Muscle Mass Deficit Indexed to Body Surface Area Predicts Poor Physical Health and Quality of Life in Hemodialysis Patients

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Introduction. Hemodialysis patients experience significantly lower quality of life compared to the healthy individuals, largely due to symptoms such as bone pain, fatigue, pruritus, anorexia, inflammation, malnutrition, and anemia. This study aimed to investigate the effects of sarcopenia and low muscle mass on quality of life, with a particular focus on physical health indices.
Methods. The study included 62 patients on maintenance hemodialysis. Sarcopenia was diagnosed using the fat-free mass index (FFMI), defined as skeletal muscle mass divided by height squared (kg/m²). Additionally, skeletal muscle mass was normalized to body surface area (BSA); values below the sample mean of 46.12 kg/m² were classified as low muscle mass. Quality of life was assessed with the Kidney Disease Quality of Life (KDQOL) Version 1.3 questionnaire and scored using the KDQOL-SF™ Version 1.3 Scoring Program.
Results. Sarcopenia was present in 18 patients (29%) according to FFMI. Patients scored lowest in general health (35.6), energy/fatigue (40.9), and both SF-12 physical (37.5) and mental health (37.2) domains. Sarcopenic patients reported significantly higher pain scores (60.97 ± 29.54 vs. 46.19 ± 27.37; $P = .046$), but other domains did not differ. Patients with low muscle mass/BSA (kg/m^2) had lower sleep (51.5 ± 11.7 vs. 59.6 ± 13.0; $P = .01$), energy/fatigue (35.6 ± 20.1 vs. 52.8 ± 20.7; $P = .005$), and SF-12 physical health scores (35.7 ± 9.0 vs. 40.6 ± 8.3; $P = .03$). Muscle mass indexed to BSA was an independent predictor of the SF-12 physical health composite score.
Conclusion. Low muscle mass, particularly when indexed to BSA, is associated with reduced physical health in hemodialysis patients and poorer quality of life across multiple domains. BSA-indexed muscle mass showed stronger and more consistent associations than FFMI-based definitions.

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INTRODUCTION

Chronic Kidney Disease (CKD) remains a major public health challenge globally, with steadily rising prevalence and substantial associated morbidity and mortality. In Türkiye, the number of individuals requiring kidney replacement therapy increased from 324 per million population in 2001 to 1,016 per million in 2022, according to national registry data.[1] Among these individuals, those receiving maintenance hemodialysis (HD) frequently experience a wide range of distressing symptoms—including bone pain, fatigue, pruritus, anorexia, and depression—primarily driven by uremia, inflammation, malnutrition, anemia, and mineral and bone disorders. Consequently, the overall quality of life in patients with end-stage kidney disease (ESKD) is significantly lower compared to the general population,[2,3] and diminished quality of life has been independently associated with increased mortality in patients undergoing HD.[4] Recognizing its clinical relevance, routine quality of life assessments have been recommended by the United States Centers for Medicare and Medicaid Services.[5] Numerous factors such as advanced age, comorbidities (e.g., diabetes mellitus and hypertension), polypharmacy, symptom burden, inflammation, and malnutrition have been implicated in impaired quality of life among HD patients.[5]

Sarcopenia—a progressive and generalized skeletal muscle disorder associated with adverse outcomes such as falls, fractures, functional decline, and mortality—is particularly prevalent in this population.[6] Key contributors to sarcopenia include aging, physical inactivity, chronic inflammation, and protein-energy wasting, all of which are common in patients undergoing dialysis.[6]

Although sarcopenia is theoretically expected to contribute to reduced quality of life, previous studies have reported inconsistent findings regarding this relationship in HD populations. In particular, the clinical relevance of different muscle mass indices and their associations with quality of life remain inadequately explored. This study aimed to investigate the impact of sarcopenia and reduced skeletal muscle mass—standardized using different indexing methods—on the quality of life of patients undergoing maintenance hemodialysis, with a specific focus on physical health outcomes.

MATERIALS AND METHODS

This cross-sectional case-control study was conducted between April and November 2024 in the hemodialysis unit of Kahramanmaras Sutcu Imam University Faculty of Medicine Hospital. The study was initiated after obtaining ethical approval from the Kahramanmaras Sutcu Imam University local ethics committee with session number 2024/24 and decision number 06 dated 23.09.2024. All patients gave written informed consent. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion Criteria for the Study

Patients on chronic HD aged over 18 who were receiving hemodialysis treatment for at least six months at the Kahramanmaras Sutcu Imam University Medical Faculty Hemodialysis Unit were included in the study.

