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Sex-based variations in the nutritional and functional status of hemodialysis patients in Palestine: a cross-sectional study

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Abstract

Introduction Hemodialysis affects patients' nutritional status in several ways, resulting in malnutrition, which, in turn, increases the rates of morbidity and mortality worldwide. The main aim of this study was to comprehensively examine the effect of sex-based differences on the nutritional status of Palestinian patients on hemodialysis.

Methodology This study involved hemodialysis patients from An-Najah National University Hospital (NNUH) at Nablus/Palestine. A structured questionnaire was used in this study to collect data about sociodemographic data, medical history, lifestyle habits, and functional status, as well as nutritional status, which was assessed using 4 components (anthropometric measurements, biochemical data, clinical data, and dietary data). Patients' reports were reviewed to obtain laboratory values. The malnutrition-inflammation score was used to assess the prevalence of malnutrition. Data were analyzed using univariate and multivariate analysis.

Results A total of 188 hemodialysis patients participated in the study. The mean age was 57.8 ± 14.0 years, ranging from 19 to 86 years old. Females were more likely to experience nausea and headache during hemodialysis than men ($p < 0.05$). The findings also showed that the MIS score was significantly higher in women than in men. Biochemical findings revealed that female patients had significantly lower levels of blood urea nitrogen ($p = 0.003$), carbon dioxide ($p = 0.020$), ferritin levels ($p = 0.025$), and serum phosphate levels ($p = 0.000$). In addition, women had significantly lower intakes of total carbohydrate, total fat, saturated fat, monounsaturated fatty acids, water, vitamin B1, vitamin B2, vitamin B3, calcium, phosphate, sodium, and zinc, except for vitamin B12, which was higher in females. Furthermore, functional assessments indicated that males have significantly higher handgrip strength than females, while females represented more severe malnutrition compared to males.

Conclusion Our data indicates that women have more severe malnutrition compared to men, suggesting the need to consider sex-based nutritional and functional differences in hemodialysis patients by healthcare professionals.

Keywords Hemodialysis, Malnutrition, Sex-based differences, Functional status

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Background

End-stage renal disease (ESRD) is a global health burden [1], and is associated with many health complications, necessitating renal replacement therapy through either kidney transplantation or hemodialysis [2]. Hemodialysis is one of the most efficient therapies and accounts for 89% of the worldwide treatment for cases with ESRD [1]. It is mainly aimed at correcting disturbances in acid-base balance, electrolytes, and fluid status, as well as removing uremic toxins within a short period of time [3].

Hemodialysis alters metabolism, reduces appetite, and causes loss in soluble vitamins and protein, which in turn may affect nutritional status, resulting in protein-energy wasting and malnutrition [4]. Malnutrition is a widespread health issue among hemodialysis patients, which affects between 28% and 54% of them worldwide [5], and increases the likelihood of mortality from 1.61 to 4.08 [6].

Using the best available methods for assessing patients' nutritional status is an important step to provide them with an appropriate nutritional care plan [7]. In addition, the presence of renal dietitians in hemodialysis centers is crucial for aiding in early diagnosis of malnutrition and creating specific strategies to avoid further nutritional deterioration [8]. Therefore, the most precise way for assessing nutritional status is anthropometric measurements such as arm circumference, waist circumference, skinfold thickness, and body mass index (BMI). All of these measures exist in the malnutrition inflammation score (MIS) [9]. Besides that, MIS also includes total iron binding capacity (TIBC) and serum albumin level, which is one of the biochemical parameters that can be used for the diagnosis of malnutrition, and it is found to be a powerful predictor of mortality in epidemiological studies of patients undergoing hemodialysis [10, 11]. Numerous studies found that MIS is strongly correlated with mortality and morbidity in hemodialysis patients [11–13].

Patients undergoing hemodialysis are facing numerous challenges, including the need to follow the principles of a modified renal diet to reduce disease complications and improve their survival rate [14]. The National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines recommend hemodialysis patients consume adequate energy intake ranging from 30 to 35 kcal/kg/day with an aim to spare protein and protect the body's nutrient stores [15]. In addition, hemodialysis patients are recommended to increase protein intake to 1.2 g/kg/day, of which at least half is from animal-based protein [16], because of the catabolic state and protein losses that accompany hemodialysis [17].

In addition, special attention should be given to their electrolyte balance, and their intake of sodium, potassium, and phosphate should be restricted. Because renal failure can lead to oliguria, which, in turn, can result in sodium retention, hyperkalemia, and hyperphosphatemia. Hemodialysis patients should adjust their water and sodium intake to allow for a fluid gain of less than 4% of body weight, and this can be achieved by restricting fluid intake (as a rule, approximately 750 ml/day in addition to the amount of the urine output) and limiting sodium intake from 1500 to 2000 mg/day [18]. Moreover, to limit their consumption of potassium and phosphate, the guidelines recommend hemodialysis patients limit potassium intake to 3 to 4 g/day, which can differ among patients according to residual renal function, and restrict phosphorus intake to less than 1200 mg/day [18, 19]. However, nutritional intake and dietary pattern are potential determinants of health outcomes in hemodialysis patients [20]. Similarly, functional status is a significant predictor of the patient's overall well-being and is associated with adverse outcomes when impaired [21].

