

Nutritional Status, Biochemical Parameters, Dietary Intake, and Factors Associated with Obesity among Hemodialysis Patients in Morocco

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ABSTRACT

Background

Chronic kidney disease (CKD) is a major global public health concern due to its increasing prevalence, largely driven by diabetes, hypertension, cardiovascular disease, and obesity. Obesity, considered a modifiable risk factor, results from a complex interaction of sociodemographic, nutritional, and biochemical determinants.

Objectives

This study aimed to assess the nutritional, anthropometric, sociodemographic, and biochemical characteristics of haemodialysis patients, compare nutritional intake between dialysis and non-dialysis days, and examine the associations between obesity and these parameters, as well as their impact on the overall health status of patients with end-stage kidney disease (ESKD).

Method and Materials

A descriptive cross-sectional study was conducted among 200 haemodialysis patients from three Moroccan cities: Kelaa des Sraghna, El Jadida, and Kénitra. Participants had been receiving haemodialysis treatment for more than three months and had no major disability preventing anthropometric assessment.

Results

The mean age of participants was 55.24 ± 15.07 years. The findings showed no significant association between obesity and sociodemographic variables, except for region of residence ($p = 0.023$). A highly significant association was observed between obesity and initial nephropathy ($p = 0.000$), particularly diabetic (26.5%) and hypertensive nephropathies (33.5%). Obesity was also significantly associated with caloric intake on dialysis and non-dialysis days ($p = 0.000$), as well as protein intake on dialysis days ($p = 0.000$) and non-dialysis days ($p = 0.001$). In addition, significant associations were identified between anthropometric and body composition parameters, including BMI, muscle mass, skeletal mass, visceral fat, and body water, and nutritional intake in haemodialysis patients. The results particularly highlighted the role of energy and protein intake in maintaining muscle mass and overall nutritional status, as well as the importance of fluid balance, closely related to total body water and fluid intake. Furthermore, specific dietary components, such as sugar, garlic, and parsley consumption, appeared to be associated with variations in body composition parameters, suggesting the potential influence of qualitative dietary habits beyond quantitative intake alone.

Conclusion

These findings emphasize the complexity of the interactions between nutrition, body composition, and clinical status in this population and underline the need for individualized nutritional management in hemodialysis patients, integrating energy and protein requirements, fluid intake control, and overall dietary quality. Further longitudinal studies are nevertheless needed to better understand causal relationships and optimize nutritional strategies in this clinical context.

INTRODUCTION

Chronic kidney disease (CKD) represents a major global public health challenge due to its high prevalence, substantial morbidity and mortality, and its profound impact on patients' quality of life.¹ CKD is defined as abnormalities of kidney structure or function, including a persistent reduction in glomerular filtration rate (GFR), that are present for more than three months and have implications for health.² Physiologically, the kidneys play a central role in maintaining internal homeostasis through their filtration and reabsorption functions, as well as their endocrine and metabolic activities. Progressive deterioration of renal function in CKD compromises these essential processes, leading to disturbances in fluid, electrolyte, acid-base, and metabolic balance.³

The etiology of chronic kidney disease (CKD) is multifactorial and involves a wide range of risk factors, including hypertension, diabetes mellitus, glomerular diseases, acute kidney injury, autoimmune disorders such as systemic lupus

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erythematosus, genetic predisposition, and excess body weight, particularly overweight and obesity⁴. Obesity has become one of the leading contributors to the global burden of chronic diseases and is recognized as an independent risk factor for CKD.⁴ In addition, it is associated with numerous comorbidities, including cardiovascular disease, type 2 diabetes mellitus, hypertension, dyslipidemia, respiratory disorders, musculoskeletal diseases, several types of cancer—including renal cancer—and a substantial reduction in quality of life⁵.

Globally, approximately 843.6 million people had CKD in 2017⁶. In the United States, it affects more than one-third of the adult population (35%, or approximately 78.6 million people) and results in annual healthcare costs exceeding \$140 billion⁷. Furthermore, the prevalence of obesity-related kidney disease has increased significantly in recent years, with an elevated risk of CKD, particularly in cases of central obesity⁸. In Morocco, the MaReMar study (Chronic Kidney Disease in Morocco) estimated that 2.6% of the adult population is affected, with 7.2% in the end-stage⁹. At this advanced stage, patients require maintenance hemodialysis to stay alive. In adults, the standard regimen generally consists of three weekly sessions of approximately four hours each. However, in certain situations (advanced age, low body weight) or in low- and middle-income countries, this frequency may be reduced to two weekly sessions due to material and financial constraints¹⁰.

Patients undergoing maintenance hemodialysis experience substantial physical, psychological, social, and financial challenges that significantly affect their overall well-being. Limited access to healthcare services, dependence on caregivers, and the high burden of comorbidities contribute to impaired quality of life and a high prevalence of depressive symptoms¹⁰. In addition, overweight and obesity are increasingly reported among patients receiving hemodialysis and may further influence clinical outcomes and nutritional status.¹¹ Comprehensive nutritional assessment is therefore essential in this population, as it provides valuable information on body composition and adipose tissue distribution. This assessment includes anthropometric indices, such as the waist-to-hip ratio (WHR), as well as body composition parameters obtained by bioelectrical impedance analysis (BIA), including body fat mass, lean body mass, skeletal muscle mass, and hydration status¹².

Against this background, the present study aimed to compare obese and non-obese patients undergoing maintenance hemodialysis with respect to their anthropometric characteristics, dietary intake, sociodemographic profile, nutritional status, and general health characteristics. In addition, the study sought to identify the factors associated with obesity in this population.

MATERIALS AND METHODS

Sampling

An observational analytical cross-sectional study was conducted in three cities (Kélla des Sraghna, El Jadida, and Kenitra). In El Jadida, the study was conducted at Mohammed V Hospital under authorization number 5460 and at a private hemodialysis center. In Kélla des Sraghna, the study was conducted at a private hemodialysis center. In Kenitra, the study was conducted at a private hemodialysis center.

The study was conducted between March 2024 and September 2024 and included 200 patients with end-stage renal disease (ESRD) aged 18 years or older, who had been undergoing hemodialysis for more than three months and who had no major disabilities limiting the collection of anthropometric data. All participating patients underwent dialysis two or three times a week (each session lasting 3 to 5 hours). All subjects were informed of the purpose of the questionnaire.

Method used

The classic sample size formula for descriptive cross-

$$n = \frac{z^2 \times P \times (1 - P)}{d^2} \text{ sed disc:}$$

n: minimum required sample size

Z: critical value for a 95% confidence level

p: estimated prevalence of obesity among hemodialysis patients

d : desired precision

Inclusion and exclusion criteria

The study was carried out in patients aged 18 years or over, undergoing hemodialysis treatment for more than three months, and with no major handicap limiting the taking of anthropometric parameters. All participating patients were dialyzed two or three times a week (each session lasting 3 to 5 hours).

All patients were informed about the aim of the study, and their participation was voluntary and anonymous, in accordance with ethical standards.

Data Collection

The data were collected using a structured questionnaire covering sociodemographic characteristics (age, sex, educational level, household size, marital status, educational level), health status (health insurance coverage, number of dialysis sessions per week, residual urine output, cause of the disease, duration of hemodialysis treatment, gastrointestinal symptoms, and substance use habits)

Anthropometry

Weight was measured while the subjects were fully clothed and barefoot on a mechanical scale, and height was measured using a wall-mounted height rod, with the subjects standing upright, barefoot, and with their shoulders in a natural position.

BMI (body mass index) was calculated by dividing weight (kg) by the square of height (m²), according to World Health Organization (WHO) criteria, underweight was defined as a BMI < 18 kg/m², normal weight as 18 ≤ BMI ≤ 24.9 kg/m², overweight as 25 ≤ BMI ≤ 29.9 kg/m², and severe obesity as a BMI ≥ 30 kg/m² ¹³.

Fat mass, muscle mass, skeletal mass, visceral fat, and body water were measured by the reference impedancemeter (TAN313BC) to differentiate between the different body compartments and between obesity caused by excess fat mass and hydrosodic overload caused by excess water.

We divided the sample group into two subgroups: an obese group (subjects who are overweight or obese) and a non-obese group (subjects who are of normal weight or underweight). We classified the two groups based on body fat percentage, with normal ranges varying by gender (for women: normal is between 20% and 35%; for men: normal is between 10% and 25%)¹⁴. There were 40 non-obese participants and 160 obese participants.

