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Original Article

Design and Investigation of the Validity and Reliability of a Food Frequency Questionnaire for Hemodialysis Patients: A Cross-sectional Study

Hannane Jozi[1,2], **Aarefeh Jafarzadeh Kohneloo**[3], **Pardis Ghotaslou**[1], **Ali Tarighat-Esfanjani**[2*]

[1]Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran
[2]Nutrition Research Center, Department of Clinical Nutrition, School of Nutrition and Food Sciences, Tabriz University of Medical Sciences, Tabriz, Iran
[3]Department of Statistics and Epidemiology, Faculty of Health, Tabriz University of Medical Sciences, Tabriz, Iran

***Corresponding Author:** Ali Tarighat-Esfanjani, Email: tarighat45@gmail.com

Summary

Introduction: Chronic kidney disease patients undergoing hemodialysis are at high risk for malnutrition and electrolyte imbalances, making accurate dietary assessment essential. This study aimed to develop and validate a culturally-adapted food frequency questionnaire (FFQ) for Iranian hemodialysis patients, assessing its validity and reliability against food records and biochemical markers.

Methods: A cross-sectional study was conducted among 145 adult hemodialysis patients at Imam Reza Hospital, Tabriz. A 113-item was developed and validated through expert review and pilot testing. The FFQ was administered twice, three months apart, to assess test-retest reliability. Six-day food records and biochemical markers (blood urea nitrogen, creatinine, calcium, phosphorus, sodium, and potassium) served as reference standards. Validity was evaluated using Pearson correlations, tertile classification agreement, and comparison with biochemical data. Test-retest reliability was assessed using intraclass correlation coefficients.

Findings: The FFQ overestimated energy and most nutrient intakes compared to food records (mean energy: 2163 kcal vs. 2040 kcal). Validity correlations were highest for vegetable oil ($r = 0.99$) and polyunsaturated fat ($r = 0.96$), and lowest for nuts ($r = 0.382$) and folate ($r = 0.581$). Agreement in tertile classification was highest for vegetable oil (86.8%) and lowest for cholesterol and folate (22%). Significant positive correlations were observed between FFQ-derived protein intake and BUN/urea ($r = 0.224$, $P = 0.007$). Test-retest reliability was high, with no significant differences between FFQ administrations.

Conclusion: The developed FFQ is a valid and reliable tool for assessing dietary intake in Iranian hemodialysis patients and can improve dietary management in this population.

Keywords: Food frequency questionnaire, Hemodialysis, Dietary assessment, Validity, Iran

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Introduction

Chronic kidney disease (CKD), particularly its end stage (ESKD), presents a significant global health challenge, with hemodialysis serving as a primary life-sustaining intervention.[1] CKD affects 8–16% of adults worldwide, and as of 2010, over 2.62 million individuals required dialysis- a figure projected to double by 2030.[2,3] In Iran, the annual growth rate of hemodialysis utilization is 6%, with 48% of ESKD patients relying on this therapy, highlighting the urgent need for targeted interventions.[4] ESKD patients face a 10% higher mortality risk than the general population, largely due to malnutrition and electrolyte imbalances, such as hyperphosphatemia and hyperkalemia.[5] Effective nutrition management is essential, focusing on maintaining appropriate fluid, phosphorus, and potassium levels.[6,7] Additionally, lifestyle modifications, including adherence to healthy dietary patterns and regular physical activity, are crucial in mitigating risk factors for chronic conditions such as cardiovascular diseases and hypertension.[8,9]

Dietary assessment plays a pivotal role in managing these patients; however, existing tools are often inconsistent, especially in regions with unique nutritional practices, like Iran.[10] Methods such as 24-hour recalls, food records, and food frequency questionnaires (FFQ) are utilized in epidemiological studies to assess dietary intake, but evaluating long-term dietary patterns remains challenging FFQs are widely regarded as suitable for capturing habitual dietary intake in large-scale studies.[11]

Several countries have developed FFQs tailored to ESKD patients on hemodialysis, enabling the evaluation of their nutritional status.[12-15] While some valid FFQs exist for special populations in Iran, there is a notable gap in validated FFQs specifically designed for hemodialysis patients. The existing Iranian FFQs, such as those developed by Mirmiran et al and Malekshah et al, focus on a comprehensive nutrient profile for the general population or specific disease cohorts like esophageal cancer.[16,17] To clearly illustrate the unique contribution and tailored design of our tool, Table 1 provides a direct