Chronic kidney disease (CKD) is one of many diseases that exhibit sex-based differences in many aspects. For instance, the prevalence of CKD in the United States is higher in females, while the incidence of ESRD is higher in males. Furthermore, women are known to commence maintenance hemodialysis later than men, and the mortality rate among them is higher [22]. However, the physiologic and hormonal differences between males and females could be impactful on dialysis treatment [23]. Nevertheless, there is a lack of universal application for sex-based differences regarding the cut-off values of markers of kidney dysfunction [22], which increases the need for addressing sex-specific differences.

Over the past few years, the Palestinian community saw an increase in the overall number of ESRD patients. In 2021, the total number of patients undergoing hemodialysis was 1611 in comparison to 1216 patients in 2017, indicating a notable increase in patients needing hemodialysis [24, 25]. Several studies have been conducted in Palestine on patients undergoing hemodialysis [13, 26–28]. Nonetheless, no previous study investigated comprehensively sex-based variation in terms of nutritional and functional status in the hemodialysis population. Therefore, the main purpose of this study is to define precisely sex-based differences regarding nutritional and functional status among a representative sample of hemodialysis patients at An-Najah National University Hospital in Palestine.

Methods

Study design and sample characteristics

This cross-sectional study was conducted on a representative sample of patients undergoing hemodialysis treatment at the hemodialysis unit at NNUH in Nablus City, Palestine. The research protocols were in accordance with the Declaration of Helsinki and reported in line with the STROBE checklist for reporting cross-sectional studies.

The study protocol was approved by the Institutional Review Board at An-Najah National University (Ref: Med Sep 2021/78). Permissions and approval to conduct the study were obtained from the Palestinian Ministry of Health and the An-Najah National University Hospital administration. The data collection started in November 2021-January 2022 by a team of three trained researchers who collected the data by face-to-face interview. The inclusion criteria were patients who were aged more than 18 years old, had been on maintenance hemodialysis for at least three months, and agreed to participate in the study. Patients with the following criteria were excluded: (1) patients with medical conditions that may affect their nutritional status (e.g., cancer patients who are currently undergoing chemotherapy or radiotherapy), (2) pregnant women, and (3) those who underwent a major surgery within the last six months.

Sample size calculation

The sample size was calculated by using OpenEpi software, according to the mean difference between two independent groups, an accepted margin of error of 5%, a confidence level of 95%, and a power of 80%. The Ramos et al. (2021) study was used to obtain information on the mean and standard deviation of total energy intake among hemodialysis patients; the expected difference between male and female was considered 3 kcal/kg/day. The required number of patients in each group was 60. With dropouts, the minimum number of patients in both groups is 140 patients (70 males and 70 females) [29].

Data collection and research tools

Data was collected through face-to-face interviews using a pre-tested questionnaire, which was divided into six sections: (1) Sociodemographic information including age, gender, area of living, monthly income, educational level, and working status; (2) medical history: presence of chronic health problems, undergoing a previous surgical operation, and regular use of medications; and (3) lifestyle habits & functional status, which included information about smoking, sleeping, and physical activity habits. Patients' functional status was assessed using two self-reported questions: Do you need support with daily activities? And do you need support to transfer? Moreover, the muscle strength was assessed using a handgrip test, which is a valid predictor of muscle status and function [30], (4) hemodialysis-related data, (5) hemodialysis side effects, and (6) nutritional status assessment. The hemodialysis-related section included hemodialysis-related data and hemodialysis side effects, while nutritional assessments were adapted from previous similar studies conducted in Palestine [27, 31, 32]. Hemodialysis patients were verbally instructed about the purpose of the study and the type of data that would be collected, with affirmation of their optional participation. Patients who agreed to sign the written informed consent form were included in the study.

Nutritional status assessment

Body weight status was assessed using anthropometric measurements (weight and height) following the standard methods reported by Lee and Nieman [33]. Patients were weighed pre-dialysis and post-dialysis. BMI was calculated as (body weight in kilograms divided by height squared in meters (kg/m^2), and then classified according to the World Health Organization (WHO) cut-off points [34]. Additionally, we obtained the following laboratory values from patients' records, including blood urea nitrogen, carbon dioxide, fasting blood glucose, ferritin, hemoglobin, parathyroid hormone, serum albumin, calcium, chloride, phosphate, potassium, sodium, total iron binding capacity, and transferrin.

We assessed malnutrition using the MIS tool, which consists of 10 items distributed across four sections. Five items were adopted from subjective global assessment; two items were for physical examination, one item was for BMI, and the remaining two items were for biochemical parameters. Each item could be graded from 0 (normal) to 3 (severely abnormal), and then all the grades of all four sections are summed. In the end, the cumulative grade ranges from 0 to 30, with higher scores indicating a more severe degree of malnutrition and inflammation [11].

Dietary data

Hemodialysis patients were asked to document their diet on two consecutive days (hemodialysis day and non-hemodialysis day) and one weekend day using 3-day food records (3-DFR). They were given instructions on how to complete the 3-DFR. Then, they were asked to estimate and document the details of all main meals and snacks they consumed, including the methods used in cooking, the amount of food eaten, the ingredients, added toppings (such as herbs, jam dressings, jam, spices, etc.), and drinks.