Anthropometric measurements were taken after the hemodialysis session for all participants.

Dietary Habits

Dietary data were collected using a food frequency questionnaire and two separate 24-hour dietary recalls

on non-consecutive days ^{15,16}, including one day on dialysis and one day off dialysis. The data primarily concerned: consumption of various foods from different food groups and the quantities consumed; quantities were estimated using a photo guide for estimating food portions and then converted to grams ^{17,18}, intakes were then analyzed using the 2020 CIQUAL food composition database; the estimated intakes from the two 24-hour dietary recalls were used to reflect the usual intake for each nutrient on a normal day and on a hemodialysis day.

The nutritional assessment was based on estimates of energy requirements (30 kcal/kg/day) and protein requirements (1.2 g/kg/day) in hemodialysis patients. A comparison of intake and requirements made it possible to characterize dietary profiles in terms of energy and protein adequacy ¹⁹.

Biochemical data

We collected the patients' most recent laboratory test results from the follow-up log, including complete blood counts and calcium-phosphorus panel results.

Physical Activity

Levels of physical activity and sedentary behavior were assessed using the International Physical Activity Questionnaire (IPAQ, short version), which has been validated in several countries for reliability and validity ²⁰.

Statistical Analysis

Data analyses were performed using SPSS statistical software, version 26.0. Variables were expressed as mean ± standard deviation. The Student's t-test was used to compare differences in means, the chi-square test was used to examine associations between variables, correlation was used to describe the relationship between variables, and regression was used to better represent the relationships between variables. In all statistical analyses, a p-value less than 0.05 is considered statistically significant.

RESULTS

The association between various sociodemographic factors and obesity levels

This table shows the associations between various sociodemographic factors and obesity levels

Table 1 : Distribution of sociodemographic data by obesity status (chi-square test)

parameters		Obesity level (fat mass)				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Gendre	Male	13%	26	38.5%	77	0.130
	Female	17%	34	31.5%	63	
	Single	5.5%	11	6%	12	0.103
Martimonial situation	Married	18.5%	37	54.5%	109	
	Divorced	1.5%	3	2%	4	
	Widower	4.5%	9	7.5%	15	
Region	El kelaa sraghna	11.5%	23	27%	54	0.023*
	Kenitra	2%	4	15%	30	
	El jadida	16.5%	33	28%	56	
Private/hospital	Private	23.5%	47	61.5%	123	0.084
	Hospital	6.5%	13	8.5%	17	
Household size	1	1.5%	3	3.5%	7	0.758
	1 to 3	9%	18	18%	36	
	3 to 5	9%	18	26.5%	53	
	Over 5	10.5%	21	22%	44	
Professional status	Employee	0.5%	1	4.5%	9	0.496
	Self-employed	2%	4	5%	10	
	Seasonal work	0.5%	1	0.5%	1	
	Unemployed	27%	54	60%	120	
Education level	Illiterate	13.5%	27	32.5%	65	0.542
	Primary	7%	14	16%	32	
	Middle school	2%	4	9.5%	19	
	High school	4%	8	6.5%	13	
	Higher education	3.5%	7	5.5%	11	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The results of the chi-square test (Table 1) showed that there was no significant association between gender, marital status, and type of facility (private clinic or hospital) in relation to obesity level ($p = 0.130$, $p = 0.103$, $p = 0.084$, respectively). Similarly, no significant association was observed between household size, employment status, and educational level in relation to obesity level ($p = 0.758$, $p = 0.496$, $p = 0.542$, respectively). However, the results revealed a significant association between geographic region and obesity levels ($p = 0.023$).

II. The Relationship Between Health Status and Obesity Level

This table illustrates the relationship between health status and obesity level

Table 2: Health status among obese and non-obese hemodialysis patients (chi-square test)

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Physical activity	Sedentarity	11%	22	34%	68	0.077
	Moderate activity	9%	18	11.5%	23	
	High physical activity	10%	20	24.5%	49	
Medical coverage	Health insurance fund	6.5%	13	10%	20	0.149
	Insurance	7%	14	17.5%	35	
	AMO	13%	26	39%	78	
	Without	3.5%	7	3.5%	7	
The duration of the illness	Less than 1 year	4%	8	12%	24	0.034*
	Between 1 and 5 years	9%	18	33.5%	67	
	Between 5 and 10 years	5.5%	11	6.5%	13	
	More than 10 years	11.5%	23	18%	36	
Number of sessions /week	2 sessions	9%	18	18.5%	35	0.463
	3 sessions	21%	42	52.5%	105	
Residual diuresis	Yes	24.5%	49	54.5%	109	0.544
	No	5.5%	11	15.5%	31	
Cause of the disease	HTA	10.5%	21	23%	46	0.000***
	Diabetes	2.5%	5	24%	48	
	Urological	1.5%	3	3%	6	
	Glomerular	5%	10	5%	10	
	Side effect of medications	1.5%	3	0.5%	1	
	Undetermined	5%	10	13%	26	
	Anemia	2.5%	5	1%	2	
	Intoxication	1%	2	0.5%	1	
	Lupus	0.5%	1	0%	0	
Gastrointestinal symptoms	No symptoms	12.5%	25	34.5%	69	0.342
	Gastrœsophageal reflux disease	3%	6	12%	24	
	Heartnurn	3.5%	7	6%	12	
	Gastric ulcer	5.5%	11	10%	20	
	Nausea and vomiting	4.5%	9	7%	14	
	Irritable bowel syndrome	1%	2	0.5%	1	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The results revealed a non-significant association between physical activity, health insurance coverage, number of sessions, and residual urine output in relation to the degree of obesity ($p=0.077$, $p=0.149$, $p=0.463$, $p=0.544$, respectively); however, the results showed a significant association between disease duration and

obesity level ($p=0.034$), and these results also revealed a highly significant association between the cause of the disease and obesity level ($p=0.000$); finally, no significant association was found between the presence of gastrointestinal symptoms and the degree of obesity ($p = 0.342$).

III. The Relationship Between Various Anthropometric Measures and Obesity

This table shows the various relationships between anthropometric parameters and obesity

Table 3: Distribution of anthropometric data according to obesity (chi-square test)

parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
BMI	Underweight	6.5%	13	0%	0	0.000***
	Normal weight	20.5%	41	20%	40	
	Overweight	2.5%	5	30.5%	61	
	Obesity	0.5%	1	19.5%	39	
Waist-to-hip ratio	Low risk	14.5%	29	20%	40	0.015*
	Moderate risk	5%	10	11%	22	
	High risk	10.5%	21	39%	78	
Skeletal mass	Normal	1%	2	38.5%	77	0.000***
	Perfect	29%	58	31.5%	63	
Muscle mass	Low	6%	12	0%	0	0.000***
	Normal	21.5%	43	27.5%	55	
	Perfect	2.5%	5	42.5%	85	
Visceral fat	Normal	30%	60	18%	36	0.000***
	Overweight	0%	0	26.5%	53	
	Obesity	0%	0	25.5%	51	
BODY WATER	Low	0%	0	21.5%	43	0.000***
	Normal	0%	0	38.5%	77	
	Perfect	30%	60	10%	20	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The results revealed a significant association between the waist-to-hip ratio and the degree of obesity ($P = 0.015$); furthermore, there was a highly significant association between BMI, skeletal mass, muscle mass, visceral fat, and body water and the degree of obesity ($P = 0.000$).

