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Relationship between phase angle, nutritional status, and blood biochemical parameters in hemodialysis patients: an example study in Edirne city center*

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ABSTRACT

Aims: Phase angle (PA) is recommended as a noninvasive and objective index to make an assessment of hemodialysis patients' nutritional conditions. This study aimed to investigate the relationship of PA with nutritional status and blood biochemical parameters in patients on hemodialysis.

Methods: A descriptive and cross-sectional research design was employed. The study was conducted with 100 hemodialysis patients (mean±SD: 62.79±11.73 years) between February and July 2024. Data collection tools included a questionnaire about patients' descriptive characteristics, a 24-hour food record form, the Global Leadership Initiative on Malnutrition (GLIM) criteria, the Malnutrition Universal Screening Tool (MUST), the 7-point Subjective Global Assessment (7p-SGA) scale, and the Nutritional Risk Screening-2002 (NRS-2002) scale.

Results: Patients with or at risk of malnutrition, identified using GLIM, MUST, and 7p-SGA criteria, had significantly lower mean PA, than patients without malnutrition risk (p=0.001, p=0.008, p=0.004, respectively). According to NRS-2002 criteria, participants who were at risk of malnutrition and needed starting a nutrition plan had significantly lower mean PA than those requiring weekly NRS-2002 assessments (p=0.017). The association of PA with lean body-mass (r=0.257, p=0.010), muscle mass (r=0.264, p=0.008), TSF thickness (r=0.259, p=0.009) and albumin (r=0.313, p=0.002) was positive, weak or very weak, and statistically meaningful.

Conclusion: Hemodialysis patients with or at risk of malnutrition had lower PA values according to various assessment tools. This suggests that PA may function as a possible indicator for identifying nutritional deficiencies in hemodialysis patients without delay.

Keywords: Phase angle, nutritional status, biochemical parameters

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INTRODUCTION

Chronic renal failure (CRF) is a public health concern that is increasingly common worldwide, has links to above average levels of morbidity and mortality risks, and impacts quality of life adversely.[1] Protein energy wasting (PEW) in hemodialysis patients is defined as the loss of somatic and circulating body protein along with energy reserves and is a common complication.[2,3] Therefore, nutrition has critical importance in terms of the survival rates of patients. For this reason, studying hemodialysis patients' nutrition and detecting malnutrition are of critical significance to reduce mortality and morbidity.[4] Parameters indicating body composition, such as body-mass index (BMI), lean body-mass (kg), muscle percentage, total fat mass (kg), total fat percentage, and triceps skinfold (TSF) thickness and biochemical parameters, such as albumin, total protein, and C-reactive protein (CRP), are utilized to reveal nutritional status as objective indicators.[5]

In addition, the nutritional status assessment and screening tools, such as the Global Leadership Initiative on Malnutrition (GLIM) criteria, the Malnutrition Universal Screening Tool (MUST), the Nutritional Risk Screening-2002 (NRS-2002), and the 7-point Subjective Global Assessment (7p-SGA) scale, which are used to evaluate individuals, BMI, unintentional body weight loss, decreased muscle mass, changes in food intake, and functional capacity, provide an international standard for defining malnutrition.[6-8]

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Phase angle (PA), measured with BIA, has recently become a focus of interest as a noninvasive assessment method and an objective indicator of nutritional status.[3]

The BIA-measured PA reflects the body's resistance and response to an external current. PA is the most clinically relevant impedance parameter and an index of cell membrane integrity and viability. PA is a direct measure of BIA and therefore is not affected by assumptions that may involve body composition or hydration assessments. A lower PA level indicates reduced cell integrity or cell death, while a higher value indicates a large amount of intact cell membrane. Furthermore, PA has recently been utilized to assess the advancement of disease and predict clinical outcomes in many clinical situations.[3] Therefore, it has been shown as a reliable marker for the early detection of malnutrition in many clinical areas. A decrease in PA indicates a deterioration in nutritional status.[4]

Some studies have shown that PA values are lower in individuals with malnutrition and PEW, there is a link between these lower values and elevated malnutrition and PEW risk, and that PA functions as an independent predictor of these conditions.[7,9]

A review of the literature indicated that there was no study on the examination of the PA by using more than one nutritional screening tool. In the present study, four screening tools, namely GLIM, 7p-SGA, NRS-2002, and MUST, were used to investigate whether PA produced parallel results with these tools. In addition, the relationship between PA and anthropometric measurements, handgrip strength, biochemical parameters, energy, and nutritional indicators such as protein intake was evaluated. In this way, our study aimed to make a significant contribution to the literature by showing the usability of PA in nutritional status assessments with a broader perspective. As a result, we aimed to examine the association of PA with nutritional status and blood biochemical parameters in hemodialysis patients.

METHODS

Ethics

The study was approved by the Ethics Committee of Trakya University Faculty of Medicine (Date: 13.11.2023, Decision No: 17/37). Afterwards, to initiate the study in the specified hospitals, the necessary institutional approvals were taken (Trakya University Directorate of Health Research and Application Center [No: E-79056779-600-577279, approved on 5 January 2024] and Edirne Governorship Provincial Health Directorate [No: E-98308410-806.01-234001145, approved on 12 January 2024]). At the outset, individuals signed an informed consent form explaining the objective of the research. The Declaration of Helsinki was followed in the present research.