Nutrient analysis

All foods recorded in 24 h were reviewed by a trained researcher. Thereafter, the mean nutrient intake for each patient was calculated. The Palestinian food composition database (Al-Quds Nutrition System, Palnut, Palestine Food Composition Database) was used to analyze the diet in terms of energy, macronutrients, and micronutrients [35].

Statistical analysis

The data analysis was done using the statistical package for the social sciences, SPSS version 21. Continuous

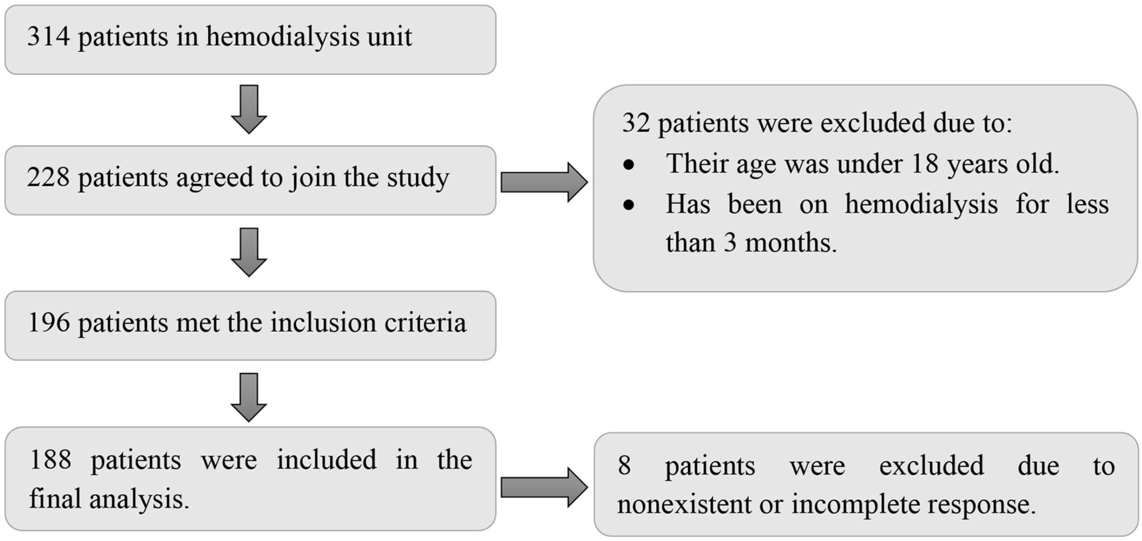

Fig. 1 Patients' recruitment steps

Table 1 Sex-based demographic characteristics presented in numbers (n) and percentages (%)

Variables		Males (*n* = 117)		Females (*n* = 71)		Total (*n* = 188)	
		n	%	n	%	n	%
Marital status	Married	100	85.5	35	49.3	135	71.8
	Single	17	14.5	36	50.7	53	28.2
Educational level	Primary education	44	37.6	47	66.2	91	48.4
	Secondary education	48	41.0	15	21.1	63	33.5
	Diploma	8	6.8	3	4.2	11	5.9
	Bachelor's degree or above	17	14.5	6	8.5	23	12.2
Place of residence	City	56	47.9	29	40.8	85	45.2
	Camp/village	61	52.1	42	59.2	103	54.8
Employment status	Employed	33	28.2	4	5.6	37	19.7
	Unemployed	84	71.8	67	94.4	151	80.3
Monthly income	< 1500 NIS	47	40.2	38	53.5	85	45.2
	1500–3000 NIS	48	41.0	20	28.2	68	36.2
	> 3000 NIS	22	18.8	13	18.3	35	18.6

NIS: New Israeli Shekel

variables were assessed for normality of distribution graphically and via the Shapiro-Wilk test. Descriptive analysis, including the means and standard deviation, was used to analyze continuous variables, while categorical variables were described in percentages and frequencies. The Mann-Whitney test was used to investigate the relationship between continuous variables and gender. On the other hand, the Chi-Square test was used for analyzing the association between gender and categorical data. The significance level was set at $p < 0.05$. Further analysis was performed using a binary logistic regression model, and the Hosmer-Lemeshow goodness-of-fit test was employed to assess how well the model fits the data.

Results

Patients' recruitment

Patients were recruited from the hemodialysis unit at NNUH. A total of 314 patients were invited to participate in the study, of whom 196 patients met the inclusion criteria and signed a written consent to join the study. Only 188 participants were included in the final analysis. The rest of the participants were excluded mainly due to nonexistent or incomplete responses, as shown in Fig. 1.

Patients' demographic characteristics

A total of 188 hemodialysis patients aged 19–86 years (57.8 ± 14.0) were analyzed (Table 1). The majority of participants were males (62.2%), married (71.8%), and unemployed (80.3%). About half of the studied patients received a primary education (48.4%), 45.2% were living

Table 2 Sex-based medical history presented in numbers (n) and percentages (%)