IV. The Relationship Between Various Nutritional Parameters and Obesity

This tables shows the various relationships between nutritional parameters and obesity

Table 4: Consumption of red meat, poultry, fresh fish, canned fish, dairy products, liver and offal, eggs, and fluid and salt intake depending on obesity level (chi-square test)

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
The amount of added salt/day	0g	3.5%	7	9.5%	19	0.735
	5g	19%	38	41%	82	
	10g	6%	12	17.5%	35	
	15g	1.5%	3	2%	4	
Water intake/ day	Less than 500 ml	6%	12	6.5%	13	0.001**
	Between 500 ml and 1 l	22%	44	41%	82	
	Between 1l and 1,5l	1.5%	3	12%	24	
	Between 1,5l and 2l	0.5%	1	10.5%	21	
Dairy products	Less than 3 times a day	13.5%	27	29.5%	59	0.181
	More than 3 times a day	0%	0	5%	10	
	Less than 3 times a week	3%	6	7.5%	15	
	More than 3 times a week	8%	16	18.5%	37	
	Once a month	0%	0	1.5%	3	
	Twice a month	0%	0	1%	2	
	0 times	5.5%	11	7%	14	
Red meat	Less than 3 times a day	3%	6	5%	10	0.479
	Less than 3 times a week	10.5%	21	27%	54	
	More than 3 times a week	3.5%	7	8%	16	
	Once a month	2%	4	6%	12	
	Twice a month	1.5%	3	3%	6	
	Three times a month	1%	2	0%	0	
	0 times	8.5%	17	21%	42	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Poultry	Less than 3 times a day	13%	26	30%	60	0.946
	Less than 3 times a week	6%	12	16.5%	33	
	More than 3 times a week	9.5%	19	20%	40	
	Once a month	0.5%	1	0.5%	1	
	Twice a month	0%	0	0.5	1	
	0 times	1%	2	2.5%	5	
Fresh fish	Less than 3 times a week	9.5%	19	29.5%	59	0.106
	More than 3 times a week	1.5%	3	5%	10	
	Once a month	5%	10	8.5%	17	
	Twice a month	2.5%	5	9%	18	
	Three times a month	0%	0	2.5%	5	
	0 times	11.5%	23	15.5%	31	
Canned fish	Less than 3 times a week	4.5%	9	8%	16	0.276
	More than 3 times a week	1%	2	1%	2	
	Once a month	2.5%	5	7%	14	
	Twice a month	1.5%	3	4.5%	9	
	Three times a month	1%	2	0%	0	
	0 times	19.5%	39	49.5%	99	
Liver and offal	Less than 3 times a week	1%	3	4.5%	9	0.731
	More than 3 times a week	0%	0	1%	2	
	Once a month	3%	6	10%	20	
	Twice a month	2.5%	5	3.5%	7	
	Three times a month	0.5%	1	0.5%	1	
	0 times	22.5%	45	50.5%	101	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Eggs	Less than 3 times a day	2%	4	12%	24	0.404
	Less than 3 times a week	9.5%	19	24.5%	49	
	More than 3 times a week	6.5%	13	14%	28	
	Once a month	1%	2	1%	2	
	Twice a month	1.5%	3	3.5%	7	
	Three times a month	0.5%	1	0.5%	1	
	0 times	9%	18	14.5%	29	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The results revealed several significant and non-significant associations between dietary habits and obesity levels. No significant association was found between the amount of salt added to food preparations and obesity levels ($P=0.735$). However, a highly significant association was observed between the amount of water consumed and the level of obesity ($P=0.001$). With regard to food products, no significant

association was found between the consumption of dairy products, red meat, and poultry and the level of obesity ($P=0.181$, $P=0.479$, $P=0.946$, respectively). Similarly, the association between the consumption of fresh fish, canned fish, liver and offal, as well as eggs, and the level of obesity was not significant ($P=0.106$, $P=0.276$, $P=0.731$, $P=0.404$, respectively).

Table 5: Consumption of wholemeal bread, semolina bread, rice, pasta, couscous, potatoes, oils, fortified fats, fruits, vegetables and fruit juices depending on the level of obesity (chi-square test)

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Whole wheat bread and barley bread	Less than 3 times a day	6%	12	16.5%	33	0.197
	More than 3 times a day	6.5%	13	20.5%	41	
	Less than 3 times a week	2%	4	1%	2	
	More than 3 times a week	0.5%	1	2%	4	
	Once a month	1%	2	0.5%	1	
	0 times	14%	28	29.5%	59	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Semolina bread and white bread	Less than 3 times a day	10.5%	21	18%	36	0.866
	More than 3 times a day	10%	20	27%	54	
	Less than 3 times a week	2.5%	5	8%	16	
	Once a month	4.5%	9	11%	22	
	Twice a month	0.5%	1	0.5%	1	
	Three times a month	0.5%	1	1%0%	2	
	0 times	1.5%	3	4.5%	9	
Rice, pasta, couscous, potatoes, pulses	Less than 3 times a day	20%	40	42%	84	0.408
	More than 3 times a day	2%	4	4%	8	
	Less than 3 times a week	0%	0	4.5%	9	
	More than 3 times a week	7.5%	15	18.5%	37	
	Twice a month	0.5%	1	0.5%	1	
	Three times a month	0%	0	0.5%	1	
Olive oil and sunflower oil	Less than 3 times a day	14.5%	29	40.5%	81	0.292
	More than 3 times a day	12.5%	25	27.5%	55	
	Less than 3 times a week	1%	2	0.5%	1	
	More than 3 times a week	0.5%	1	0.5%	1	
	Three times a month	0.5%	1	0%	0	
	0 times	1%	2	1%	2	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Saturated fat (butter, smen)	Less than 3 times a day	3.5%	7	7%	14	0.052
	Less than 3 times a week	6.5%	13	21%	42	
	More than 3 times a week	1%	2	8%	16	
	Once a month	3%	6	4.5%	9	
	Twice a month	2%	4	1%	2	
	Three times a month	0%	0	3%	6	
	0 times	14%	28	25.5%	51	
Fruits	Less than 3 times a day	14%	28	44.5%	89	0.191
	More than 3 times a day	1%	2	2%	4	
	Less than 3 times a week	4%	8	4%	8	
	More than 3 times a week	10%	20	16%	32	
	Twice a month	0%	0	0.5%	1	
	0 times	1%	2	3%	6	
Olive	Less than 3 times a day	3%	6	11%	22	0.212
	Less than 3 times a week	11.5%	23	19.5%	39	
	More than 3 times a week	1.5%	3	10.5%	21	
	Once a month	2%	4	3.5%	7	
	Twice a month	1%	2	4%	8	
	0 times	11%	22	21.5%	43	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Vegetable	Less than 3 times a day	16.5%	33	44.5%	89	0.500
	More than 3 times a day	2.5%	5	3.5%	7	
	Less than 3 times a week	4%	8	5%	10	
	More than 3 times a week	6%	12	15.5%	31	
	Once a month	0%	0	0.5%	1	
	0 times	1%	2	1%	2	
Fruit juice	Less than 3 times a day	3.5%	7	10.5%	21	0.466
	Less than 3 times a week	3.5%	7	11%	22	
	More than 3 times a week	2%	4	4.5%	9	
	Once a month	0.5%	1	4%	8	
	Twice a month	2%	4	1.5%	3	
	Three times a month	0%	0	0.5%	1	
	0 times	18.5%	37	38%	76	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The results showed that no significant association was observed between the consumption of white bread, semolina bread, whole-grain bread, and barley bread ($P=0.866$, $P=0.197$, respectively). Similarly, consumption of rice, couscous, potatoes, pasta, and legumes showed no significant association with obesity levels ($P=0.408$). In contrast, a significant association was found between the consumption of saturated

fats and the level of obesity ($P=0.052$), while the consumption of olive oil and vegetable oils showed no significant link ($P=0.292$).

The results also showed no significant association between the consumption of fruits, vegetables, and olives and the level of obesity ($P=0.191$ for fruits, $P=0.212$ for olives, $P=0.500$ for vegetables), as well as between the consumption of fruit juice ($P=0.466$).

Table 6: Consumption of aromatic herbs, almonds, pistachios, apricots, sweets, sugar, coffee, tea and fried foods depending on obesity level (chi-square test)