Table 1. Comparison of the developed hemodialysis FFQ with previously validated Iranian FFQs

	Our FFQ	Previous FFQ$_1$	Previous FFQ$_2$
Population	Hemodialysis patients	General	General
Primary purpose	Assessing intake of dialysis-critical nutrients	General nutrient intake	Investigating dietary links to esophageal cancer
Number of items	113 Items	168 Items	48 Items
Nutrients included	Local foods, food groups, dialysis-critical nutrients	Macro, micro nutrients	Food groups, opium use, tea temperature
Validation methods	Six-day food record Biochemical markers Test-retest reliability	24-hour dietary recalls Biomarkers markers Test-retest reliability	24-hour dietary recalls Biomarkers markers Test-retest reliability

comparison of its key features against other prominent Iranian FFQs. Recognizing the increasing global burden of chronic diseases, public health strategies play a vital role in addressing this challenge.[18] This cross-sectional study aimed to develop and validate a hemodialysis-specific FFQ in Tabriz, Iran, comparing its data against 3-day food records and serum markers, including calcium, phosphorus, sodium, and potassium. By incorporating local food items and portion sizes, this study provides a regionally adapted model for hemodialysis nutritional assessments. The findings have the potential to improve dietary management for similar patient populations globally.

Methods

Study design and sample size

This cross-sectional study was conducted between June and August 2024 at Imam Reza Hospital, Tabriz, Iran-the largest hemodialysis center in northwestern Iran. The primary objective was to develop and validate an FFQ specifically tailored to hemodialysis patients, focusing on protein, calcium, phosphorus, sodium, and potassium intake. The sample size was determined based on a previous study reporting a correlation coefficient of 0.62 between FFQ and food records, with a type I error of 0.05 and 80% power.[15] Initial calculations indicated a required sample size of 120, which was increased to 145 to account for a 20% attrition rate. Random sampling and face-to-face interviews were used for recruitment.

Participants

Eligible participants were adults (≥18 years) with non-transplanted kidneys who had been undergoing hemodialysis for at least three months. Participants needed to be capable of completing the questionnaire independently or with minimal assistance and willing to provide informed consent. Exclusion criteria included illiteracy, cognitive or physical impairments (e.g., dementia, severe arthritis), and severe comorbidities (such as malignancies or psychiatric disorders) that could significantly affect dietary habits. Demographic data (age, sex, education, and marital status) and anthropometric measurements (weight, height, and BMI) were collected at baseline and after three months.

FFQ development and validation

A preliminary 168-item FFQ, previously validated for reliability, was refined to 113 items following expert review and pilot testing with 30 hemodialysis patients. This reduction aimed to minimize patient fatigue and enhance feasibility. The revised FFQ underwent content validation by a panel of eight nutrition experts. Test-retest reliability was assessed by administering the FFQ twice, three months apart. The FFQ captured data on average dietary consumption over the past 12 months. Participants were queried about any significant dietary changes during the study.

Six-day dietary records (including two dialysis days, two non-dialysis days, and two holidays) were collected weekly. Nutrient intake data from FFQs and dietary records were converted to grams/day using household measures and analyzed using Nutritionist IV software, supplemented with the Iranian Food Composition Table for traditional foods.[19] Caloric, macronutrient, and micronutrient intake (including sodium, potassium, calcium, phosphorus, magnesium, thiamin, riboflavin, and folate) was calculated.

Consumption of seasonal foods, such as fruits, was assessed based on their use during their respective seasons, with daily intake estimates adjusted accordingly. Biochemical parameters, including blood urea nitrogen (BUN), creatinine (Cr), calcium (Ca), phosphorus (P), sodium (Na), and potassium (K), were measured using venous blood samples collected post-dialysis. To ensure patient safety and reflect stable metabolic conditions, blood samples were routinely collected immediately after the hemodialysis session, following the standard clinical protocol of the dialysis unit.

Statistical analysis

The validity of the FFQ was assessed by comparing nutrient intake estimates against averages from six days of food records and relevant biochemical markers using Pearson correlation coefficients. Nutrient intakes were calibrated for energy intake using the residual method to account for variations in total energy consumption. To further evaluate the accuracy and consistency of the FFQ data, triangulated correlations among the FFQ, dietary records, and biochemical data were examined using a three-way correlation model. Additionally, test-retest reliability was determined through intraclass correlation coefficients (ICC) between two FFQ administrations. Normality of nutrient intake data was assessed using the Shapiro-Wilk test. Where necessary, non-parametric tests or log-transformations were applied to meet statistical assumptions. An independent sample t-test was conducted to compare mean nutrient intakes between the FFQs and food records, evaluating the level of agreement between the two methods.