Exclusion Criteria from the Study

Patients under the age of 18, those with acute kidney injury, malignancies, muscle diseases such as muscular dystrophy, myasthenia gravis, polymyositis, patients who have been on HD treatment for less than 6 months, patients with congenital or acquired diseases of the musculoskeletal system (disability, etc.) were excluded from the study.

Method of Obtaining Demographic Data

Patients' demographic characteristics (e.g., age, sex), comorbid conditions (e.g., hypertension, coronary artery disease, diabetes mellitus), etiology of renal failure, medical history, duration of hemodialysis treatment, and current medications (including antidiabetic and antihypertensive agents) were collected through a review of medical records and patient-reported history.

Method of Obtaining Laboratory Data

Laboratory parameters—including urea, creatinine, sodium, potassium, calcium, phosphorus, LDL cholesterol, triglycerides, liver enzymes, C-reactive protein (CRP), Kt/V, urea reduction ratio (URR), albumin, uric acid, and others—were obtained from patients' medical records. These tests are routinely performed on a monthly basis and systematically documented in the clinical files as part of standard hemodialysis follow-up.

Health Related Quality of Life Survey

The KDQOL Version - 1.3 quality of life questionnaire[7] was administered to the patients two hours after a hemodialysis session. The obtained scores were entered into the KDQOL-SF™ Version 1.3 Scoring Program (v3.0) database for standardized analysis and interpretation. Quality of life scores for the following domains were obtained: Symptom/problem list (12 questions), Effects of kidney disease (8), Burden of kidney disease (4), Work status (2), Cognitive function (3), Quality of social interaction (3), Sexual function (2), Sleep (4), Social support (2), Dialysis staff encouragement (2), Overall health (1), Patient satisfaction (1), Physical functioning (10), Role limitations-physical (4), Pain (2), General health (5), Emotional well-being (5), Role limitations-emotional (3), Social function (2), Energy/fatigue (4), SF-12 Physical Health Composite, and SF-12 Mental Health Composite scores. The KDQOL Version-1.3 quality of life questionnaire has been translated into many languages, including Turkish, and is publicly available.[8] The Turkish reliability and validity of the KDQOL-SF 1.3 version of the scale were established by Yıldırım *et al.* in 2007.[9]

Diagnosis of Sarcopenia and Low Muscle Mass

Muscle mass measurements were performed by Bioelectrical-Impedance Analysis (BIA) using the Tanita DC 360 ST body analysis device. Prior to the measurement, patients were instructed to remove all electronic and metallic items (such as coins, money, mobile phones, watches, bracelets, etc.), as well as socks and shoes, before stepping onto the device. Muscle mass (kg), skeletal muscle mass (kg), Muscle ratio (%), fat mass (kg), fat ratio (%), mineral ratio (%), protein ratio (%), fluid ratio (%), lean body mass (kg) and bone mass (kg) were measured.

According to the EGSWOP 2 (European Working Group on Sarcopenia in Older People-2018), three criteria should be evaluated for the diagnosis of sarcopenia. These are 1. Low muscle strength, 2. Low muscle quantity or quality and 3. Low physical performance. Low muscle strength suggests sarcopenia but is not diagnostic. A definitive diagnosis is made by combining the 2nd criterion, decreased muscle quantity or quality, with low muscle strength. The presence of all three criteria indicates that sarcopenia is severe.[6] An appendicular skeletal muscle mass (ASM) of less than 20 kg in men and 15 kg in women, or a ratio of appendicular skeletal muscle mass to the square of height (appendicular skeletal muscle mass index-ASMI) of less than 7 kg in men and 5.5 kg/m^2 in women, indicates low muscle mass.

However, since our body composition device could not measure appendicular muscle mass, we used the fat-free mass index (FFMI), another criterion for low muscle mass.[10] Kawakami at al. showed that the FFMI is highly correlated with ASMI and suggested that the optimal FFMI cut-off values measured by BIA in the screening for low muscle mass were 17.5 kg/m^2 (sensitivity 89%, specificity 88%) for men and 14.6 kg/m^2 (sensitivity 80%, specificity 86%) for women.[10] Fat-free mass index was calculated by dividing fat-free mass by height squared.