Variables	Total ($n=188$)	Males ($n=117$)	Females ($n=71$)	*P*-value
Chronic diseases				
Hypertension [yes n (%)]	155 (82.4)	98 (83.8)	57 (80.3)	0.543
Cardiovascular disease [yes n (%)]	87 (46.3)	58 (49.6)	29 (40.8)	0.245
Diabetes mellitus [yes n (%)]	103(54.8)	63 (53.8)	40 (56.3)	0.739
Cancer [yes n (%)]	4 (2.1)	4 (3.4)	0 (0.0)	0.115
Cerebrovascular disease [yes n (%)]	4 (2.1)	2 (1.7)	2 (2.8)	0.610
Dietary supplements use				
Vitamin D supplements [yes n (%)]	176 (93.6)	106 (90.6)	70 (98.6)	0.030*
Calcium supplements [yes n (%)]	160 (85.1)	97 (82.9)	63 (88.7)	0.277
Iron supplements [yes n (%)]	170 (90.4)	104 (88.9)	66 (93)	0.358
Medications				
Phosphate binders [yes n (%)]	48 (25.5)	31 (26.5)	17 (23.9)	0.697

*Significant at $P<0.05$ using Pearson Chi-square test

Table 3 Sex-based lifestyle and functional status characteristics

Variables		Total ($n=188$)	Males ($n=117$)	Females ($n=71$)	*P*-value
Lifestyle habits					
Smoking	Regular smoker [n (%)]	61 (32.4)	49 (41.9)	12 (16.9)	0.000*
	Former smoker [n (%)]	51 (27.1)	38 (32.5)	13 (18.3)	
	Non-smoker [n (%)]	76 (40.4)	30 (25.6)	46 (64.8)	
Exercise	Yes [n (%)]	11 (5.9)	6 (5.1)	5 (7.0)	0.404
Walking	Yes [n (%)]	74 (39.4)	55 (47.0)	19 (26.8)	0.004*
Walking duration [minutes/day; median, range]		28 (0-120)	35 (0-120)	24 (0–60)	0.009*
Sleeping duration [hours/day; median, range]		7 (4–16)	6 (6–16)	8 (4–12)	0.219
Functional status					
Ability to transfer	Yes [n (%)]	69 (36.7)	32 (27.4)	37 (52.1)	0.001*
Ability to do daily activities	Yes [n (%)]	49 (26.1)	19 (16.2)	30 (42.3)	0.000*
Handgrip strength [kg; median, range]		7.5(0-100)	25 (0-100)	5 (0–40)	0.000*

Data are presented as *n* (%) or mean ± SD; SD: standard deviation. * $p<0.05$. Pearson Chi-square test is employed for categorical variables and Mann-Whitney test for continuous variables

in the city, and 45.2% had a monthly income of less than 1500 NIS.

Patients' medical history, lifestyle habits, and functional status

The majority of the patients (82.4%) had hypertension, followed by diabetes mellitus (54.8%). While 2.1% of hemodialysis patients reported that they had cancer and cerebrovascular disease, as demonstrated in Table 2. It was also noticed that most of the current patients were taking vitamin D supplements (are these the 1 alpha D3), iron supplements, calcium supplements, and phosphate binders: 93.6%, 90.4%, 85.1%, and 25.5%, respectively. There were no significant statistical differences between male and female groups in terms of medical history except for taking vitamin D supplements, which was significantly more common among females receiving hemodialysis therapy in comparison to their counterparts, as shown in Table 2.

Regarding lifestyle habits, 32.4% of participants were regular smokers, and 27.1% were former smokers. Moreover, seventy-four of the patients (39.4%) stated that they were walking for an average of 24.7 ± 42.3 min per day. Only eleven of the hemodialysis patients (5.9%) reported that they were exercising on a daily basis. The analysis also revealed that the average sleeping time of patients was 7.6 ± 2.2 h per day. Males and females showed a statistically significant difference from each other in terms of smoking, walking, and walking duration ($p<0.05$) (Table 3).

Table 3 also shows that hemodialysis patients were able to transfer and do daily activities by 36.7% and 26.1%, respectively. Moreover, 65.6% of study patients had muscle weakness. In addition, there were statistically significant differences between sexes in terms of functional status ($p<0.05$).

Table 4 Sex-based Hemodialysis-related data

Variables		Total (*n* = 188)	Males (*n* = 117)	Females (*n* = 71)	*P*-value
Duration of hemodialysis [months; median, range]		42 (6-168)	41 (6-168)	44 (6-156)	0.720
Duration of hemodialysis sessions [minutes; median, range]		180 (120–240)	180 (120–240)	180 (120–240)	0.769
Dialysis access	Arteriovenous fistula [n (%)]	163 (86.7)	103 (88.0)	60 (84.5)	0.316
	Hemodialysis catheter [n (%)]	25 (13.3)	14 (12.0)	11 (15.5)	
Nutrition consultation	Yes [n (%)]	67 (35.6)	45 (38.5)	22 (31.0)	0.190
Source of nutrition information	Health team professionals [n (%)]	107 (56.9)	63 (53.8)	44 (62.0)	0.174
	Other sources [n (%)]	81 (43.1)	54 (46.2)	27 (38.0)	

Data are presented as *n* (%) or mean ± SD; SD: standard deviation. Pearson Chi-square test is employed for categorical variables and Mann-Whitney test for continuous variables