The validity of the FFQ was determined by comparing its data with the average values from food records and biochemical markers using Pearson correlation coefficients.[20] Nutrient intakes were calibrated to account for variations in energy consumption using the residual method. To address daily fluctuations in dietary intake that can underestimate correlations between FFQ and food records, deattenuated correlation coefficients were calculated to adjust for within-person variations.[21] Participants were categorized into tertiles based on dietary intake, and the FFQ's accuracy in classifying individuals into these intake groups was assessed using food records as the reference. Agreement and disagreement percentages were reported to quantify classification accuracy. All statistical analysis were performed using SPSS version 27, with significance set at $P<0.05$.

Results

The average age of the 145 participants was 53.94 years (SD = 15.1), including 108 males and 37 females. Demographic and anthropometric characteristics are detailed in Table 2. Table 3 presents energy, nutrients, and food group intakes as assessed by both methods. Significant differences were found in the intake of dairy products, vegetables, fruits, energy, and most macronutrients, except cholesterol and saturated fat, potassium, calcium, phosphorus, thiamin, and folate. The mean energy intake recorded by the FFQ (2163 kcal) was higher than that from the food record (2040 kcal). The FFQ consistently provided higher estimated intakes of macronutrients, grains, legumes, dairy products, vegetables, and fruits.

Before energy adjustment, the highest correlation coefficient was for vegetable oil (0.99), while the lowest was for nuts (0.382). Polyunsaturated fat showed the highest correlation (0.96), whereas folate displayed the lowest (0.581) (Table 4). After energy adjustment, vegetable oil maintained the highest correlation (0.991), and nuts remained the lowest (0.391). Unsaturated fat continued to exhibit the highest correlation (0.969), while folate remained the lowest (0.594) (Table 5).

Table 6 presents the proportion of participants classified into the correct or adjacent categories, expressed as agreement percentages. The highest agreement between FFQ and food records was observed for Vegetable oil (86.8%) and energy (50.3%), while the lowest was for cholesterol and folate (22%) and fruits (34.4%). Table 7 shows the correlation between dietary data from FFQ_1 and biochemical markers, revealing significant positive correlations for protein intake with BUN and urea, while other nutrients showed weaker, non-significant relationships.

To evaluate reliability, Table 8 presents the estimated daily intake of various food groups and nutrients based on FFQ_1 and FFQ_2. No significant differences ($P > 0.05$) were observed between the two FFQs, indicating consistency. Table 9 shows the correlation coefficients for various dietary components between FFQs, before and after energy adjustment. Strong positive correlations were observed for most items, confirming reliability. Lower correlations for nuts and folate suggest areas with weaker agreement.

Table 2. Characteristic of participants

Characteristic	Mean	SD
Age (years)	53.94	15.1
BMI (kg/m^2)	24.84	4.91
	No.	**%**
Marital status		
Married	122	84.1
Single	15	10.3
Divorced	2	1.4
Widow	6	4.1
Sex		
Female	37	25.5
Male	108	74.5
Education level		
Under diploma	75	51.7
Diploma	33	22.8
Advanced Diploma	8	5.5
Bachelor	21	14.5
Master	7	4.8
Doctorate	1	0.7

Abbreviations: BMI, Body mass index; No, Number; SD, Standard deviation.
Note: Mean and Standard deviation are presented for age and BMI data. Numbers and percentages are presented for qualitative data.