In addition to the FFMI, a novel index was calculated by dividing the measured muscle mass by body surface area (BSA) to allow more accurate comparisons across individuals with varying body sizes, as BSA accounts for both height and weight. The Du Bois formula was used to calculate BSA:[11]

$$\text{BSA [m}^2\text{]} = 0.007184 \times \text{Height [cm]}^{0.725} \times \text{Weight [kg]}^{0.425}$$

Statistical Analysis

All statistical analyses were performed using SPSS software (IBM Corp. Released in 2020. IBM SPSS Statistics for Windows, version 27.0. Armonk, NY: IBM Corp). Continuous variables were tested for normality using the Shapiro–Wilk test and are presented as mean ± standard deviation or median (interquartile range), as appropriate. Categorical variables were expressed as frequencies and percentages. Between-group comparisons were conducted using the independent samples t-test for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Correlations between skeletal muscle mass indices and quality of life parameters were assessed using Pearson or Spearman correlation coefficients, depending on data distribution.

To evaluate factors independently associated with the SF-12 Physical Health Composite Score, multivariate linear regression analysis was performed. Variables with established associations with physical functioning and quality of life in hemodialysis patients, as supported by prior literature, were included in the regression model. Multicollinearity was assessed using variance inflation factors, and model assumptions were evaluated using standard diagnostic procedures.

Skeletal muscle mass was indexed using both fat-free mass index (FFMI) and body surface area (BSA). Given the absence of validated cut-off values for BSA-indexed muscle mass in hemodialysis patients, patients were stratified according to the sample mean value for exploratory analyses. This approach was adopted solely for hypothesis-generating purposes and not as a diagnostic classification.

Sample size was estimated by the use of previously published studies evaluating quality of life differences according to sarcopenia status in chronic disease populations.[12] However, due to the exploratory nature of the present study and the lack of hemodialysis-specific data with comparable methodology at the time of study design, a formal a priori sample size calculation tailored specifically to the hemodialysis population was not feasible.

All statistical tests were two-sided, and a *P*-value < .05 was considered statistically significant.

RESULTS

A total of 62 patients on chronic hemodialysis were included in the study. According to FFMI, sarcopenia was detected in 18 patients (29%), while 44 patients did not have sarcopenia. KDQOL Version - 1.3 scores of the patients are presented in Table 1.

Patients with sarcopenia had significantly lower body mass index (BMI) (21.99 ± 3.15 vs. 29.19 ± 5.13; *P* < .001), fat content (15.60 ± 8.53 vs. 27.75 ± 12.24; *P* < .001), uric acid (5.26 ± 1.03 vs. 5.92 ± 1.00; *P* = .016) and triglyceride levels (138 ± 55 vs. 197 ± 83; *P* = .005) than those without sarcopenia. Sarcopenic patients were younger (age 46.66 ± 17.16 vs. 58.00 ± 12.46 years; *P* = .012), and the male gender ratio was higher (M/F 13/5 vs. 19/25; *P* = .03). When KDQOL scores were compared, sarcopenic patients had higher pain scores (60.97 ± 29.54 vs. 46.19 ± 27.37; *P* = .046) and SF-12 Physical Health Scores (42.10 ± 9.68 vs 36.28 ± 8.22; *P* = .030) but other scores, including SF-12 mental scores, were not different in patients with and without sarcopenia (Table 2 and Supplementary Table 1).

The mean value of muscle mass/BSA of the patients was calculated as 46.12 kg/m^2 and patients below this value were considered to have low muscle mass and those above were considered to have normal muscle mass. The results are summarized in Table 3 and Supplementary Table 2. Patients

Table 1. KDQOL Version - 1.3 quality of life questionnaire results

Scale (Number of items in scale) n = 62	Mean	Median	SD
Symptom/problem list (12)	66.93	66.67	18.08
Effects of kidney disease (8)	53.76	56.25	18.32
Burden of kidney disease (4)	30.27	25.00	24.73
Work status (2)	7.03	0.00	19.65
Cognitive function (3)	43.96	43.33	27.44
Quality of social interaction (3)	39.27	40.00	21.32
Sexual function (2)	67.50	62.50	30.18
Sleep (4)	54.92	56.25	12.21
Social support (2)	68.23	66.67	28.44
Dialysis staff encouragement (2)	79.10	81.25	23.89
Overall health (1)	45.47	50.00	19.99
Patient satisfaction (1)	69.79	66.67	23.17
Physical functioning (10)	47.27	47.50	28.70
Role limitations--physical (4)	27.34	0.00	37.98
Pain (2)	48.91	45.00	28.06
General health (5)	35.63	35.00	20.40
Emotional well-being (5)	54.88	56.00	19.12
Role limitations--emotional (3)	20.83	0.00	36.85
Social function (2)	49.41	50.00	30.25
Energy/fatigue (4)	40.94	37.50	21.27
SF-12 Physical Health Composite	37.59	37.43	8.79
SF-12 Mental Health Composite	37.72	36.19	10.07

The numbers in parentheses indicate the number of questions that evaluate this subsection.