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Thyme	Less than 3 times a day	1.5%	3	4.5%	9	0.913
	Less than 3 times a week	4%	8	9.5%	19	
	More than 3 times a week	1%	2	4.5%	9	
	Once a month	3.5%	7	8.5%	17	
	Twice a month	1.5%	3	2%	4	
	0 times	18.5%	37	41%	82	
Parsley	Less than 3 times a day	28%	56	70%	140	0.023*
	Less than 3 times a week	0.5%	1	0%	0	
	More than 3 times a week	0.5%	1	0%	0	
	Twice a month	1%	2	0%	0	
Garlic	Less than 3 times a day	20.5%	41	61.5%	123	0.020*
	Less than 3 times a week	3%	6	2.5%	5	
	More than 3 times a week	2%	4	1.5%	3	
	Once a month	0%	0	0.5%	1	
	Twice a month	0.5%	1	0%	0	
	0 times	4%	8	4%	8	
Mint	Less than 3 times a day	14.5%	29	32.5%	65	0.795
	More than 3 times a day	1%	2	1.5%	3	
	Less than 3 times a week	2%	4	7%	14	
	More than 3 times a week	1%	2	4%	8	
	Once a month	0.5%	1	0.5%	1	
	Twice a month	0%	0	1.5%	3	
	0 times	11%	22	23%	46	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Almond, pistachio,walnut	Less than 3 times a day	0%	0	3%	6	0.612
	More than 3 times a day	0%	0	0.5%	1	
	Less than 3 times a week	5.5%	11	10%	20	
	More than 3 times a week	2.5%	5	6%	12	
	Once a month	2.5%	5	7.5%	15	
	Twice a month	0.5%	1	2.5%	5	
	Three times a month	0%	0	1%	2	
	0 times	19%	38	58.5%	117	
Apricots, figs, dates, raisins	Less than 3 times a day	4%	8	12.5%	25	0.698
	Less than 3 times a week	7.5%	15	13.5%	27	
	More than 3 times a week	4.5%	9	9.5%	19	
	Once a month	3.5%	7	6%	12	
	Twice a month	1%	2	5.5%	11	
	Three times a month	0%	0	1%	2	
	0 times	9.5%	19	22%	44	
Sugar	Less than 3 times a day	25.5%	51	45.5%	91	0.009**
	More than 3 times a day	2%	4	2.5%	5	
	Less than 3 times a week	1%	2	3%	6	
	More than 3 times a week	0%	0	0.5%	1	
	0 times	1.5%	3	18.5%	37	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Cake and pastries	Less than 3 times a day	6%	12	11%	22	0.294
	Less than 3 times a week	9%	18	18.5%	37	
	More than 3 times a week	1.5%	3	7%	14	
	Once a month	4%	8	11%	22	
	Twice a month	3%	6	3.5%	7	
	Three times a month	1.5%	3	1%	2	
	0 times	5%	10	18%	36	
Fried food	Less than 3 times a day	0.5%	1	0.5%	1	0.050*
	Less than 3 times a week	6.5%	13	21.5%	43	
	More than 3 times a week	1%	2	11%	22	
	Once a month	2.5%	5	7%	14	
	Twice a month	4%	8	4%	8	
	Three times a month	1%	2	1%	2	
	0 times	14.5%	29	25%	50	
Coffee	Less than 3 times a day	5.5	11	19.5%	39	0.464
	More than 3 times a day	0%	0	0.5%	1	
	Less than 3 times a week	6%	12	11%	22	
	More than 3 times a week	3.5%	7	9.5%	19	
	Once a month	2.5%	5	3.5%	7	
	Twice a month	0%	0	2%	4	
	0 times	12.5%	25	24%	48	

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Tea	Less than 3 times a day	26.5%	53	58%	116	0.081
	More than 3 times a day	1.5%	3	2.5%	5	
	Less than 3 times a week	0.5%	1	3%	6	
	More than 3 times a week	0%	0	4%	8	
	Once a month	1%	2	0%	0	
	0 times	0.5%	1	2.5%	5	
Sweets	Less than 3 times a day	5%	10	9.5%	19	0.443
	More than 3 times a day	0.5%	1	0%	0	
	Less than 3 times a week	6.5%	13	11%	22	
	More than 3 times a week	3.5%	7	6%	12	
	Once a month	3%	6	5.5%	11	
	Twice a month	2%	4	4.5%	9	
	Three times a month	0.5%	1	1%	2	
	0 times	9%	18	32.5%	65	
Salt	Less than 3 times a day	25.5%	51	58.5%	117	0.868
	More than 3 times a day	1%	2	1.5%	3	
	More than 3 times a week	0%	0	0.5%	1	
	0 times	3.5%	7	9%	18	

Statistical significance is indicated by asterisks ($p < 0.05$; $**p < 0.01$; $***p < 0.001$), with a significance level set at $p < 0.05$.

Concerning herbs such as thyme and mint, no significant association was observed ($P=0.913$ for thyme, $P=0.795$ for mint), but a significant association was found between the consumption of parsley and garlic and the level of obesity ($P=0.023$ for parsley, $P=0.020$ for garlic).

Regarding dried fruits (walnuts, almonds, pistachios) and dates, figs, and raisins, no significant association

was observed ($P=0.612$ and $P=0.698$, respectively). Similarly, consumption of pastries, baked goods, and sugary products showed no significant association with obesity levels ($P=0.294$ for pastries, $P=0.443$ for sugary products). However, a significant association was observed between the consumption of fried foods and added sugar and the level of obesity ($P=0.050$, $p=0.009$).

Table 7: Calorie, calcium, phosphorus, and potassium intakes as a function of obesity level(chi-square test)

Parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Caloric intake on dialysis day	Hypocaloric	11.5%	23	60.5%	121	0.000***
	Normocaloric	13%	26	8%	16	
	Hypercaloric	5.5%	11	1.5%	3	
Caloric intake on normal day	Hypocaloric	15%	30	64.5%	129	0.000***
	Normocaloric	10.5%	21	3.5%	7	
	Hypercaloric	4.5%	9	2%	4	
Protein intake on dialysis day	Insufficient intake	15%	30	60.5%	121	0.000***
	Normal intake	3.5%	7	2%	4	
	Excessif intake	11.5%	23	7.5%	15	
Protein intake on normal day	Insufficient intake	18.5%	37	59.5%	119	0.001**
	Normal intake	2%	4	3%	6	
	Excessif intake	9.5%	19	7.5%	15	
Phosphore intake on dialysis day	Normal intake	6.5%	13	19%	38	0.416
	Excessif intake	23.5%	47	51%	102	
Phosphore intake on normal day	Normal intake	7%	14	17	34	0.885
	Excessif intake	23	46	53%	106	
Potassium intake on dialysis day	Normal intake	4%	8	5.5%	11	0.226
	Excessif intake	26%	52	64.5%	129	
Potassium intake on normal day	Normal intake	7%	14	4.5%	9	0.001**
	Excessif intake	23%	46	65.5%	131	
Calcium intake on dialysis day	Insufficient intake	29%	58	66%	132	0.479
	Normal intake	1%	2	4%	8	
Calcium intake on normal day	Insufficient intake	29.5%	59	68.5%	137	0.826
	Normal intake	0.5%	1	1.5%	3	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The chi-square test revealed a highly significant association between caloric intake on the day of hemodialysis, caloric intake on normal days and protein intake on the day of hemodialysis ($P=0.000$), as well as between protein intake on normal days and potassium intake on normal days ($P=0.001$) in relation to the level of obesity.

The results showed that there was no significant association between phosphorus intake, both on hemodialysis days and on normal days, and potassium

intake during hemodialysis sessions ($p=0.416$, $p=0.884$, $p=0.226$, respectively). Furthermore, no significant relationship was observed between calcium intake (on hemodialysis days and normal days) and obesity levels ($P=0.479$ and $P=0.826$, respectively).

V. The relationship between various biochemical parameters and the degree of obesity

This table illustrates the relationship between various biochemical parameters and obesity

Table 8: Results of biochemical analyses in obese and non-obese patients (chi-square test)

parameters		Obesity level				p value
		Non-obese		Obese		
		30%	N=60	70%	N=140	
Hemoglobin (g/dl)	No anemia	2.5%	5	4.5%	9	0.291
	Mild anemia	4.5%	9	16%	32	
	Moderate anemia	17%	34	41.5%	83	
	Severe anemia	6%	12	8%	16	
Calcium (mg/L)	Normal	12.5%	25	29.5%	59	0.275
	Deficiency	15.5%	31	39%	78	
	Excess	2%	4	1.5%	3	
Phosphorus (mg/L)	Normal	8%	16	22%	44	0.788
	Dificiency	19%	38	41%	82	
	Excess	3%	6	7%	14	

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a threshold set at $p < 0.05$.

The results of the biochemical analyses (Table 5) showed that there were no significant associations between hemoglobin, calcium, and phosphorus and the level of obesity ($P = 0.291$ for hemoglobin, $P = 0.275$ for calcium, $P = 0.788$ for phosphorus).

VI. Comparison of the means of various anthropometric and biochemical parameters according to obesity level

This table shows the difference in the means of various anthropometric and biochemical parameters according to obesity level

Table 9: Comparison of anthropometric and biochemical parameters between obese and non-obese patients (t-test)

Variables	Non-obese	obese	p value
Physical activity (min/ day)	135± 121.874	116.96±109.700	0.304
Age (mounth)	52.20±16.353	56.54±14.344	0.062
BMI (kg/m ²)	20.7±3.34	27.6±4.25	0.000***
BODY WATER (%)	59.77±2.677	53.06±2.34	0.000***
Visceral fat (kg)	3.65±2.10	12.85±4.30	0.000***
Illness duration (Month)	70.88±77.41	45.55±45.61	0.021*
Hemoglobin (g/dL)	9.49±2.06	9.96±1.70	0.092
Calcium (mg/L)	89.30±9.91	86.61±9.58	0.073
Phosphorus (mg/L)	51.38±15.66	48.01±13.01	0.147

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

The t-test revealed several differences between the obese and non-obese groups. First, no significant difference was found in terms of age between the two groups ($P = 0.062$), nor was any significant difference found between physical activity and obesity level ($p = 0.304$). However, a significant increase in BMI was observed in the obese group compared to the non-obese group (+25%; $P = 0.000$).