Discussion

In this cross-sectional study, we developed and validated a culturally tailored, 113-item FFQ designed specifically for hemodialysis patients in Tabriz, Iran. The FFQ was evaluated it against six-day food records and relevant biochemical markers. As anticipated and consistent with prior FFQ validation studies, the FFQ overestimated intakes of energy, macronutrients, and several food groups compared to food records. For instance, the mean energy intake recorded as 2163 kcal (SD = 314) via the FFQ versus 2040 kcal (SD = 353) via food records. Significant differences were especially notable

Table 3. Estimated daily intake using FFQ and FR

	Method				*P* value
	FFQ		FR		
	Mean	SD	Mean	SD	
Grain (g)	512	101	509	99.4	0.292
Legumes (g)	15.9	10.9	14.9	10.3	0.069
Meat (g)	104	38.3	108	39.2	0.059
Dairy products (g)	124	80.9	100	82.3	<0.001
Vegetables (mg)	346	104	290	114	<0.001
Fruits (g)	252	98	195	107	<0.001
Nuts (g)	2.25	1.86	2.24	3.67	0.988
Vegetable oil (g)	14.2	11.1	14.3	10.9	0.656
Animal oil (g)	10.1	9.41	10.1	9.61	0.833
Energy (kcal)	2163	314	2040	353	<0.001
Carbohydrate (g)	344	58.1	321	66.6	<0.001
Protein (g)	66.1	12.3	64.2	12.9	<0.001
Fat (g)	61.7	14.5	58	14.2	<0.001
Cholesterol (mg)	234	87.4	249	101	0.004
Saturated fat (g)	19.3	5.48	18.7	5.43	0.005
Unsaturated fat (g)	19.3	6.61	18.4	6.65	<0.001
PUFA (g)	14.2	6.57	13.2	6.56	<0.001
Fibre (g)	17.77	3.47	15.32	4.22	<0.001
Sodium (mg)	2335	816	2265	848	0.01
Potassium (mg)	2687	730	2155	787	<0.001
Calcium (mg)	567	138	503	156	<0.001
Magnesium (mg)	1.18	0.464	1.11	0.735	0.15
Phosphorus (mg)	761	163	703	167	<0.001
Thiamine (mg)	1.97	0.348	1.9	0.359	<0.001
Riboflavin (mg)	1.25	0.348	1.22	0.488	0.199
Folate (mg)	231	56.4	191	62.9	<0.001

Abbreviations: FFQ, Food frequency questionnaire; FR, Food record; PUFA, Poly unsaturated fat; SD, Standard deviation.
Note: Data are presented as mean and Standard deviation. Independent samples T test was used for statistical analysis.

Table 4. Correlation coefficients between FFQs and FR

	FFQ_1/FR		FFQ_2/FR		FFQ_a/FR	
	P	r	*P*	r	*P*	r
Grain (g)	<0.001	0.9	<0.001	0.907	<0.001	0.91
Legumes (g)	<0.001	0.803	<0.001	0.801	<0.001	0.804
Meat (g)	<0.001	0.848	<0.001	0.837	<0.001	0.846
Dairy products (g)	<0.001	0.738	<0.001	0.698	<0.001	0.724
Vegetables (g)	<0.001	0.695	<0.001	0.671	<0.001	0.686
Fruits (g)	<0.001	0.649	<0.001	0.667	<0.001	0.665
Nuts (g)	<0.001	0.382	<0.001	0.399	<0.001	0.392
Vegetable oil (g)	<0.001	0.99	<0.001	0.99	<0.001	0.994
Animal oil (g)	<0.001	0.907	<0.001	0.941	<0.001	0.935
Energy (kcal)	<0.001	0.907	<0.001	0.905	<0.001	0.909
Carbohydrate (g)	<0.001	0.894	<0.001	0.9	<0.001	0.901
Protein (g)	<0.001	0.909	<0.001	0.898	<0.001	0.905
Fat (g)	<0.001	0.897	<0.001	0.897	<0.001	0.899
Cholesterol (mg)	<0.001	0.786	<0.001	0.795	<0.001	0.793
Saturated fat (g)	<0.001	0.887	<0.001	0.901	<0.001	0.903
Unsaturated fat (g)	<0.001	0.948	<0.001	0.943	<0.001	0.949
PUFA fat (g)	<0.001	0.96	<0.001	0.958	<0.001	0.96
Fibre (g)	<0.001	0.645	<0.001	0.665	<0.001	0.66
Sodium (mg)	<0.001	0.931	<0.001	0.912	<0.001	0.926
Potassium (mg)	<0.001	0.589	<0.001	0.616	<0.001	0.608
Calcium (mg)	<0.001	0.78	<0.001	0.762	<0.001	0.773
Magnesium (mg)	<0.001	0.667	<0.001	0.571	<0.001	0.627
Phosphorus (mg)	<0.001	0.809	<0.001	0.801	<0.001	0.807
Thiamine (mg)	<0.001	0.914	<0.001	0.915	<0.001	0.919
Riboflavin (mg)	<0.001	0.769	<0.001	0.719	<0.001	0.749
Folate (mg)	<0.001	0.581	<0.001	0.59	<0.001	0.589

Abbreviations**:** FFQ, Food frequency questionnaire; FR, Food record; PUFA, Poly unsaturated fat; SD, Standard deviation.
Note: Pearson correlation analysis was applied for statistical analysis.

for dairy products, vegetables, fruits, and key nutrients, highlighting a systematic bias common in self-reported dietary assessments.