Table 2. Comparison of relevant demographic and laboratory parameters, BIA results and quality of life scales between routine HD patients with and without sarcopenia diagnosed based on FFMI. Additional data and subscales assessed are provided in Supplementary Table 1

	Sarcopenic Mean ± SD n = 18	Non-sarcopenic Mean ± SD n = 44	*P**
Age (year)	46.66 ± 17.16	58.00 ± 12.46	.012
Gender (Male/Female)	13/5	19/25	.03
BMI (kg/m^2)	21.99 ± 3.15	29.19 ± 5.13	< .001
SCr (mg/dL)	7.80 ± 2.19	8.13 ± 2.22	.647
DM(%)	22.25	36.4	.28
HT (%)	72.2	88.6	.11
Albumin (g/L)	3.78 ± 0.66	3.96 ± 0.30	.229
Bioimpedance Analysis Results			
Fat Percent (%)	24.48 ± 10.75	35.30 ± 12.17	.002
Fat Mass (kg)	15.60 ± 8.53	27.75 ± 12.24	< .001
Muscle percent (%)	71.65 ± 10.22	61.81 ± 11.07	.002
Muscle Mass (kg)	43.32 ± 7.71	47.28 ± 9.60	.147
Skeletal Muscle Mass (kg)	25.92 ± 4.74	28.13 ± 5.73	.198
Mineral Mass (%)	4.47 ± 1.39	4.12 ± 1.04	.310
Protein mass (%)	16.08 ± 8.45	17.36 ± 11.20	.804
Fat Free Mass (kg)	43.70 ± 10.41	49.65 ± 10.27	.078
Bone Mass (kg)	2.31 ± 0.39	2.50 ± .48408	.164
Fluid Percent (%)	49.40 ± 19.53	42.77 ± 17.14	.007
Handgrip strength (kg)	25.20 ± 8.28	31.57 ± 47.79	.317
Walking Speed (m/sec)	0.82 ± 0.42	0.79 ± 0.38	1.00
KDQOL questionnaire results some relevant domains			
Pain	60.97 ± 29.54	46.19 ± 27.37	.046
Energy/Fatigue	43.61 ± 22.21	43.29 ± 22.22	.864
SF12 Physical Health Composite Score	42.10 ± 9.68	36.28 ± 8.22	.030

BMI: Body Mass Index. BUN: Blood urea nitrogen. SCr: Serum Creatinine. DM: Diabetes Mellitus. HT: Hypertension
*Mann-Whitney U test

with low muscle mass were older (58.8 ± 13.4 vs. 49.6 ± 14.9 years; *P* = .01), had lower creatinine levels (7.2 ± 1.5 vs. 9.0 ± 2.4 mg/dl; *P* = .002), and higher KT/V and URR values. When quality of life scores were assessed, it was noticed that patients with low muscle mass had significantly lower sleep scores (51.5 ± 11.7 vs. 59.6 ± 13.0; *P* = .01), energy/fatigue scores (35.6 ± 20.1 vs. 52.8 ± 20.7; *P* = .005) and SF-12 physical health composite scores (35.7 ± 9.0 vs. 40.6 ± 8.3; *P* = .03).

Muscle mass/BSA was significantly and strongly correlated with the symptom/ problem list score (*P* = .03, r = 0.27), pain (*P* = .03, r = 0.27), energy/ fatigue (< 0.001, r = 0.45), sleep (*P* = .04, r = 0.25), and both SF-12 physical (*P* < .001, r = 0.45) and SF-12 mental health (*P* < .001, r = 0.45) scores. SF-12 physical score showed a strong inverse correlation with fat mass (*P* = .01, r = -0.3), fat percentage (*P* < .001, r = -0.47) and serum triglyceride (*P* = .004, r = -0.36) levels.

In the crude regression analyses, age (B = -2.15; *P* = .005), triglyceride levels (B = -0.04; *P* = .004), and muscle mass indexed to body surface area (BSA) (B = 1.21; *P* < .001) were each significantly associated with the SF-12 Physical Health Composite Score. However, in the multivariate regression model, only muscle mass/BSA (B = 1.07; *P* = .02) remained a statistically significant independent predictor, whereas the associations with age and triglyceride levels were no longer significant (Table 4 - Figure 1). The model we established in the regression analysis was a significant model (ANOVA *P* = .002; Durbin Watson: 1.95; Std Residual: -1.63 to 1.67 and Cooks Distance: 0.0001 to 0.12) and these parameters analyzed explained 29% of the change in the SF-12 physical composite score (Figure 1).