Table 5 Hemodialysis side effects according to patients' sex

Variables		Total (*n* = 188)	Males (*n* = 117)	Females (*n* = 71)	*P*-value
Side effects during hemodialysis session					
Hypotension	Yes [n (%)]	140 (74.5)	82 (70.1)	58 (81.7)	0.054
Nausea	Yes [n (%)]	72 (38.3)	36 (30.8)	36 (50.7)	0.005*
Vomiting	Yes [n (%)]	56 (29.8)	27 (23.1)	29 (40.8)	0.008
Muscle cramp	Yes [n (%)]	127 (67.6)	79 (67.5)	48 (67.6)	0.561
Side effects during hemodialysis period					
Headache	Yes [n (%)]	59 (31.4)	29 (24.8)	30 (42.3)	0.010*
Itching	Yes [n (%)]	103 (54.8)	69 (59.0)	34 (47.9)	0.092
Fluid overload	Yes [n (%)]	82 (43.6)	50 (42.7)	32 (45.1)	0.435

Data are presented as *n* (%). * $p < 0.05$ using Pearson chi-square test

Hemodialysis-related data

The analysis of hemodialysis-related data revealed that the mean months on hemodialysis was 47.1 ± 35.9 months, and the mean duration of hemodialysis sessions was 195.6 ± 20.2 min/session. The arteriovenous fistula was used as dialysis access by the majority of the current patients (86.7%). There are no statistically significant differences between males and females, as shown in Table 4.

Sixty-seven patients (35.6%) received nutrition consultations related to the hemodialysis diet. The findings also showed that a little more than half of the patients (56.9%) get the nutrition information from health team professionals (e.g., doctors, nurses, dietitians), while the rest of the patients reported that they get the information from other sources (e.g., social media, friends). Sex was not associated with nutritional consultation.

Hemodialysis side effects

Table 5 shows that the most noticed side effect during the hemodialysis session was hypotension, at 74.5%, followed by muscle cramps, at 67.6%, while the least common side effect during the session was vomiting, at 29.8%. In addition, a little more than half of hemodialysis patients (54.8%) reported that they experienced itching during the entire hemodialysis period. The analysis also revealed nausea and headache were significantly more common side effects among hemodialysis females compared to their counterparts ($p < 0.05$).

Nutritional status assessment

The analysis revealed that 35.6% of hemodialysis patients had normal weight, 30.9% were overweight, and 2.1% of the study hemodialysis patients were obese. Moreover, body weight status was not significantly correlated with patients' sex ($p > 0.05$). The mean of patients' laboratory values within the last four months are presented in Table 6. The results also show that the mean BUN level, carbon dioxide level, and serum phosphate level were significantly lower among females receiving hemodialysis therapy compared to their counterparts, as indicated by $p < 0.05$ (Table 6).

Clinical data

The mean MIS score was 5.95 ± 3.16, ranging from 0 to 17 points. The findings also showed that the MIS score was 1.35 points significantly higher in women than in men (6.79 ± 3.04 vs. 5.44 ± 3.13, $p = 0.001$, effect size=-0.434, 95% CI: -0.732– -0.135), which means more severity of malnutrition.

Dietary data

The mean values of patients' dietary intake according to their sex are presented in Table 7. The findings also indicate that hemodialysis males had significantly higher intakes of carbohydrates, fat, saturated fat, monounsaturated fatty acids (MUFAs), water, vitamin B1, vitamin B2, vitamin B3, calcium, phosphate, sodium, and zinc compared to their counterparts. On the other hand, hemodialysis females had significantly higher intakes of vitamin B12 compared to hemodialysis males.

Binary logistic regression analysis

The binary logistic model included all the significant variables found in the univariate analysis (intake of vitamin D supplements, smoking, walking, ability to transfer, ability to do daily activity, handgrip strength, malnutrition,

Table 6 Laboratory values according to patients' sex

Variables	Total ($n=188$)	Males ($n=117$)	Females ($n=71$)	*P*-value
Using Mann-Whitney test (Median (range))				
BUN [a] [mg/dl]	55.05 (88.6–27.4)	57.7 (88.6–31.3)	51.7 (75.6–27.4)	0.003*
FBG [b] [mg/dl]	135 (401 – 62.8)	133 (368 – 70)	136 (401 – 62.8)	0.563
Ferritin [ng/dl]	724.5 (2164.5-3.0)	651 (2164 – 95.8)	795 (1904-3.0)	0.025*
PTH [c] [pg/ml]	318.05 (3208 – 9.5)	343.8 (3208 – 9.5)	281 (2320 – 37.9)	0.196
Serum albumin [g/dl]	3.88 (4.4–2.7)	3.92 (4.4–2.7)	3.84 (4.3–3.2)	0.175
Serum calcium [mg/dl]	8.84 (10.5–6.5)	8.81 (10.5–6.7)	8.9 (10.5–6.5)	0.631
Serum phosphate [mg/dl]	5.03 (10 – 2.3)	5.29 (10 – 2.9)	4.39 (6.5–2.3)	0.000*
TIBC [d] [mcg/dl]	203.3 (351.4-128.5)	203.6 (300-128.5)	201.4 (351 – 138)	0.063
Transferrin [mg/dl]	31.2 (86.2–16.6)	31.7 (84.2–16.6)	31 (86.2–16.9)	0.962
Using independent t-test (mean ± SD)				
Carbon dioxide [mEq/L]	22.9 ± 3.5	23.4 ± 3.5	22.1 ± 3.3	0.020*
Hemoglobin [g/dl]	11.6 ± 1.3	11.6 ± 1.4	11.5 ± 1.1	0.595
Serum chloride [mEq/L]	97.5 ± 3.2	97.4 ± 3.2	97.6 ± 3.2	0.713
Serum potassium [mEq/L]	4.9 ± 0.6	4.8 ± 0.6	4.9 ± 0.6	0.456
Serum sodium [mEq/L]	137.6 ± 2.6	137.8 ± 2.6	137.2 ± 2.7	0.099