Despite these discrepancies, the FFQ demonstrated robust validity. Pearson correlation coefficients ranged from 0.382 (nuts) to 0.99 (vegetable oil) before energy adjustment, and 0.391 (nuts) to 0.991 (vegetable oil) after adjustment- indicating strong ranking ability for most dietary components. Agreement between the FFQ and food records, assessed via tertile classification, varied, with the highest concordance for vegetable oil (86.8%) and energy (50.3%), and the lowest for cholesterol and folate (22%). These findings suggest the FFQ effectively captures habitual intake of frequently consumed items, while being less accurate for nutrients with irregular consumption patterns.

A notable finding was the significant positive correlation between FFQ-derived protein intake and biochemical markers such as BUN and urea ($r=0.224$, $P=0.007$), supporting the FFQ's utility in reflecting dietary protein metabolism in this clinical population. Test-retest reliability, assessed via ICC, showed no significant differences between the two FFQ administrations, confirming the instrument's consistency over time.

Our findings align closely with those of previous validation studies. Ahmed et al observed similar overestimation in a phosphorus-specific FFQ for Bangladeshi hemodialysis patients, with correlation coefficients ranging from 0.4 to 0.8.[13] Likewise, Wendling et al. validated an FFQ in Brazilian hemodialysis patients, reporting strong correlations for energy and macronutrients ($r=0.7–0.9$) but discrepancies in micronutrient estimates, similar to our findings for folate and cholesterol.[14] Interestingly, our exceptionally high correlation for vegetable oil ($r=0.991$) exceeds those reported elsewhere, likely reflecting its consistent and

Table 5. Correlation coefficients between FFQs and FR after energy adjustment

	FFQ_1/FR		FFQ_2/FR		FFQ_a/FR	
	P	**r**	***P***	**r**	***P***	**r**
Grain (g)	<0.001	0.828	<0.001	0.836	<0.001	0.837
Legumes (g)	<0.001	0.791	<0.001	0.794	<0.001	0.795
Meat (g)	<0.001	0.822	<0.001	0.817	<0.001	0.824
Dairy products (g)	<0.001	0.743	<0.001	0.698	<0.001	0.727
Vegetables (mg)	<0.001	0.713	<0.001	0.691	<0.001	0.707
Fruits (g)	<0.001	0.648	<0.001	0.662	<0.001	0.663
Nuts (g)	<0.001	0.381	<0.001	0.399	<0.001	0.391
Vegetable oil (g)	<0.001	0.987	<0.001	0.986	<0.001	0.991
Animal oil (g)	<0.001	0.903	<0.001	0.94	<0.001	0.933
Energy (kcal)	<0.001	0.758	<0.001	0.761	<0.001	0.764
Carbohydrate (g)	<0.001	0.911	<0.001	0.916	<0.001	0.916
Protein (g)	<0.001	0.885	<0.001	0.889	<0.001	0.891
Fat (g)	<0.001	0.765	<0.001	0.78	<0.001	0.776
Cholesterol (mg)	<0.001	0.873	<0.001	0.898	<0.001	0.895
Saturated fat (g)	<0.001	0.957	<0.001	0.955	<0.001	0.96
Unsaturated fat (g)	<0.001	0.969	<0.001	0.965	<0.001	0.969
PUFA fat (g)	<0.001	0.927	<0.001	0.906	<0.001	0.922
Fibre (g)	<0.001	0.587	<0.001	0.622	<0.001	0.613
Sodium (mg)	<0.001	0.591	<0.001	0.619	<0.001	0.611
Potassium (mg)	<0.001	0.725	<0.001	0.756	<0.001	0.742
Calcium (mg)	<0.001	0.739	<0.001	0.705	<0.001	0.727
Magnesium (mg)	<0.001	0.636	<0.001	0.543	<0.001	0.597
Phosphorus (mg)	<0.001	0.807	<0.001	0.811	<0.001	0.811
Thiamine (mg)	<0.001	0.838	<0.001	0.852	<0.001	0.849
Riboflavin (mg)	<0.001	0.706	<0.001	0.667	<0.001	0.692
Folate (mg)	<0.001	0.594	<0.001	0.61	<0.001	0.607

Abbreviations: FFQ, Food frequency questionnaire; FR, Food record; PUFA, Poly unsaturated fat; SD, Standard deviation.
Note: Pearson correlation analysis was applied for statistical analysis.

frequent use in Iranian cuisine.