DISCUSSION

This study demonstrated that reduced skeletal muscle mass in hemodialysis (HD) patients is significantly associated with impaired quality of

Supplementary Table 1.

	Sarcopenic Mean ± SD n = 18	Non-sarcopenic Mean ± SD n = 44	*P**
HD vintage (Months)	54.05 ± 57.64	77.90 ± 65.13	.193
BUN (mg/dL)	50.3 ± 8.8	52.2 ± 14.1	.768
Na (mmol/L)	137.3 ± 2.8	137.4 ± 2.5	.969
K (mmol/L)	5.1 ± 0.522	5.2 ± 0.61	.484
Ca (mg/dL)	8.7 ± 0.527	8.5 ± 0.69	.565
P (mg/dL)	4.4 ± 1.4	5.1 ± 1.4	.141
PTH (pg/mL)	265.6 ± 210.7	447.4 ± 382.9	.107
Fasting Glucose (mg/dL)	134 ± 68	135 ± 94	.675
LDL cholesterol (mg/dL)	97 ± 52	97 ± 25	.340
TG (mg/dL)	138 ± 55.6	197 ± 83.8	.005
HDL cholesterol (mg/dL)	37 ± 10	36 ± 13	.509
CRP (mg/dL)	12.8 ± 14.7	12 ± 11.7	.254
Uric acid (mg/dL)	5.26 ± 1.03	5.92 ± 1.00	.016
KT/V	1.64 ± 0.15	1.58 ± 0.17	.197
URR (%)	74.38 ± 5.00	73.28 ± 6.39	.375
SBP (mmHg)	129.5 ± 22.6	136.3 ± 22.2	.174
DBP (mmHg)	83.11 ± 14.35	82.40 ± 12.66	.751
Handgrip strength (kg)	25.20 ± 8.28	31.57 ± 47.79	.317
Walking Speed (m/sec)	0.82 ± 0.42	0.79 ± 0.38	1.00
KDQOL questionnaire results except Pain, Energy/ Fatigue and SF-12 Physical Composite Score domains			
Symptom/Problem list	71.76 ± 13.56	66.14 ± 20.29	.328
Effects of kidney disease	56.77 ± 20.59	54.40 ± 17.88	.428
Burden of kidney disease	32.29 ± 29.49	31.81 ± 24.51	.839
Work Status	11.11 ± 27.41	6.81 ± 20.43	.558
Cognitive Function	44.44 ± 30.50	39.24 ± 25.56	.591
Quality of Social Interaction	41.48 ± 26.02	35.15 ± 17.57	.702
Sexual Function	78.12 ± 25.76	63.63 ± 31.84	.571
Sleep	56.66 ± 11.72	54.60 ± 13.42	.504
Social Support	67.59 ± 29.41	70.07 ± 27.03	.773
Dialysis Staff Encouragement	81.94 ± 18.79	77.27 ± 26.03	.746
General Health	48.88 ± 19.96	46.81 ± 20.88	.713
Patients Satisfaction	67.59 ± 22.48	69.31 ± 23.55	.792
Physical Functioning	55.55 ± 30.86	49.43 ± 29.05	.484
Role Physical	36.11 ± 44.73	22.15 ± 34.61	.277
General Health Perceptions	34.16 ± 16.73	36.59 ± 22.48	.797
Emotional Well Being	53.77 ± 19.46	57.00 ± 19.21	.437
Role Emotional	24.07 ± 42.48	22.72 ± 38.56	1.00
Social Function	58.33 ± 32.65	51.42 ± 30.04	.260
SF12 Mental Health Composite Score	37.96 ± 9.99	39.40 ± 10.14	.653

HD: Hemodialysis BMI: Body Mass Index, BUN: Blood urea nitrogen, Ca: Calcium, DBP: Diastolic Blood Pressure, K: Potassium, CRP: C-reactive protein, PTH: Parathyroid hormone LDL: Low Density Lipoprotein, HDL: High Density Lipoprotein, Na: Sodium, , P: phosphorus, SBP: Systolic Blood Pressure, TG: Triglyceride, URR: Urea reduction ratio
*Mann-Whitney U test

life, particularly in the domains of physical health, energy/fatigue, and sleep. While deterioration in quality of life is a well-recognized feature of end-stage kidney disease, the specific contribution of sarcopenia and muscle mass depletion remains incompletely understood. Our findings add to the existing literature by highlighting that the method used to index muscle mass substantially influences its observed relationship with patient-reported outcomes.

