for 20% (κw between 0.21 and 0.4).

For food groups, on average, 90.7% of individuals were in the exact and adjacent tertile and 9.3% in the opposite tertile (Table 3). Disagreement between the food groups evaluated by the methods was less than 5% for "sugar and confectionery" and "processed meat, canned, salts, and seasonings"; between 5% and 10% for "cereals and tubers," legumes, miscellaneous, and oils and fats; and greater than 10% for the groups: "meat, fish, and eggs"; "nonalcoholic beverages and infusions"; "flour, bread, and pasta"; and dairy.

Scatter plots of differences between the methods are given in Figure 2 for phosphorus, sodium, and potassium and for the food groups flour, bread, and pasta and processed meats, canned, salts, and seasonings. The micronutrients and the groups represented showed excellent agreement since the mean difference between FFQ-HD and 24hR did not differ significantly from zero (p value > 0.05), and the dispersion data were mostly within the limits of agreement. Furthermore, unadjusted values for energy and all nutrients except vitamin C indicated good reproducibility (Table 4). For food groups, in turn, the adjustment per calorie indicated good reproducibility for the following groups: "cereals and tubers"; legumes; "fruits and leafy vegetables"; "meat, fish, and eggs"; "dairy products"; and "oils and fats."

DISCUSSION

The present study evaluated the relative validity and reproducibility of a specific FFQ for Brazilians undergoing HD treatment. Regarding the validity of the FFQ-HD, our results showed that the instrument has moderate validity for nutrients, highlighting those of clinical and nutritional interest, such as protein, phosphorus, potassium, sodium, and calcium, which presented higher correlation values ($r > 0.4$). Other validation studies showed higher correlation values than ours; however, the population of these studies was mostly adults with a median age ranging from 34 to 40 years and with a female predominance.[22–24] In turn, the sample of our study was mostly like elderly (55%) and male (57.3%). Lee et al. reviewed the influence of sex on food intake in validation studies and concluded that men are less able to report portion size information more accurately than women.[25] Besides, age may generally influence the reporting of consumption data due to difficulty in memorization, leading to under or overestimation of food intake.[19,26]

The agreement between the methods from the comparison between the tertiles showed a good FFQ-HD performance, with values ranging from 92.8% (potassium) to 74.7% (linolenic acid) for the exact and adjacent tertile and a mean of 13.3% for the opposite tertile. These findings were similar to other validation studies.[23,27–29] According to Masson et al. (2013), for satisfactory validation, 50% of individuals must be allocated in the same tertile and up to 10% in the opposite tertile.[30]

We also evaluated the validity of food groups since people eat food and not nutrients. Thus, we could have reliable information on more or less consumed groups as well as nutrients from which they are sources and their association with clinical outcomes in HD. The obtained coefficients can be considered satisfactory, similar to studies that also validated the FFQ by food groups in adults.[24,29,31]

However, the "nonalcoholic beverages and infusions" and "miscellaneous" groups presented weak Pearson's correlation coefficients ($r < 0.3$). This finding may be explained by the recommendation of net restriction in this population to reduce interdialitic weight gain,[32] leading to bias in reported information such as underestimation or overestimation.[3,33] In a validation study for Brazilian adults, Machado et al. (2012) obtained kappa < 0.1 for nonalcoholic beverages.[22] The authors justified the result by the underestimation of this food group in the questionnaire application. On the other hand, "cereals and tubers," "fruits and leafy vegetables," and "meat, fish, and eggs" groups, the main sources of essential amino acids in the diet of these individuals, performed better among all other groups of our study. This leads us to believe that the food groups with the most restrictions for this population were subrelated in 24hR, contributing to the low correlation and agreement, while the groups with the highest consumption had the best agreement results, due to the search for social approval during the interview.[34,35]

Another finding from our study is the "sugar and confectionery" group, for which no individual was ranked in the opposite tertile and the kappa value remained weak. We believe this result was due to low sugar assessment in both methods and the use of ERICA software, which accounts for sugar along with the preparations (e.g., coffee, tea, or sugared juices correspond to the nonalcoholic beverage and infusions group, underestimating the sugar group). We therefore believe that the choice of software may have influenced this result. Moreover, our sample has a considerable number of people with diabetes (50.9%) who tend to underestimate food consumption in relation to the general population.[36]