With regard to body parameters, visceral fat was significantly higher in the obese group (+71.59%; $P = 0.000$). Conversely, total body water was higher in non-obese subjects (+11.22%; $P = 0.000$). Disease duration was also significant ($P = 0.021$).

Biochemically, no significant differences were observed regarding hemoglobin levels, although a slight increase was recorded in the obese group (+4.71%; $P = 0.092$). Similarly, serum calcium levels were slightly higher

in the non-obese group (+3.01%; $P = 0.073$), as were serum phosphorus levels (+6.55%; $P = 0.147$), but these variations were not statistically significant.

VII. Comparison of the means of various nutritional parameters by obesity level

This table shows the difference in the means of various nutritional parameters by obesity level

Table 10: Comparison of nutritional parameters. T-test. Results are presented as mean ± standard deviation.

Variables	Non-obese	Obese	p value
Recommended protein intake (g/ day)	63.99±7.35	91.93±12.72	0.000***
Caloric intake on dialysis day (Kcal/day)	1552±434.99	1549±446.95	0.963
Caloric intake on normal day(Kcal/ day)	1443±537.6	1423±415.04	0.800
Protein intake on dialysis day(g/ day)	69.28±35.33	64.03±19.62	0.284
Protein intake on normal day(g/ day)	56.44±25.90	60.56±21.09	0.240
Phosphorus intake on dialysis day(mg/day)	651±249	669±256	0.644
Phosphorus intake on normal day(mg/day)	578.35±320.43	619.57±263.03	0.344
Potassium intake on dialysis day(mg/day)	1.89±0.75	1.85±0.62	0.670
Potassium intake on normal day(mg/day)	2.003±0.941	1.7982±0.57	0.121
Calcium intake on dialysis day(mg/day)	366±239.2	385±239.9	0.604
Calcium intake on normal day(mg/day)	278.80±226.02	268.11±201.7	0.741

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

Regarding energy requirements, a significant increase was observed in the obese group compared to the non-obese group, with a difference of 30.41% ($P=0.000$). Similarly, the recommended protein requirement was significantly higher in the obese group compared to the

non-obese group, with an increase of 30.39% ($P=0.000$). However, no significant difference in caloric intake was observed on the day of hemodialysis between the two groups ($P=0.963$). Furthermore, although caloric intake increased slightly on a normal day in the non-obese group compared to the obese group (1.38%), this difference was not significant ($P=0.800$).

With regard to protein intake on both hemodialysis days and normal days, there were non-significant increases in the obese group compared with the non-obese group, with differences of 7.5% ($P=0.284$) and 6.80% ($P=0.240$), respectively.

The results also showed several non-significant differences between the obese and non-obese groups regarding phosphorus, potassium, and calcium intake. On hemodialysis days, phosphorus intake was slightly higher in the obese group than in the non-obese group, with a difference of 2.69% ($P=0.644$), but this difference was not statistically significant. On a normal day, phosphorus intake (Figure 1, J) was also higher in the obese group (6.65%), but again, the difference did not reach statistical significance ($P=0.344$).

Regarding potassium intake, the non-obese group showed a slight increase compared to the obese group, both on hemodialysis days (2.11%, $P=0.670$) and on normal days (10.22%, $P=0.121$), but these differences were not statistically significant. Finally, regarding calcium intake, the obese group showed a non-significant increase compared to the non-obese group on the hemodialysis day (4.93%, $P=0.604$), while the non-obese group showed a non-significant increase on the normal day (3.83%, $P=0.741$).

VIII. Correlation of Biochemical and Nutritional Parameters with Obesity

This table shows the correlations between various biochemical and nutritional parameters and the degree of obesity

The results of Pearson's correlation revealed several significant relationships between various variables and the level of obesity. A significant positive correlation was observed between BMI and the level of obesity ($P=0.000$), as well as between visceral fat and the level of obesity ($P=0.000$). In contrast, a significant negative correlation was found between body water and the level of obesity ($p=0.000$).

In addition, a significant negative correlation was

Table 11: Pearson's correlation of biochemical and nutritional parameters in obese and non-obese patients

Variables	Obesity level (fat mass)	
	Pearson coefficient	P value
Anthropometric and clinical parameters		
Physical activity	-0.073	0.304
BMI	0.830	0.000***
BODY WATER	-0.942	0.000***
Visceral fat	0.942	0.000***
Illness duration	-0.227	0.001**
Hemoglobin	0.176	0.013*
Calcium	-0.074	0.295
Phosphorus	-0.081	0.254
Nutritional Parameters		
Energy requirements	0.949	0.000***
Recommended protein intake	0.949	0.000***
Caloric intake on dialysis day	0.106	0.136
Caloric intake on normal day	0.027	0.699
Protein intake on dialysis day	-0.024	0.736
Protein intake on normal day	0.085	0.232
Phosphorus intake on dialysis day	0.120	0.091
Phosphorus intake on normal day	0.093	0.189
Potassium intake on dialysis day	0.040	0.576
Potassium intake on normal day	-0.045	0.530
Calcium intake on dialysis day	0.016	0.818
Calcium intake on normal day	-0.046	0.513

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a threshold set at $p < 0.05$.

observed between disease duration and obesity level ($P=0.001$), while a significant positive correlation was found between blood hemoglobin levels and obesity level ($P=0.013$).

However, the correlation between blood calcium levels and the degree of obesity was not significant ($P=0.295$), nor was the correlation between blood phosphorus levels and the degree of obesity ($P=0.254$), nor was the correlation between physical activity levels and the degree of obesity ($P=0.304$).

The results of the Pearson correlation analysis revealed several relationships between nutritional requirements and the degree of obesity. A significant positive correlation was observed between the recommended energy requirement and the degree of obesity ($P=0.000$), as well as between the recommended protein intake and the degree of obesity ($P=0.000$).

However, some correlations were not significant. Caloric intake, both on hemodialysis days ($P=0.106$) and on normal days ($P=0.699$), showed a non-significant positive correlation with obesity levels. Similarly, protein intake, both on hemodialysis days ($P=0.736$) and on normal days ($P=0.232$), did not show a significant correlation with the level of obesity.

Intake of phosphorus, potassium, and calcium also showed non-significant positive correlations with the level of obesity. On hemodialysis days, intake of phosphorus ($P=0.091$), potassium ($P=0.576$), and calcium ($P=0.818$) did not show any significant correlation. On a normal day, phosphorus ($P=0.189$) and calcium ($P=0.513$) intake showed non-significant positive correlations, while potassium intake showed a non-significant negative correlation ($P=0.530$).

IX. Correlation of Eating Habits with Obesity

This table shows the correlations between eating habits and the degree of obesity

The results obtained using Spearman's correlation revealed several relationships between dietary habits and obesity levels:

- A non-significant negative correlation was observed between the amount of salt added to food preparations and the level of obesity ($P = 0.768$). A significant positive correlation was identified between fluid intake and the level of obesity ($P = 0.000$). Dairy consumption shows a non-significant positive correlation with obesity levels ($P = 0.802$). Regarding the consumption

Table 12 : Spearman's correlation of eating habits among obese and non-obese patients

variables	Obesity level (fat mass)	
	Spearman coefficient	P value
THE AMOUNT OF ADDED SALT	-0.021	0.768
Water intake	0.246	0.000***
Dairy products	0.018	0.802
Red meat	-0.033	0.646
Poultry	-0.068	0.337
Fresh fish	-0.165	0.019
Canned fish	0.108	0.126
Liver and offal	-0.019	0.786
Eggs	-0.152	0.031
Whole wheat bread and barley bread	-0.051	0.469
Semolina bread and white bread	0.142	0.045*
Rice, pasta, couscous, potatos, pulses	0.002	0.975
Olive oil and sunflower oil	-0.086	0.227
Saturated fat (butter, smen)	-0.036	0.612
Fruits	-0.081	0.251
Olive	0.039	0.585
Vegetable	-0.116	0.102
Fruit juice	0.007	0.916
Thyme	-0.013	0.856
Parsley	-0.187	0.008**
Garlic	-0.205	0.004**
Mint	-0.077	0.280
Almond, pistachio, walnut	0.048	0.496
Apricots, figs, dates, raisins	0.004	0.959
Sugar	0.190	0.007**
Cake and pastries	0.084	0.235
Fried food	-0.138	0.051
Coffee	-0.028	0.692
Tea	0.007	0.916
Sweets	0.251	0.000***