Assessment of quality of life in HD patients is of major clinical importance, as kidney replacement therapies aim not only to prolong survival but also to improve overall well-being. Previous

Table 3. Comparison of demographic data, laboratory parameters, BIA results and quality of life scales of chronic HD patients with Muscle Mass/BSA < 46.12 kg/m^2 and Muscle Mass/BSA > 46.12 kg/m^2. Additional data and subscales assessed are provided in Supplementary Table 2

	Muscle Mass/BSA < 46.12 kg/m^2 n = 34	**Muscle Mass/BSA > 46.12 kg/m^2 n = 28**	***P***
Age (year)	58.8 ± 13.4	49.6 ± 14.9	.01
Gender			
BMI (kg/m^2)	28.5 ± 5.4	25.3 ± 5.5	.02
SCr (mg/dL)	7.2 ± 1.5	9,0 ± 2.4	.002
Albumin (g/L)	3.9 ± 0.3	3.9 ± 0.5	.28
KT/V	1.68 ± 0.17	1.50 ± 0.12	< .001
URR (%)	75.7 ± 5.4	71.0 ± 5.6	< .001
Pain	45.9 ± 28.8	55.9 ± 27.7	.14
Energy/Fatigue	35.6 ± 20.1	52.8 ± 20.7	.005
SF12 Physical Health Composite Score	35.7 ± 9.0	40.6 ± 8.3	.03

BMI: Body Mass Index, BSA: Body Surface Area, SCr: Serum Creatinine, URR: Urea reduction ratio.

Supplementary Table 2.

	Muscle Mass/BSA < 46.12 kg/m^2 n = 34	**Muscle Mass/BSA > 46.12 kg/m^2 n = 28**	***P***
HD vintage (Months)	65.2 ± 66.2	77.8 ± 60.5	.29
BUN (mg/dL)	51.05 ± 14.2	52.4 ± 11.08	.66
Na (mmol/L)	137.2 ± 2.5	137.6 ± 2.6	.26
K (mmol/L)	5.2 ± 0.5	5.1 ± 0.5	.32
Ca (mg/dL)	8.5 ± 0.7	8.6 ± 0.5	.51
P (mg/dL)	4.8 ± 1.3	5.1 ± 1.6	.42
PTH (pg/mL)	363.2 ± 274.2	432.7 ± 427.1	.92
Fasting Plasma Glucose (mg/dL)	137.7 ± 84.9	131.2 ± 91.6	.59
LDL cholesterol (mg/dL)	103.2 ± 24.7	90.1 ± 43.9	.006
TG (mg/dL)	195.3 ± 87.8	161.2 ± 68.1	.10
HDL cholesterol (mg/dL)	39.5 ± 15	34 ± 8.5	.10
CRP (mg/dL)	13.1 ± 13.9	11.9 ± 10.6	.61
Uric acid (mg/dL)	5.5 ± 0.9	5.8 ± 1.1	.27
SBP (mmHg)	135.4 ± 27.5	132.9 ± 14.9	.53
DBP (mmHg)	80.3 ± 10.8	85.2 ± 14.9	.23
Symptom/Problem list	63.7 ± 19.8	72.6 ± 16.1	.07
Effects of kidney disease	53.0 ± 18.1	57.5 ± 19.0	.40
Burden of kidney disease	29.4 ± 27.2	35.0 ± 24.0	.31
Cognitive Function	40.7 ± 26.4	40.7 ± 28.0	.94
Quality of Social Interaction	31.9 ± 12.0	43 ± 26.2	.06
Sleep	51.5 ± 11.7	59.6 ± 13.0	.01
Social Support	69.6 ± 28.5	69 ± 26.7	.91
Dialysis Staff Encouragement	78.3 ± 27	79 ± 20,4	.74
General Health	46.7 ± 21.5	48.2 ± 19.4	.65
Patients Satisfaction	70.0 ± 23.4	67.2 ± 22.8	.59
Physical Functioning	45.8 ± 30.2	57.6 ± 27.6	.14
Role Physical	19.1 ± 34.2	34.8 ± 41.0	.08
General Health Perceptions	33.2 ± 19,5	39.1 ± 22.3	.30
Emotional Well Being	53.5 ± 18.9	59.1 ± 19.3	.25
Role Emotional	15.6 ± 33	32.1 ± 44.8	.11
Social Function	50.3 ± 33,2	57.1 ± 27.5	.39
SF12 Mental Health Composite Score	37.4 ± 8.8	40.9 ± 11.2	.18

HD: Hemodialysis BMI: Body Mass Index, BSA: Body Surface Area, BUN: Blood urea nitrogen, Ca: Calcium, Na: Sodium DBP: Diastolic Blood Pressure, CRP: C-reactive protein, K: Potassium, PTH: Parathyroid hormone, LDL: Low Density Lipoprotein, HDL: High Density Lipoprotein, Na: Sodium, P: phosphorus, SBP: Systolic Blood Pressure, TG: Triglyceride, URR: Urea reduction ratio