[a] Blood urea nitrogen; [b] Fasting blood glucose; [c] Parathyroid hormone; [d] Total iron binding capacity; SD: standard deviation, *significant at $p < 0.05$

Table 7 Sex-based dietary intake of study participants

Nutrients	Total ($n=188$)	Males ($n=117$)	Females ($n=71$)	*P*-value
Energy and macronutrients (median, range)				
Calories [kcal/kg]	22.9 (56.4–7.04)	23.7 (46.8–7.04)	22.3 (56.4–9.55)	0.585
Protein [g/kg]	0.79 (2.5 – 0.18)	0.8 (1.68 – 0.18)	0.77 (2.5 – 0.35)	0.463
Carbohydrate [g/d]	232 (478 – 85)	248.5 (478 – 85)	211 (387 – 95)	0.003*
Fat [g/d]	59.1 (148 – 13)	62.1 (148 – 13.3)	51.6 (92.6–23)	0.001*
Saturated fat [g/d]	15.6 (43.7–1.7)	16.8 (43.7–1.7)	13.4 (24.3–5.5)	0.007*
MUFAs [a] [g/d]	22.8 (60.6–6.93)	24 (60.6–6.9)	21 (45.8–7.1)	0.011*
PUFAs [b] [g/d]	10.5 (31.2-1)	11.3 (31.2-1)	9.67 (23.6–2.4)	0.071
Cholesterol [mg/d]	168.3 (121-0.0)	180.6 (1212-0.0)	159 (550 – 44.8)	0.443
Water [ml/d]	59.5 (562 – 23)	64.9 (562 – 26.4)	52.4 (441 – 23)	0.000*
Vitamins (mean ± SD/ median, range)				
Vitamin A [mcg/d]	440.5 ± 833.8	407.3 ± 574	495.4 ± 1142.5	0.878
Vitamin B1 [mg/d]	0.57 (2.4-0.21)	0.61 (2.42 – 0.21)	0.53 (0.95 – 0.22)	0.010*
Vitamin B2 [mg/d]	0.8 (12.2–0.24)	0.88 (12.2–0.24)	0.75 (3.7 – 0.31)	0.024*
Vitamin B3 [mg/d]	8.7 (32.8–1.44)	9.5 (32.8–1.44)	7.6 (22.4–2.3)	0.013*
Folate [mcg/d]	216 (787 – 34.8)	227.9 (553 – 34)	200 (787 – 69)	0.064
Vitamin B12 [mcg/d]	1.5 (68.5-0.0)	1.84 (36.9-0.0)	1.3 (68-0.25)	0.021*
Vitamin C [mg/d]	76.2 (400 – 3.7)	78.4 (400.1–3.7)	74.3 (233 – 10.6)	0.308
Vitamin D [IU/d]	39.2 (145-0.0)	38 (131-0.0)	41.3(145 – 2.55)	0.543
Vitamin E [IU/d]	2.26 (8.65-0.0)	2.27 (8.65-0.0)	2.23 (7.22-0.0)	0.381
Vitamin K1 [mcg/d]	102 (780 – 2.4)	110.5 (780 – 2.49)	102 (328 – 3.6)	0.394
Minerals and trace minerals (median, range)				
Calcium [mg/d]	479.8 (1503 – 155.9)	522.3 (1503 – 163)	424.9 (1029 – 155)	0.007*
Phosphate [mg/d]	727.6 (1802 – 161)	754.5 (1802 – 161)	652.2 (1118 – 355)	0.006*
Potassium [mg/d]	1567 (8287 – 370)	1475 (8287 – 370)	1644 (4460 – 597)	0.107
Sodium [mg/d]	2591 (5416 – 672)	2702 (5416 – 672)	2448 (4195 – 959)	0.029*
Iron [mg/d]	11.5 (39-1.95)	11.7 (39-1.95)	10.9 (29.5–3.2)	0.129
Selenium [mcg/d]	31.4 (90.6–1.3)	34 (90.6–1.3)	29.3 (72.6–5.5)	0.083
Zinc [mg/d]	6.8 (16.6–1.3)	7.51 (16.6–1.39)	6.24 (11.7-3)	0.004*

[a] Monounsaturated fatty acid; [b] Polyunsaturated fatty acids; *significant at $P < 0.05$ using Mann-Whitney test

Table 8 Logistic regression analysis of sex-based related factors in Hemodialysis patients