Conversely, lower correlations for nuts (r = 0.391) and folate (r = 0.594) mirror challenges identified by Cade et al, who highlighted recall bias and variability in consumption as common limitations in FFQ validation studies.[20] The significant correlation between protein intake and BUN/urea parallels results from Beer et al, who documented biochemical validation of dietary protein intake with correlation coefficients ranging from 0.3 to 0.5.[15] However, our lower agreement percentages for cholesterol and folate (22%) differ from those reported by Mirmiran et al in a general Iranian population (40–60%), suggesting that hemodialysis-specific dietary restrictions and metabolic alterations may amplify these discrepancies.[16] These differences likely stem from the unique nutritional constraints, therapeutic regimens, and cultural dietary patterns inherent to the hemodialysis population.[22]

Table 6. Agreement and disagreement of FFQ and FR

	Agreement (%)	Disagreement (%)
Grain (g)	77.2	22.8
Legumes (g)	69.6	30.4
Meat (g)	68.2	31.8
Dairy products (g)	46.8	53.2
Vegetables (g)	36.5	63.5
Fruits (g)	34.4	65.6
Nuts (g)	36.5	63.5
Vegetable oil (g)	86.8	13.2
Animal oil (g)	77.9	22.1
Energy (kcal)	50.3	49.7
Carbohydrate (g)	23.4	76.6
Protein (g)	25.5	74.5
Fat (g)	35.1	64.9
Cholesterol (mg)	22	78
Saturated fat (g)	36.5	63.5
Unsaturated fat (g)	26.2	73.8
PUFA fat (g)	48.9	51.1
Fibre (g)	23.4	76.6
Sodium (mg)	26.8	73.2
Potassium (mg)	31.7	68.3
Calcium (mg)	37.9	62.1
Magnesium (mg)	31	69
Phosphorus (mg)	37.9	62.1
Thiamine (mg)	25.5	74.5
Riboflavin (mg)	31	69
Folate (mg)	22	78

Abbreviations: FFQ, Food frequency questionnaire; FR, Food record; PUFA, Poly unsaturated fat; SD, Standard deviation.
Note: Data are presented as percentages. Cohen's kappa was used for statistical analysis.

The observed overestimation of nutrient intakes relative to food records may be attributed to recall bias, a well-recognized issue in self-reported dietary assessments.[23] Hemodialysis patients, often motivated to report socially desirable behaviors, might overstate consumption of recommended foods such as fruits and vegetables, artificially inflating estimates. Additionally, the use of standardized portion sizes within the FFQ may inadequately capture individual variability, particularly in a population whose eating patterns are frequently disrupted by dialysis schedules, uremic symptoms, and dietary restrictions.[7] The strong correlations observed after adjusting for energy intake reflect the FFQ's reliable ranking ability, a crucial attribute in epidemiological research, given the modulatory effect of total energy intake on nutrient consumption.[24,25]

The biologically plausible association between dietary protein intake and BUN/urea levels is consistent with established metabolic pathways, as dietary protein directly contributes to urea production via amino

Table 7. Correlation between FFQ and biochemical data

FFQ1		BUN	Urea	Cr	Na	K	Ca	P
Protein (g)	*r*	0.224	0.224	0.172				
	P	0.007	0.007	0.38				
Sodium (mg)	*r*				-0.089			
	P				0.485			
Potassium (mg)	*r*					-0.083		
	P					0.325		
Calcium (mg)	*r*						0.139	
	P						0.096	
Phosphorus (mg)	*r*							0.086
	P							0.306

Abbreviations: FFQ, Food frequency questionnaire; BUN, Blood urea nitrogen; Cr, Creatinine; Na, Sodium Serum; K, Potassium Serum; Ca, Calcium Serum; P, Phosphorus Serum.
Note: Pearson correlation analysis was used for statistical analysis.