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a threshold set at $p < 0.05$.

of red meat, chicken, liver, and offal, non-significant negative correlations were found ($P = 0.646$, $P = 0.337$, and $P = 0.786$, respectively). A significant negative correlation was observed between the consumption of fresh fish and eggs and the level of obesity ($P = 0.019$ and $P = 0.031$, respectively). A non-significant positive correlation was observed for the consumption of canned fish ($P = 0.126$). Whole-grain bread and barley bread show a non-significant negative correlation with obesity ($P = 0.469$), while a significant positive correlation was identified for white bread and semolina bread ($P = 0.045$). The consumption of potatoes, rice, legumes, and couscous shows a non-significant positive correlation with the level of obesity ($P = 0.975$). Unsaturated oils and saturated fatty acids show non-significant negative correlations with the level of obesity ($P = 0.277$ and $P = 0.612$, respectively). Fruit and vegetable consumption also showed non-significant negative correlations ($P = 0.251$ and $P = 0.102$, respectively). Olives and fruit juices showed non-significant positive correlations with

obesity levels ($P = 0.585$ and $P = 0.916$, respectively). A non-significant negative correlation was recorded for the consumption of thyme and mint ($P = 0.856$ and $P = 0.280$, respectively). However, a highly significant negative correlation was found for the consumption of parsley and garlic ($P = 0.008$ and $P = 0.004$, respectively). Nuts and dried fruits showed non-significant positive correlations with obesity ($P = 0.496$ and $P = 0.959$, respectively). A highly significant positive correlation was noted between the consumption of added sugar and sweets and the level of obesity ($P = 0.007$ and $P = 0.000$, respectively). Pastries and baked goods show a non-significant positive correlation with obesity ($P = 0.235$). The consumption of fried foods shows a significant negative correlation with the level of obesity ($P = 0.051$). Finally, a non-significant negative correlation was found for coffee consumption ($P = 0.692$), while tea consumption shows a non-significant positive correlation ($P = 0.916$).

X. Regression of Biochemical and Nutritional Parameters as a Function of Obesity Level

This table shows the linear regression between various biochemical and nutritional parameters in relation to obesity

Table 13: Regression of Biochemical and Nutritional Parameters as a Function of Obesity (linear regression)

parameters	B	Erreur standard	p value	Confidence interval (CI)	
				Lower bound	Upper bound
Physical activity	0.000042	0.000	0.808	0.000	0.000
Age	0.004	0.123	0.062	0.000	0.008
BMI	0.033	0.053	0.538	-0.073	0.139
Visceral fat	0.635	0.101	0.000***	0.436	0.835
Body water	-0.605	0.109	0.000***	-0.820	-0.390
Hemoglobi	-0.081	0.083	0.328	-0.245	0.082
Calcium	0.011	0.014	0.457	-0.018	0.039
Phosphorus	-0.015	0.010	0.116	-0.035	0.004
The amount of added salt	-0.251	0.216	0.246	-0.678	0.175
Water intake	0.115	0.183	0.530	-0.247	0.478

parameters	B	Erreur standard	p value	Confidence interval (CI)	
				Lower bound	Upper bound
Dairy products	-0.067	0.064	0.301	-0.194	0.060
Red meat	0.079	0.065	0.223	-0.049	0.207
Poultry	0.008	0.087	0.924	-0.164	0.181
Fresh fish	-0.045	0.070	0.524	-0.183	0.093
Canned fish	0.107	0.082	0.193	-0.055	0.269
Liver and offal	-0.008	0.097	0.936	-0.200	0.184
Eggs	-0.059	0.061	0.330	-0.180	0.061
Whole wheat bread and barley bread	-0.044	0.047	0.351	-0.138	0.049
Semolina bread and white bread	-0.013	0.090	0.886	-0.191	0.165
Rice, pasta, couscous, potatos, pulses	0.093	0.100	0.357	-0.105	0.291
Olive oil and sunflower oil	-0.043	0.124	0.728	-0.287	0.201
Saturated fat (butter, smen)	0.029	0.059	0.626	-0.087	0.145
Olive	-0.062	0.057	0.278	-0.174	0.050
Fruits	-0.008	0.085	0.926	-0.176	0.160
Vegetables	0.104	0.100	0.301	-0.094	0.301
Fruits juice	-0.058	0.056	0.296	-0.169	0.052
Parsley	-0.505	0.264	0.047*	-1.027	-0.016
Thyme	0.118	0.068	0.082	-0.015	0.252
Garlic	-0.022	0.070	0.752	-0.160	0.116
Mint	-0.023	0.046	0.618	-0.113	0.067
Almond, pistachio, walnut	-0.061	0.072	0.401	-0.204	0.082
Apricots, figs, dates, raisins	0.062	0.060	0.302	-0.057	0.181
Sugar	-0.016	0.054	0.767	-0.122	0.090

parameters	B	Erreur standard	p value	Confidence interval (CI)	
				Lower bound	Upper bound
Cake and pastries	-0.080	0.062	0.196	-0.203	0.042
Fried food	-0.094	0.071	0.188	-0.234	0.046
Coffee	-0.021	0.056	0.713	-0.132	0.090
Tea	0.063	0.104	0.545	-0.143	0.270
Sweets	0.096	0.057	0.097	-0.017	0.210
Recommended protein intake	0.066	0.034	0.048*	-0.102	-0.004
Caloric intake on dialysis day	-0.001	0.000	0.121	-0.001	0.000
Protein intake on dialysis day	0.000	0.008	0.987	-0.015	0.015
Phosphorus intake on dialysis day	0.001	0.001	0.281	-0.001	0.002
Potassium intake on dialysis day	-0.514	0.091	0.971	-0.002	0.002
Calcium intake on dialysis day	0.000	0.001	0.517	-0.002	0.001
Caloric intake on normal day	0.000	0.000	0.387	0.000	0.001
Protein intake on normal day	-0.007	0.011	0.53	-0.029	0.015
Phosphorus intake on normal day	-0.001	0.001	0.461	-0.003	0.001
Potassium intake on normal day	0.106	0.264	0.689	-0.416	0.627
Calcium intake on normal day	0.001	0.001	0.232	-0.001	0.003

Statistical significance is indicated by asterisks ($p < 0.05$; ** $p < 0.01$; *** $p < 0.001$), with a significance level set at $p < 0.05$.

Linear regression analysis of obesity levels reveals varying effects of the different variables considered, with significant results for certain parameters.

Age and physical activity level showed no positive effect on obesity levels ($p > 0.05$).

For anthropometric data, BMI ($B=0.033$, $p=0.538$) had no significant impact on the level of obesity; however, visceral fat ($B=0.067$, $p=0.000$) had a significant

positive effect on the level of obesity. Conversely, body water ($B = -0.605$, $p = 0.000$) has a significant negative effect on the level of obesity. These effects are supported by a confidence interval that does not contain zero.

For biochemical data, hemoglobin ($B = -0.081$, $p = 0.328$), phosphorus ($B = 0.015$, $p = 0.116$), and calcium ($B = 0.011$, $p = 0.457$) have no impact on obesity levels; the p-values exceed the significance threshold,

suggesting that their effect on obesity levels is weak or not substantial.

With regard to dietary habits, the amount of salt added to food preparations ($B=0.251$, $p=0.246$), fluid intake ($B=0.115$, $p=0.530$), and consumption of dairy products ($B=-0.067$, $p=0.301$) did not have an impact on obesity levels; similarly, consumption of red meat ($B=0.079$, $p=0.223$), chicken consumption ($B=0.008$, $p=0.924$), fresh fish consumption ($B=-0.045$, $p=0.524$), and canned fish consumption ($B=-0.045$, $p=0.193$) do not have an impact on obesity levels. In particular, for the consumption of liver and offal ($B = -0.008$, $p = 0.936$), the consumption of eggs ($B = -0.059$, $p = 0.330$), the consumption of whole-grain bread and barley bread ($B = -0.044$, $p = 0.351$), consumption of white bread and semolina bread ($B = -0.013$, $p = 0.886$), and consumption of rice, pasta, potatoes, and legumes ($B = 0.093$, $p = 0.357$) do not have an impact on obesity levels; the p-values exceed the significance threshold.