Factors (reference)	B	*P*-value	Exp (B)[a]	Confidence Interval	Exp (B)[a]	*P*-value of model
On Vitamin D supplement	-2.371	0.065	0.093	0.008–1.158	0.630	0.003*
Smoking (non- and ex-smokers)	0.944	0.004*	2.570	1.363–4.846		
Walking	-0.162	0.807	0.850	0.233–3.110		
Ability to transfer	0.926	0.226	2.524	0.564–11.304		
Ability to do daily activity	-0.690	0.328	0.501	0.126–1.998		
Handgrip strength	-0.113	< 0.001**	0.893	0.848–0.941		
Malnutrition (MIS)	0.407	0.408	1.503	0.450–5.021		
BUN level	0.032	0.303	1.033	0.971–1.098		
CO_2 level	-0.137	0.134	0.872	0.728–1.043		
Ferritin level	0.000	0.747	1.000	0.998–1.001		
Phosphate level (continuous)	-0.786	0.009*	0.456	0.252–0.824		
Carbohydrate intake	-0.001	0.906	1.001	0.986–1.016		
Fat intake	-0.003	0.962	0.997	0.889–1.118		
Saturated fat intake	-0.002	0.986	0.998	0.789–1.263		
MUFAs intake	-0.057	0.456	0.945	0.815–1.096		
Water	0.012	0.136	1.012	0.996–1.028		
Vitamin B1 intake	3.131	0.254	22.898	0.106–4934.5		
Vitamin B2 intake	-1.420	0.084	0.242	0.048–1.208		
Vitamin B3 intake	-0.063	0.555	0.939	0.762–1.157		
Vitamin B12 intake	0.071	0.191	1.074	0.965–1.195		
Calcium intake	-0.004	0.054	0.996	0.992-1.000		
Phosphate intake	0.005	0.071	1.005	1.000-1.010		
Sodium intake	0.000	0.400	1.000	0.999–1.002		
Zinc intake	-0.345	0.071	0.708	0.487–1.030		
Nausea	-0.777	0.162	0.460	0.155–1.367		
Headache	-1.338	0.034*	0.262	0.076–0.907		

*: $p < 0.05$, **: $p < 0.001$ using binary logistic regression. [a]: Exponentiation of the B coefficient

levels of BUN, CO_2, ferritin, and phosphate, intake of carbohydrate, fat, saturated fat, MUFAs, water, vitamin B1, B2, B3, and B12, calcium, phosphate, sodium, and zinc). The Hosmer-Lemeshow test for the final model showed that goodness of fit of the model was acceptable ($p = 0.759$); Cox & Snell R square was 0.488; and Nagelkerke R square was 0.662. According to this model, smoking, handgrip strength, serum phosphate level, and nausea are significantly associated with hemodialysis patients according to their sex ($p < 0.05$), as shown in Table 8.

Discussion

Malnutrition is a prevalent problem among hemodialysis patients and is highly correlated with the risk of morbidity and mortality in affected patients [6]. In Palestine, the nutritional status of hemodialysis patients is probably neglected since hemodialysis centers suffer from a shortage of healthcare staff due to the economic crisis [36]. In this study, we investigated sex-based effects on nutritional status in a group of hemodialysis patients in Palestine. In this regard, the nutritional status of patients was more objectively and closely assessed using not only biochemical data but also dietary intake and malnutrition scoring tool (MIS).

In the present study, no sex-based variation was found regarding sociodemographic factors. However, lifestyle characteristics varied between males and females undergoing hemodialysis, including smoking, walking, and waking duration, whereas the multivariate analysis identified smoking as a significant predictor associated with sex, with higher prevalence observed among male patients. Our findings regarding smoking agree with a previous study that showed that smoking prevalence differed by sex in hemodialysis patients and may have an effect on outcomes, whereas men have a significantly higher prevalence of smoking [37]. Regarding walking, a recent multicenter study revealed that males represent a higher walkable area than females, but not at a significant level [38]. In another study evaluating the quality of life of patients undergoing hemodialysis, male sex is highlighted as a predictor of better physical health [39].

In the present study, women were more likely to have severe malnutrition compared to men, and the association between patients' gender and the was significant ($p = 0.001$). Similarly, a Korean study showed that malnutrition was significantly more common in women compared to men [40]. In another Iranian study, all women undergoing hemodialysis had severe malnutrition, and the study found a significant association between nutritional status and patient's gender ($p = 0.03$) [41].

In the current group of hemodialysis patients, we found statistically significant sex-based variation regarding their hemodialysis side effects, including headache and nausea, which were more frequent among females compared to males. In addition, headache was also confirmed as an independent predictor associated with sex, according to the multivariate analysis after controlling confounding variables, suggesting that women are more susceptible to certain hemodialysis-related symptoms. Similarly, a former Palestinian study conducted by Badrasawi et al. found that women undergoing hemodialysis were more likely to experience headaches during hemodialysis treatment [27]. Furthermore, a recent study revealed that women generally had a higher burden of symptoms that were of greater severity compared to men [42].

Regarding biochemical data, the current findings showed that female patients had significantly lower serum blood urea nitrogen, carbon dioxide, ferritin, and serum phosphate levels compared to males. This finding is consistent with a former study by Carrero et al., which indicated that hemodialysis women had significantly lower blood urea nitrogen levels compared to hemodialysis men [43]. Sex-related differences for protein synthesis can partially explain sex differences in BUN levels [44]. However, low levels of total CO_2 might result from metabolic acidosis [45], which was found to be more common in females compared to males, each of which might explain our findings regarding low CO_2 levels in females [22]. However, much less is known about variation in CO_2 level according to sex, requiring more comprehensive investigations. In line with our findings as well, ferritin levels were found to be significantly lower among women on hemodialysis compared with men, which may be linked to sex-specific differences in regulation of iron status by hormones such as estrogens and testosterone or altered immune regulation and inflammatory profiles between men and women based on genetic and hormonal factors [46]. The findings about phosphate levels in the current study were in contrast with previous findings in which either no sex-based differences were observed in phosphate levels [47], or women undergoing hemodialysis had higher phosphate levels [22]. Our findings could be explained by the hormonal role in menopausal women that can influence phosphate regulation since the mean age of women participating in this study is about 60 years old [48]. However, lower phosphate levels in women were also confirmed as an independent predictor in the multivariate analysis in the current study, suggesting that this relationship is not a byproduct related to other biochemical or dietary differences.