Table 8. Estimated daily intake using FFQs

	Method				
	FFQ_1		FFQ_2		*P* value
	Mean	SD	Mean	SD	
Grain (g)	513	102	512	102	0.854
Legumes (g)	15.8	10.84	15.98	11	0.375
Meat (g)	104	38.3	104	38.7	0.726
Dairy products (g)	125	82.6	123	80.3	0.273
Vegetables (mg)	346	106	347	103	0.662
Fruits (g)	254	101	250	96.7	0.108
Nuts (g)	2.25	1.85	2.24	1.88	0.696
Vegetable oil (g)	14.2	11.2	14.2	11.2	0.587
Animal oil (g)	10	9.44	10.1	9.6	0.832
Energy (kcal)	2165	315	2165	305	0.37
Carbohydrate (g)	344	58.4	346	58.1	0.294
Protein (g)	66.2	12.2	66.1	11.7	0.357
Fat (g)	61.7	14.5	61.1	13.6	0.49
Cholesterol (mg)	234	87.1	232	84.2	0.29
Saturated fat (g)	19.3	5.55	19.4	5.59	0.812
Unsaturated fat (g)	19.2	6.61	19.2	6.39	0.264
PUFA fat (g)	14.3	6.55	13.8	6.03	0.196
Fibre (g)	17.82	3.55	17.8	3.43	0.233
Sodium (mg)	2336	821	2295	813	0.918
Potassium (mg)	2699	740	2720	756	0.134
Calcium (mg)	567	140	567	139	0.611
Magnesium (mg)	1.18	0.47	1.18	0.44	0.717
Phosphorus (mg)	762	164	757	158	0.507
Thiamine (mg)	1.97	0.35	1.98	0.358	0.642
Riboflavin (mg)	1.25	0.349	1.24	0.323	0.549
Folate (mg)	231	57.1	232	54.6	0.181

Abbreviations: FFQ, Food frequency questionnaire; FR, Food record; PUFA, Poly unsaturated fat; SD, Standard deviation.
Note: Data are presented as mean and Standard deviation. Independent samples T test was applied for statistical analysis.

Table 9. Correlation coefficients between FFQs and FR

	FFQ_1/FFQ_2			
	Before Energy adjusted		Energy adjusted	
	P	r	*P*	r
Grain (g)	<0.001	0.9	<0.001	0.907
Legumes (g)	<0.001	0.803	<0.001	0.801
Meat (g)	<0.001	0.848	<0.001	0.837
Dairy products (g)	<0.001	0.738	<0.001	0.698
Vegetables (g)	<0.001	0.695	<0.001	0.671
Fruits (g)	<0.001	0.649	<0.001	0.667
Nuts (g)	<0.001	0.382	<0.001	0.399
Vegetable oil (g)	<0.001	0.99	<0.001	0.99
Animal oil (g)	<0.001	0.907	<0.001	0.941
Energy (kcal)	<0.001	0.907	<0.001	0.905
Carbohydrate (g)	<0.001	0.894	<0.001	0.9
Protein (g)	<0.001	0.909	<0.001	0.898
Fat (g)	<0.001	0.897	<0.001	0.897
Cholesterol (mg)	<0.001	0.786	<0.001	0.795
Saturated fat (g)	<0.001	0.887	<0.001	0.901
Unsaturated fat (g)	<0.001	0.948	<0.001	0.943
PUFA fat (g)	<0.001	0.96	<0.001	0.958
Fibre (g)	<0.001	0.645	<0.001	0.665
Sodium (mg)	<0.001	0.931	<0.001	0.912
Potassium (mg)	<0.001	0.589	<0.001	0.616
Calcium (mg)	<0.001	0.78	<0.001	0.762
Magnesium (mg)	<0.001	0.667	<0.001	0.571
Phosphorus (mg)	<0.001	0.809	<0.001	0.801
Thiamine (mg)	<0.001	0.914	<0.001	0.915
Riboflavin (mg)	<0.001	0.769	<0.001	0.719
Folate (mg)	<0.001	0.581	<0.001	0.59

Abbreviations: FFQ, Food frequency questionnaire; FR, Food record; PUFA, Poly unsaturated fat; SD, Standard deviation.
Note: Pearson correlation analysis was applied for statistical analysis.