Table 4. Independent parameters predicting the SF-12 physical health composite scores

	Crude analysis				Adjusted			
	B	*P*	%95 Confidence Interval		B	*P*	%95 Confidence Interval	
			Lower limit	Upper Limit			Lower limit	Upper Limit
Age	-2.15	.005	-0.36	-0.06	-0.12	.11	-0.28	0.03
Creatinine	0.37	.48	-6.75	1.42	-0.54	.33	-1.67	0.58
TG	-0.04	.004	-0.06	-0.01	-0.02	.08	-0.05	0.004
KT/V	-8.59	.20	-21.8	4.6	2.47	.73	-12.12	17.06
Muscle mass/BSA	1.21	< .001	0.58	1.83	1.07	.02	0.16	1.97

BSA: Body Surface Area TG: Triglyceride.

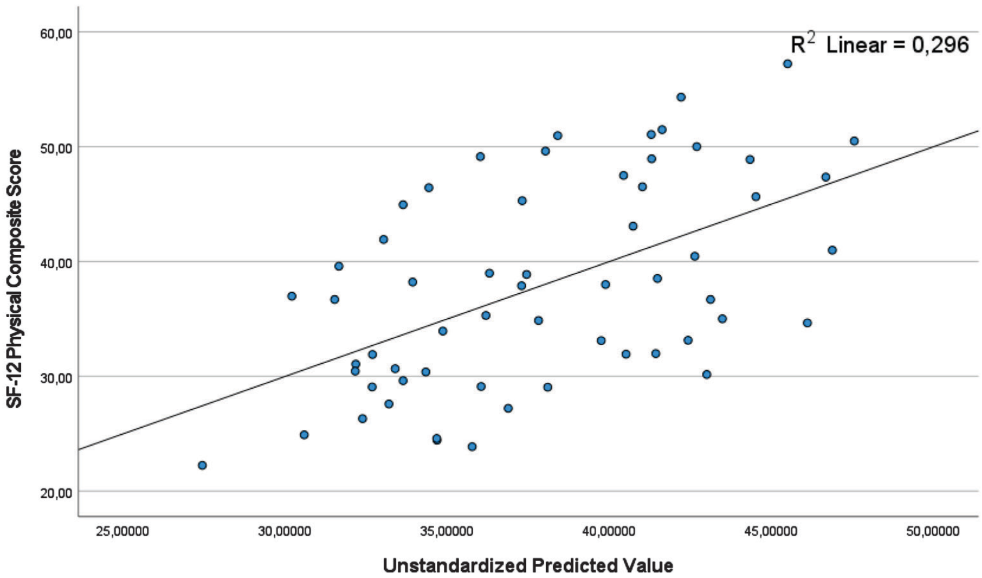

Figure 1. SF-12 physical health composite score prediction curve of the regression model.

studies have reported impaired quality of life in HD populations; however, methodological heterogeneity limits comparability across studies. For example, Kaner *et al.* reported an overall KDQOL score (mean KDQOL-36.1.3 score of 57.07 ± 18.98) in 74 HD patients and identified comorbidities as key determinants of quality of life such as cardiovascular disease and hypertension.[13] Nevertheless, the developers of the KDQOL instrument discourage the use of aggregated total scores due to the lack of validated interpretability.[14] Accordingly, in the present study, we analyzed individual KDQOL subdomains, with a particular focus on physical health–related outcomes, given their close link to muscle mass and functional status.

The mean SF-12 Physical Health Composite Score (PCS) in our cohort was consistent with values reported in large observational studies such as DOPPS.[15] Importantly, SF-12 PCS scores below 43 have been shown to be strong predictors of mortality and hospitalization risk in HD patients, with each unit decrease associated with an approximately 2% increase in this risk, underscoring the clinical relevance of our primary outcome.[16] Furthermore, another study demonstrated that patients in the lowest quartile of SF-12 PCS had a 93% higher mortality rate compared to those in the highest quartile.[17] In this context, the observed association between reduced muscle mass and lower SF-12 PCS supports the hypothesis that skeletal muscle depletion contributes to functional impairment and diminished quality of life in this population. Few studies have explored the relationship between sarcopenia and SF-12 PCS in this population. In non-HD older adults, Maccarone *et al.* observed that increased sarcopenia severity was correlated with modest but significant declines in SF-12 PCS.[18] In HD patients, Wu *et al.* reported a sarcopenia prevalence of 59.8% and found that sarcopenic patients had significantly lower scores across several

SF-36 subdomains, aligning with our findings.[19]

An unexpected finding of our study was that patients classified as sarcopenic according to fat-free mass index (FFMI) demonstrated higher SF-12 physical health scores, which contradicts our initial hypothesis. This paradoxical result is most likely attributable to confounding rather than a true protective effect of sarcopenia. In our cohort, FFMI-defined sarcopenic patients were significantly younger and had a higher proportion of males—both factors that are strongly associated with better physical functioning and higher SF-12 PCS scores.