In addition, the current study showed no significant association between BMI and patients' sex. This is parallel to findings from former studies [43, 49], but in contrast with Hecking et al., who showed that hemodialysis women patients had significantly higher BMI compared to men [37].

As expected, the findings of this study denoted that there is a statistically significant relationship between sex and handgrip strength among the studied patients, which is identified as an independent predictor according to the multivariate regression analysis, suggesting that male patients had significantly higher handgrip strength compared to women, which is in agreement with a former study [40]. This can be explained by the fact that men have greater muscle mass than women, while women have greater body fat mass than men.

Moreover, we found that women on hemodialysis had significantly lower intakes of carbohydrates, fat, saturated fat, monounsaturated fat, water, vitamin B1, vitamin B2, vitamin B3, calcium, phosphate, sodium, and zinc compared to men. Whereas vitamin B12 intake was significantly higher in women compared to men. These differences might be attributed to several factors. First, women generally have lower energy requirements than men due to variations in body composition and size [50]. In addition, dietary restrictions among hemodialysis patients imply poor dietary intake, causing deficiency in the intake of macro- and micronutrients, including trace elements and some vitamins [51]. Consequently, women are thought to be representing higher adherence to dietary restriction in our study. In a former study, protein and energy intake was significantly higher in hemodialysis men compared to women [40]. To our knowledge there is no other study showing the effect of gender on dietary intake of vitamins and minerals in hemodialysis patients. Therefore, more studies are needed to identify the variations in the dietary intakes between women and men undergoing hemodialysis. In the same context, it is worth noting that only one-third of study participants receive dietary consultation, which raises concerns about adherence to dietary restrictions and lack of awareness about the importance of dietary interventions among patients participating in the current study. However, a previous study revealed that the dietary intake of patients on hemodialysis is usually inconsistent with guideline recommendations [52].

Importantly, the multivariate regression analysis identified smoking, handgrip strength, serum phosphate levels, and headaches as significant predictors independently associated with the sex of hemodialysis patients, which confirms the findings of the univariate analysis and necessitates the need to consider the burden of sex-based difference in terms of functional status and hemodialysis-related symptoms as well as dietary and biochemical indicators among hemodialysis patients.

The findings of the current study should be mentioned in the framework of certain limitations. First, the study is cross-sectional, so it does not support causal inferences. Second, the study included hemodialysis patients from one center, possibly making the findings not representative of all hemodialysis patients in Palestine. In addition, some of the collected data was self-reported, which makes it prone to recall and reporting bias, including the 3-DFR. Moreover, insufficient data on dialysis adequacy limit the capacity to assess its link to nutritional and functional status according to sex. Regardless of these limitations, this study presents comprehensive data collection, uses detailed diet assessment of patients' dietary intake using 3-DFR, and is the first of its kind in providing worthy data about the influence of sex differences on the nutritional status of hemodialysis patients.

Conclusion

This study provides valuable insight into gender variation in nutritional and functional status among hemodialysis patients in Palestine. Our findings revealed several sex-based differences, some of which may be correlated with physiological, hormonal, physical performance, and dietary intake pattern variations. These findings highlight the need for targeted intervention to optimize dietary intake, personalized nutritional counseling, addressing malnutrition, and improving nutritional and functional status, which are crucial to improving patients' outcomes. Further research is needed using objective assessments of nutritional and functional status for further elucidation to identify sex-specific variation among hemodialysis patients.

Abbreviations

NNUH	An-Najah National University Hospital
BMI	body mass index
BUN	Blood urea nitrogen
CKD	Chronic kidney disease
ESRD	End-stage renal disease
KDOQI	National Kidney Foundation's Kidney Disease Outcomes Quality Initiative
MIS	Malnutrition inflammation score
MUFAs	Monounsaturated fatty acids
TIBC	Total iron binding capacity
WHO	World Health Organization
3-DFR	3-day food records

Supplementary Information

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Supplementary Material 1

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Author contributions

ZH: Suggested the idea and drafted the problem statement, data evaluation, reviewing and editing. ZN: optimize the methodology, data validation, reviewing and editing supervise the data collection, data interpretation. SZ: Data acquisition, curation and contribute in the manuscript draft writing, LB, SI and SS: wrote the full proposal, applied for the ethics, data collection, data entry, and data analysis. MB: Conceptualization and study design, methodology, reviewing and editing. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board at An-Najah National University (Ref: Med Sep 2021/78). Permissions and approval to conduct the study were obtained from the Palestinian Ministry of Health and the An-Najah National University Hospital administration. Written and verbal informed consent was obtained from all subjects prior to data collection. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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