Also, the Bland–Altman graphs were used to evaluate the agreement between nutrient intake and food groups. This method is considered the most robust analysis in validation studies since correlation measures only evaluate the direction of the relationship between the methods.[37] For the micronutrients and for the groups, they suggest that FFQ-HD and 24hR showed good agreement between them since less than 10% of the sample were outside the agreement limits, besides the small average difference between the methods. In this sense, the phosphorus, potassium, and sodium micronutrients stood out in this analysis. Studies show that proper homeostasis of these minerals reduces CKD complications such as bone mineral disease and cardiovascular changes.[38,39] Thus, knowing the consumption of these minerals would decreased related metabolic complications as well as public health costs and mortality rates.[3,40] A differential of our FFQ-HD is the categorization of fruits and vegetables, according to potassium content (low, medium, and high) and in strategic location (second and third groups of the instrument), corroborating for greater information accuracy.[37]

The foods and ingredients that contribute to the group of "processed meats, canned, salts, and seasonings" may have been forgotten and consequently underestimated during application of 24hR, as shown in the scatter plot (Figure 2e). However, during FFQ-HD application, they were mentioned, for example, the consumption of salt-based sauces and seasonings or canned ingredients in the preparations, indicating that a comprehensive food list, although overestimating the intake, also captures the few reported food intake.[37,41]

The reproducibility of our instrument was considered acceptable for almost all nutrients (mean ICC = 0.6 and 0.5 for raw and adjusted nutrients, respectively), except for vitamin C, considering correlation coefficients between 0.40 and 0.70 are indicative of good reproducibility.[19] The reproducibility of FFQ-HD for nutrients was better in relation to food groups, reaching a maximum ICC of 0.72, compared to 0.59 for groups. The interval between FFQ-HD applications (1 year) may be the reason for this lower agreement since at very long intervals, there may be changes in eating habits, especially in our sample.[37] In this sense, 6-month reproducibility could be assessed in the NUGE-HD cohort. Regarding vitamin C, this micronutrient may be found in few foods, and reproducibility is more difficult to obtain due to variations in the intake of source foods over 12 months.

Considering the methods to assess food intake, the 24hR and the food record would not be useful in this population since our sample is composed of elderly people with low education, in addition to difficulty in memorization. Another reason would be to capture the usual intake through the FFQ, which does not occur with other dietary tools.[42] Therefore, the FFQ-HD would be essential for monitoring dietary adherence. Recently, our research group reported the FFQ-HD was useful to capture the intake of restrictive nutrients such as potassium and phosphorus, preventing poor prognosis outcomes.[11] Another useful application of the FFQ-HD would be to assess the protein intake, macronutrient with low consumption of proteins among HD subjects. In this sense, FFQ-HD may detect the inefficient intake of essential food sources for the maintenance of lean mass and prevention of sarcopenia.[43]

LIMITATIONS/STRENGTHS

The present study has certain limitations. First, the FFQ-HD contains a long list of food items, which can lead respondents to fatigue (30–40 min to fill). However, this list provides a wide range of important foods from a nutritional epidemiological point. Another limitation is the several dietary restrictions of this population, which may lead to under- or overestimated information, seeking social approval of the diet in front of the interviewers. Third, the reference method used (24hR) has certain disadvantages such as depending on the ability to report food and portion size and memory difficulty. In this sense, we use statistical strategies for data correction because the 24hR is one of the most used methods in epidemiological and validation studies.[33,44] In turn, we do not perform biomarker analysis for validation; however, we consider that this use would not be adequate as our population is metabolically unstable[41] and use methods to control phosphorus and serum potassium, such as the use of phosphorus chelators and techniques to decrease the potassium in food, respectively. We still use substitute information sources (caregivers and/or companions) to collect data from individuals and elderly with low cognition and education, which may have contributed to attenuate our correlation coefficients.[3,19] Therefore, this strategy was necessary since these peculiarities are common in this population.[45,46]

As strengths of our study, we highlight the originality of our FFQ-HD, which can have great epidemiological utility to assess specific foods and/or dietary and nutritional patterns in the clinical outcomes of Brazilians on HD. In addition, our instrument did not overestimate the reference method (as most studies have shown),[27–29,47] possibly due to factors related to dialysis treatment and to CKD itself, such as lack of appetite for uremia.[11,48] Moreover, the use of various appropriate and robust statistical tests, including correlation coefficients, tertile classification, and Bland–Altman plots, increases the accuracy of our validation. Sample size is also adequate and sufficient to perform the type of study.

CONCLUSION

The findings of this study indicate the FFQ-HD has satisfactory validity and reproducibility for some energy, nutrients, and food groups, especially micronutrients and food groups of clinical importance for the NUGE-HD cohort study population. The food groups "sugars and confectionery," "nonalcoholic beverages and infusions," and "miscellaneous" should be interpreted with caution, and correction factors should be applied to these groups and other nutrients (vitamin C) in analyses using data from this instrument.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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