Furthermore, FFMI may inadequately capture clinically relevant muscle depletion in HD patients, particularly in those with altered hydration status or increased fat mass, leading to potential misclassification. Taken together, these factors likely explain the unexpected direction of the association and further question the suitability of FFMI-based sarcopenia definitions in the hemodialysis population.

The limited performance of FFMI observed in our study highlights important methodological concerns. FFMI normalizes fat-free mass by height squared, an approach that may not accurately reflect muscle depletion in populations with heterogeneous body composition. Both FFMI and ASMI standardize muscle mass by height squared (kg/m^2), but recent literature questions whether this approach is optimal in specific populations, especially those with obesity. Kittiskulnam *et al.* tested several indices for muscle mass normalization—including height squared, weight, BSA, and BMI—and found no clear superiority in predicting survival.[20] However, they noted that height-based indexing underestimates sarcopenia in obese patients. Another analysis of the same cohort indicated that muscle mass normalized by height was less predictive of gait speed than BSA- or BMI-based indices.[21] Kim *et al.* also demonstrated that appendicular lean mass indexed by BSA showed strong correlations with multiple physical performance measures.[22] In HD patients, chronic inflammation, protein-energy wasting, and fluctuations in fluid status can substantially affect BIA-derived estimates of lean mass.[11] Fluid overload, in particular, may result in overestimation of fat-free mass and thereby obscure true skeletal muscle loss. Although measurements in our study were performed under standardized conditions, residual volume overload could not be entirely excluded. This limitation may have disproportionately affected FFMI-based classifications and contributed to misclassification of sarcopenia status.

In contrast, indexing skeletal muscle mass to body surface area (BSA) demonstrated more consistent and clinically meaningful associations with quality-of-life outcomes. BSA accounts for both height and body weight and is widely used in clinical nephrology, most notably in the estimation of glomerular filtration rate. In our cohort, muscle mass indexed to BSA was not only associated with multiple quality of life domains—including physical health, energy/fatigue, and sleep—but also emerged as the only independent predictor of SF-12 PCS in multivariate analysis. These findings suggest that BSA-based normalization may better capture functionally relevant muscle depletion in HD patients compared with height-based indices.

Limitations of the study

Nevertheless, the muscle mass/BSA cut-off value used in this study was derived from the sample mean and should not be interpreted as a validated diagnostic threshold. Due to the limited sample size and the absence of an established clinical gold standard for BSA-indexed muscle mass, more sophisticated approaches such as ROC-derived cut-offs were not methodologically robust. Therefore, BSA-indexed muscle mass should be regarded as an exploratory, hypothesis-generating measure. Larger, prospective studies are needed to validate this approach and to determine clinically meaningful cut-off values.

Finally, the cross-sectional design of this study precludes causal inference. The observed associations between muscle mass indices and quality of life outcomes should therefore be interpreted with caution and viewed as descriptive rather than causal. Longitudinal studies are required to clarify the temporal relationship between muscle mass decline and deterioration in quality of life in HD patients.

CONCLUSION

Sarcopenia and reduced skeletal muscle mass are common among patients undergoing maintenance hemodialysis and are associated with impaired quality of life, particularly in physical health–related domains such as energy and sleep. In this study, muscle mass indexed to body surface area showed more consistent associations with physical health scores than fat-free mass index–based definitions and emerged as an independent correlate of the SF-12 Physical Health Composite Score.

These findings suggest that body surface area–based normalization of muscle mass may better reflect clinically relevant muscle depletion in hemodialysis patients. However, given the cross-sectional design and methodological limitations, this approach should be regarded as exploratory. Further large-scale, prospective studies are required to validate BSA-indexed muscle mass and to establish clinically meaningful cut-off values before it can be recommended for routine clinical use.

DECLERATIONS

Ethical approval

Ethics approval was received from the local ethics committee of Kahramanmaras Sutcu Imam University, dated 23.09.2024, with meeting number 2024/24 and decision number 06.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

Written informed consent was obtained from all patients.

Competing Interest

The authors declare that they have no conflict of interest.

Data Availability Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

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