The consumption of olive oil and sunflower oil ($B = -0.043$, $p = 0.728$) and the consumption of saturated fat ($B = 0.029$, $p = 0.626$) had no effect on obesity levels.

The consumption of fruit ($B = -0.008$, $p = 0.926$), the consumption of vegetables ($B = 0.104$, $p = 0.301$), and the consumption of fruit juice ($B = -0.058$, $p = 0.296$) had no impact on obesity levels. For herbs, the consumption of thyme ($B=0.118$, $p=0.082$), the consumption of garlic ($B=-0.022$, $p=0.752$), and the consumption of mint ($B=-0.023$, $p=0.618$) had no impact on obesity levels; however, the consumption of parsley ($B=-0.505$, $p=0.047$) had a significant negative effect on obesity levels. As for the consumption of dried fruits ($B=0.062$, $p=0.302$), the consumption of nuts ($B=-0.061$, $p=0.401$), and the consumption of added sugar ($B=-0.016$, $p=0.767$), these have no impact on obesity levels; similarly, consumption of cakes and pastries ($B = -0.080$, $p = 0.196$), consumption of sweets ($B = 0.096$, $p = 0.097$), and consumption of fried foods ($B = 0.094$, $p=0.188$) have no effect on obesity levels; similarly, coffee consumption ($B=-0.021$, $p=0.713$) and tea consumption ($B=0.063$, $p=0.104$) have no impact on obesity levels.

Regarding nutrient intake on the day of hemodialysis, calorie intake ($B = -0.001$, $p = 0.121$), protein intake ($B = 0.000$, $p = 0.987$), phosphorus intake ($B = 0.001$, $p = 0.281$), potassium intake ($B=0.514$, $p=0.971$), and calcium intake ($B=0.000$, $p=0.517$) had no impact on obesity levels.

Regarding intakes on a typical day, caloric intake ($B = -0.000$, $p = 0.387$), protein intake ($B = -0.007$, $p = 0.53$), phosphorus intake ($B = -0.001$, $p = 0.461$), potassium intake ($B = 0.106$, $p = 0.689$), calcium intake ($B=0.001$, $p=0.232$) have no impact on obesity levels; however, the recommended protein intake ($B=0.066$, $p=0.048$) has a significant positive effect on obesity levels.

DISCUSSION

The relationship between obesity and sociodemographic, nutritional, and anthropometric variables is complex and multifactorial, influenced by determinants such as socioeconomic status, educational level, and anthropometric indicators. The present study aims to investigate the relationships between levels of obesity and nutritional, anthropometric, and biochemical parameters, as well as overall health status, in patients with end-stage renal disease^{21,22,23}

The aim of this study is to analyze the associations between the degree of obesity and nutritional and biochemical parameters, as well as overall health status, in patients with end-stage renal disease undergoing hemodialysis.

In terms of sociodemographic characteristics, the prevalence of overweight and obesity was higher among men (38.5%) than among women (31.5%), although this difference was not statistically significant. Among all the sociodemographic variables examined, only the region of residence was significantly associated with obesity. These findings are partly consistent with those reported by the World Health Organization (WHO), which indicate a similar prevalence of overweight among men and women worldwide (39% and 40%, respectively), while obesity is more prevalent among women (15%) than men (11%)²⁴. Likewise, the MAREMAR study, conducted among more than 10,000 Moroccan adults, reported an overall obesity prevalence of 23.2% in the general population, with marked sex-related disparities. Specifically, obesity was significantly more common in women than in men (36.4% vs. 11.3%), and its prevalence also varied significantly across age groups⁹.

With regard to general health characteristics, a significant association was observed between obesity and disease duration. Similarly, *Mussnig et al.*, in a study conducted in Austria, reported that longer durations of maintenance hemodialysis were associated with higher body weight and body mass index (BMI)²⁵.

A significant association was observed between the underlying cause of kidney disease and obesity status. In our study, diabetes was identified as the primary etiology in 24.0% of obese patients, compared with only 2.5% of non-obese patients. This finding is consistent with previous studies highlighting the close relationship between diabetes and obesity among patients undergoing maintenance hemodialysis (MHD). In a retrospective study conducted in the United States, obesity was substantially more prevalent among diabetic than non-diabetic patients receiving MHD (64% vs. 40%). Furthermore, obese diabetic patients exhibited a significantly higher risk of mortality than their obese non-diabetic counterparts²⁶.

In contrast, *Afghahi et al.*, in a Swedish cohort of 3,235 diabetic patients receiving maintenance hemodialysis, reported that overweight and obesity were associated with improved survival. Compared with patients with a normal BMI (18.5–25.0 kg/m²), those with BMI values ranging from 25.1 to 40.0 kg/m² had a significantly lower risk of all-cause mortality, whereas underweight patients (BMI ≤18.5 kg/m²) had a significantly increased mortality risk²⁷.

A significant association was observed between obesity status and hypertension. In our study, hypertension was present in 23.0% of obese patients compared with 10.5% of their non-obese counterparts. This finding is consistent with previous studies reporting a close relationship between excess body weight and elevated blood pressure among patients undergoing maintenance hemodialysis. An Indonesian study demonstrated a significant positive correlation between body mass index (BMI) and blood pressure in hemodialysis patients²⁸. Likewise, an Italian study found that blood pressure variability (BPV) was significantly associated with obesity in this population, further supporting the relationship between hypertension and excess body weight²⁹.

Regarding anthropometric characteristics, BMI was strongly associated with obesity status. As expected, obese patients had significantly higher BMI values than non-obese patients, demonstrating a positive relationship between BMI and the degree of obesity. This finding is consistent with the prospective cohort study by Miyamoto et al. conducted in Japan, which identified BMI as a key indicator associated with obesity among patients undergoing maintenance hemodialysis³⁰.

Similarly, a retrospective study conducted in Brazil

reported that higher BMI was associated with improved survival in hemodialysis patients. Four-year survival rates increased progressively across BMI categories, from 58% in underweight patients to 70% in those with normal weight, 75% in overweight patients, and 80% in obese patients³¹.

Significant associations were observed between visceral fat accumulation and obesity status. Obese patients exhibited significantly higher visceral fat levels than non-obese patients, demonstrating a positive relationship between visceral adiposity and the degree of obesity. Furthermore, physical activity levels were also significantly associated with visceral fat accumulation. These findings are consistent with those of an observational study conducted in Spain, which reported that 38.9% of patients undergoing maintenance hemodialysis had a visceral fat area (VFA) ≥100 cm², including 29.6% of men and 54.5% of women, highlighting the high prevalence of visceral adiposity in this population and its close association with obesity³².

A significant association was observed between the waist-to-hip ratio (WHR) and obesity status in our study, indicating that central adiposity increased with the degree of obesity. These findings are consistent with those of a multicenter prospective cohort study conducted in China, which demonstrated that a low BMI combined with a high WHR was associated with a significantly increased risk of all-cause mortality in patients undergoing maintenance hemodialysis³³.

We found an association between body water and obesity level, highlighting a significant increase in body water among non-obese subjects, as well as a negative correlation and a negative effect with respect to obesity level. Similarly, a study conducted in South Korea revealed that high volume, as indicated by the edema index, is inversely associated with muscle mass and physical performance in hemodialysis patients, suggesting that an increase in body water content is correlated with a decrease in weight and physical capacity³⁴. Another Japanese study showed that the ratio of extracellular water to total body water in hemodialysis patients tends to decrease in obese individuals, indicating intravascular dehydration. This suggests a relationship between body water balance and weight status, reflecting changes in nutritional status and the difference between predetermined dry weight and optimal body weight³⁵.

In our study, we found no significant association between hemoglobin levels and obesity status. Similarly, a study conducted in Indonesia found no significant association between hemoglobin levels and obesity status in hemodialysis patients, suggesting that these parameters are independently influenced by various factors, despite the presence of the obesity paradox in some patients ³⁶.

With regard to dietary habits, a significant association was found between fluid intake and obesity levels, highlighting a positive correlation with obesity. Similarly, a study conducted in Indonesia revealed a strong correlation between adherence to fluid intake restrictions and weight gain between dialysis sessions among hemodialysis patients. More specifically, 87.5% of respondents were classified as not adhering to fluid intake restrictions, resulting in an average weight gain of 70.8% between dialysis sessions. Statistical analysis revealed a significant relationship, indicating that non-compliance with fluid intake recommendations has a negative impact on these patients' weight status, ultimately affecting their quality of life ³⁷.