acid catabolism, a process accentuated in patients with impaired renal clearance.[26] In contrast, weaker associations for other nutrients (e.g., sodium, potassium) likely reflect confounding influences from dialysis regimens, medication use (e.g., phosphate binders), and fluid shifts, which may obscure direct dietary-biochemical relationships.[27] The low agreement for cholesterol and folate intakes likely reflects irregular consumption patterns, and challenges in accurate recall or portion estimation limitations frequently reported in the dietary assessment literature.[20]

Compared to existing FFQs, this newly developed questionnaire offers several advantages. Its emphasis on dialysis-relevant nutrients, comprehensive structure, and cultural relevance enhances its utility for nutritional assessment in hemodialysis patients. Consequently, its application in clinical and research settings can support the development of more effective, culturally appropriate dietary interventions aimed at improving the nutritional status and clinical outcomes in this vulnerable population.[15,22]

A notable strength of our study is its rigorous methodological design. The use of a random sampling method enhances the representativeness of our findings within the context of our single center. Furthermore, we employed a comprehensive validation strategy rarely applied in previous hemodialysis FFQ studies, which triangulated data from detailed dietary records, relevant biochemical markers, and test-retest reliability. A key feature that strengthened the data collection process was the use of a single interviewer alongside photographic aids for portion size estimation, which improved consistency and accuracy. What fundamentally distinguishes this FFQ is its targeted emphasis on nutrients of critical importance for dialysis patients—namely sodium, potassium, calcium, phosphorus, and protein. By focusing on these key dietary components and integrating local eating habits and region-specific foods (such as *kashk*), the questionnaire directly addresses the nutritional factors most likely to influence patient outcomes, filling a significant gap in the Iranian context.

Nonetheless, several limitations should be acknowledged. The single-center recruitment may limit the generalizability of our findings to broader hemodialysis populations. The inherent reliance on self-reported dietary data introduces the potential for recall bias. Additionally, although the three-month interval between FFQ administrations aligns with standard practice for assessing reliability, it may not fully capture long-term dietary stability. Furthermore, dialysis-related factors, including treatment adequacy and the post-dialysis timing of biochemical measurements, could have attenuated associations between dietary intake and biochemical markers, particularly for electrolytes like potassium and sodium.

Future research should aim to validate this FFQ in multi-center cohorts and incorporate objective dietary assessment methods, such as doubly labeled water, to enhance accuracy and generalizability. Such efforts would further strengthen the evidence base for its application in both clinical and research settings.

Conclusion

This study established a validated and culturally adapted FFQ for hemodialysis patients in Iran, demonstrating its acceptable reliability and moderate-to-high validity for assessing dietary intake, particularly for energy, macronutrients, and protein-related biochemical biomarkers. While the FFQ exhibited robust reliability for most dietary components, further refinements are warranted to improve its accuracy in assessing sporadically consumed items. Future research should focus on enhancing the questionnaire's precision for nutrients with lower agreement levels, such as cholesterol and folate, and evaluating its applicability across more diverse hemodialysis populations. These efforts would pave the way for broader of this tool in both nutritional epidemiology and clinical dietary management for dialysis patients.

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Authors' Contribution

Conceptualization: Hannane Jozi, Ali Tarighat-Esfanjani.
Data curation: Hannane Jozi, Pardis Ghotaslou.
Formal analysis: Hannane Jozi, Aarefeh Jafarzadeh kohneloo.
Funding acquisition: Ali Tarighat-Esfanjani.
Investigation: Hannane Jozi, Pardis Ghotaslou.
Methodology: Hannane Jozi, Aarefeh Jafarzadeh kohneloo, Ali Tarighat-Esfanjani.
Project administration: Ali Tarighat-Esfanjani.
Resources: Ali Tarighat-Esfanjani.
Supervision: Aarefeh Jafarzadeh kohneloo, Ali Tarighat-Esfanjani.
Validation: Hannane Jozi.
Writing-original draft: Hannane Jozi, Ali Tarighat-Esfanjani.
Writing-review & editing: Hannane Jozi, Ali Tarighat-Esfanjani.

Competing Interests

The authors declare no conflicts of interest.

Ethical Approval

The study protocol was approved by the Ethics Committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1403.037). Written informed consent was obtained from all participants, who retained the right to withdraw from the study at any stage without any repercussions. All procedures adhered strictly to the principles outlined in the Declaration of Helsinki.

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Artificial Intelligence Use Disclosure

None.

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