A significant association between sugar intake and obesity levels has been identified. In contrast, a study conducted in Brazil found no significant association between sugar intake and interdialytic weight gain in hemodialysis patients ($p > 0.05$). Other food groups, including sugars, were not correlated with weight fluctuations ³⁸.

With regard to nutritional intake, a significant association was found between recommended energy intake and the degree of obesity, highlighting a significant increase in recommended energy intake among obese individuals, as well as a positive correlation. Similarly, *Boaz et al.* demonstrated that overweight or obese hemodialysis patients did not differ in terms of energy and macronutrient intake compared to normal-weight patients, indicating that there is no clear link between recommended energy requirements and the body weight status of hemodialysis patients. Compliance with dietary recommendations was generally low ¹¹.

A significant association was found between recommended protein intake and obesity levels, highlighting a significant increase in recommended protein intake among obese individuals, a positive correlation with obesity levels, and a positive effect on obesity levels. Similarly, a study conducted in the Netherlands on 115 hemodialysis patients revealed that protein requirements based on body weight were

significantly higher in obese hemodialysis patients ³⁹.

With regard to dietary habits and the intake of various nutrients on the day of hemodialysis, our results showed that 72% of patients had an insufficient caloric intake (60.5% of obese patients versus 11.5% of non-obese patients), while 21% of patients had a normal intake (8% of obese patients versus 13% of non-obese patients) and 7% had a high-calorie intake (5.5% of obese patients versus 1.5% of non-obese patients), clearly demonstrating a significant association between caloric intake and obesity. Regarding dietary habits and intake of various nutrients on a typical day, it was found that 79.5% of patients had an insufficient caloric intake (64.5% of obese patients versus 15% of non-obese patients), while 14% had a normal intake (3.5% of obese patients versus 10.5% of non-obese patients) and 6.5% of patients had a high-calorie intake (2% of obese patients versus 4.5% of non-obese patients), clearly demonstrating a significant association between caloric intake and obesity. In contrast, *Boaz et al.* demonstrated that overweight or obese hemodialysis patients did not differ from their normal-weight counterparts in terms of energy and macronutrient intake or the distribution of these nutrients in their diet. This suggests that caloric intake is not significantly associated with obesity rates among hemodialysis patients. Furthermore, regardless of their body weight, all patients showed poor adherence to the dietary recommendations of the International Society of Renal Nutrition and Metabolism, indicating the need to improve dietary compliance ¹¹. Another Taiwanese study found that insufficient dietary energy intake was significantly associated with a higher prevalence of obesity among hemodialysis patients. This suggests that lower caloric intake correlates with increased rates of obesity, underscoring the importance of adequate dietary energy intake for managing metabolic abnormalities and obesity in this patient population ⁴⁰.

A Moroccan study conducted in the Sidi Bennour region found that only 36.1% of hemodialysis patients met the recommended caloric intake, averaging 1,905.68 kcal/day—which is below the energy levels required for optimal health ⁴¹.

With regard to protein intake on the day of hemodialysis, it was found that 75.5% of patients had an insufficient intake (60.5% of obese patients, 15% of non-obese patients), while 5.5% of patients had a normal intake and 19% of patients had a high-protein intake (7.5% of

obese patients, 11.5% of non-obese patients), indicating a highly significant association between protein intake and obesity. For protein intake on a typical day, 78% of patients had an insufficient intake (59.5% of obese patients, 18.5% of non-obese patients), while 5% had a normal intake and 17% had an excessive protein intake (7.5% of obese patients, 9.5% of non-obese patients), indicating a highly significant association between protein intake and obesity. Similarly, a Turkish study found that protein intake among patients on maintenance hemodialysis was below recommended levels, which correlated with lower anthropometric measures such as BMI ⁴².

Regarding potassium intake on the day of hemodialysis, it was found that 9.5% of patients had a normal intake, while 90.5% had an excessive intake (64.5% of obese patients versus 26% of non-obese patients). Regarding potassium intake on a normal day, 11.5% of patients had a normal intake, while 88.5% had an excessive intake (65.5% of obese patients versus 23% of non-obese patients), revealing a significant association. In contrast, a systematic review conducted between 2014 and 2024 yielded mixed results regarding potassium intake and obesity, with some studies establishing a link between high potassium intake and reduced body weight and BMI, while others suggested an increased risk of obesity ⁴³. Another multicenter study conducted in Portugal found that adherence to a potassium-rich diet, such as the DASH diet, was not correlated with an increase in serum potassium levels, suggesting that potassium intake does not directly influence obesity rates ⁴⁴.

With regard to phosphorus intake on the day of hemodialysis, it was found that 25.5% of patients had a normal intake, while 74.5% had an excessive intake (51% of obese patients versus 23.5% of non-obese patients). For phosphorus intake, 24% of patients had a normal intake, compared with 76% who had an excessive intake (53% of obese patients versus 23% of non-obese patients).

Regarding calcium intake, 95% of patients had an insufficient intake on the day of hemodialysis (66% among obese patients, compared to 29% among non-obese patients). These results did not show a statistically significant association. Regarding calcium intake on a normal day, 98% of patients had an insufficient intake (68.5% of obese patients versus 29.5% of non-obese patients).

Analysis of the results shows that most participants have an insufficient intake of calories and protein, an excessive intake of potassium and phosphorus, and an insufficient intake of calcium. These results are similar to those of a study conducted in India, which found that 96.3% of hemodialysis patients did not adhere to dietary and fluid intake recommendations. Biochemical assessments classified 74.07% as low-risk and 25.92% as high-risk for non-compliance, highlighting that failure to meet recommendations is due to non-adherence to dietary guidelines ⁴⁵. *Fernandes et al.* demonstrated that effective dietary counseling improves adherence and biochemical parameters in patients ⁴⁵.

A study conducted in Saudi Arabia showed that non-adherence to nutritional recommendations among hemodialysis patients is common, influenced by factors such as gender, nationality, marital status, education, employment, and income. Female patients showed higher rates of non-compliance, while non-Saudi, older, married, educated, and employed patients demonstrated relatively better compliance ⁴⁶.

In our study, a non-significant association was found between physical activity and obesity levels. In contrast, a study conducted in Guinea showed that low physical activity among hemodialysis patients was significantly correlated with obesity ⁴⁷.

The results obtained in this study directly address the initial objective, highlighting significant associations between anthropometric parameters, nutritional intake, and certain dietary factors with the level of obesity in hemodialysis patients

CONCLUSION

This study highlights significant associations between anthropometric and body composition parameters (BMI, muscle mass, skeletal mass, visceral fat, and body water) and nutritional intake in hemodialysis patients. The results particularly emphasize the role of energy and protein intake in maintaining muscle mass and overall nutritional status, as well as the importance of fluid balance, which is closely linked to total body water and fluid intake.

Furthermore, certain specific dietary components, such as the consumption of sugar, garlic, and parsley, appear to be associated with variations in body parameters, suggesting the potential influence of qualitative dietary habits beyond mere quantitative intake. These

observations highlight the complexity of the interactions between nutrition, body composition, and clinical status in this population.

Taken together, these results underscore the need for individualized nutritional care in hemodialysis patients, incorporating energy and protein requirements, fluid intake control, and overall dietary quality. However, future longitudinal studies are needed to better understand causal relationships and optimize nutritional strategies in this clinical context.

Conflict of Interest

The authors declare no conflict of interest.

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Consent for Publication

This study was approved by the research authorities of Ibn Tofail University, Morocco, under the supervision of the Laboratory of Natural Resources and Sustainable

Development, Research Unit in Nutrition, Metabolism, and Physiology. Although the university does not have a formal ethics committee, the research protocol was reviewed and authorized by institutional guidelines. The study was conducted in full compliance with the ethical principles outlined in the Declaration of Helsinki. All participants gave their informed consent before inclusion, and all procedures were carried out with strict attention to privacy, confidentiality, and participant welfare.

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Authorship Contribution

Every author made a substantial contribution to the project in terms of its conception, design, or the use, collection, analysis, or interpretation of data, and/or all these respective areas. Each author contributed to the physical writing, editing, and/or reviewing of the article, provided their final written approval for the published version of the article, approved the choice of a journal in which the article will be published, and therefore will be responsible for all aspects of the project.

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