Study Design and Participants

This descriptive, cross-sectional study was conducted between February and July 2024 at the Trakya University Hospital Hemodialysis Unit, Edirne Sultan Murat I Hospital Dialysis Unit, and Private Diyamar Dialysis Center. The study included patients who could understand and speak Turkish, were aged ≥20 years, had CRF, were on standard four-hour three-days-a-week fashion hemodialysis treatment for six months or longer, gained ≤4 kg between two hemodialysis sessions, and had diabetes, hyperlipidemia, or hypertension or several of them. Patients who used antihypertensive drugs before hemodialysis, had amputations or physical or mental disabilities, received parenteral nutrition support during the study, were hospitalized for surgical or medical treatment within the last month, had active infection or rheumatic disease, had cancer, had endocrine diseases, such as liver disease, thyroid, parathyroid, or adrenal gland diseases, had neurological and psychiatric disorders, had chronic inflammation such as active hepatitis or HIV (+), had a history of ischemic heart disease, were scheduled for transplantation, had recently undergone transplantation and were on dialysis again, were pregnant or breastfeeding, or smoked or consumed alcohol were excluded from the study.

G*power 3.1.9 software was utilized to estimate sample size. According to the correlation analysis with a statistical power of 80% and a significance level of α=0.05 performed on G*power 3.1.9 software, the smallest sample size required to achieve an effect size of d=0.30 was calculated as 84, and the study was completed with 100 people.[10]

Measurements

The researchers gathered study data. A questionnaire form about the sociodemographic characteristics, dietary habits, body composition, and biochemical parameters, a 2-day 24-hour food consumption record form (non-dialysis day-dialysis day), the GLIM criteria, the MUST, the Subjective global assessment-7 point scale (SGA-7P), and the nutritional risk screening scale - 2002 (NRS-2002) were applied to the patients.

Before the study was initiated, a patient group of 15 was evaluated to ensure the consistency and accuracy of measurements. Anthropometric measurements of each patient were taken three times, and the averages of these measurements were included in the evaluation. In addition, the responses of the individuals to the nutritional status screening and assessment tools were collected with three different repeated measurements. All measurements were performed by a single expert who had education in the field to ensure the consistency and accuracy of measurements and to eliminate bias.

The descriptive characteristics form: This form consists of questions about gender, age, marital status, duration of kidney disease, and presence of accompanying diseases.

Anthropometric measurements and body composition: Patients' height values were measured with a stadiometer (Holtain, England), with the head in the Frankfort plane and the feet adjacent. The individuals' BMI (kg/m^2), lean body mass (kg), muscle mass (kg), body weight (kg), body fat mass (kg), and body fat percentage (%) measurements were taken using the Tanita MC-780 MA model bioelectrical impedance analyzer. BIA measurements were taken from the dry weights of the patients one hour after the hemodialysis session. Individuals' BMI values were evaluated with reference to the World Health Organization (WHO) categorization: <18.5 kg/

m², underweight; 18.5–24.9 kg/m², normal weight; 25-29.9 kg/m², overweight; and ≥30.0 kg/m², obese.[11]

The TSF thickness measurements of the patients were made in the sitting position by using a Holtain skinfold caliper. The skin and subcutaneous fat tissues were measured at the midpoint between the elbow and shoulder on the back of the arm by gently holding and compressing it with the thumb and index finger, and the value was recorded in millimeters.[8]

The PA measurements of the patients were made using a Tanita MC-780 MA model bioelectrical impedance analyzer. PA is the arctangent value calculated from the resistance and reactance obtained from the BIA and represents cellularity, cell membrane integrity, and cell function. The higher the PA value is, the better the patient's nutritional status is.[12]

The patients' hand grip strength (HGS) measurements were performed using a hand dynamometer (Camry) before dialysis (after at least five minutes of rest). First, patients sat on a chair and held their arms at a right angle (90°). The measurement was started with the arm with the least fistula or the dominant arm and then moved on to the second arm. A one-minute interval was left between each measurement. The evaluation was based on the mean value of three readings from the dominant hand.[13]

Biochemical parameters: The data regarding the blood biochemical parameters of the patients measured within the last month, such as total protein (g/dl), serum albumin (g/dl), CRP (mg/l) were obtained from medical records.

24-hour food consumption record: The 24-hour food consumption records of the patients were taken two times, one on the dialysis treatment day and the other on the day when there was no dialysis session. Participants delivered an account of everything they ate or drank during a certain period, which the researcher recorded on the relevant form. The mean energy consumption for these two days was calculated eventually. The energy and protein values taken with the daily diet were analyzed on the "computer-assisted nutrition information system (BeBis) full version 9".[14]

The Global Leadership Initiative on Malnutrition (GLIM): The leaders of the prominent clinical nutrition societies (ESPEN, ASPEN, Latin American Federation of Nutritional Therapy, Clinical Nutrition, and Metabolism (FELANPE), and Asian Parenteral and Enteral Nutrition Association (PENSA)] designed the GLIM diagnostic criteria by consensus. The aim of establishing the GLIM criteria was to provide global standardization in the diagnosis of malnutrition and to prevent delays in diagnosis and treatment.

GLIM criteria adopt a two-step approach to diagnosing malnutrition. In the first step, the nutritional risk is determined using a validated screening tool. In the second step, a comprehensive assessment is performed to diagnose malnutrition and grade its severity. The GLIM criteria include three phenotypic (unintentional weight loss, low BMI, and decreased muscle mass) and two etiological criteria (reduced nutrient intake or digestion and inflammation/disease burden). The diagnosis of malnutrition requires the presence of at least one phenotypic and one etiological criterion. The degree of malnutrition is then determined according to the phenotypic criteria and classified as moderate or severe.[15]

The Malnutrition Universal Screening Tool (MUST): The MUST was developed by the British Association for Parenteral and Enteral Nutrition (BAPEN) in 2003. It can be applied in the community, hospitals, and all other care settings to detect malnutrition, risk for malnutrition, and obesity in adults.[16]

The MUST consists of five steps and three sections used to question BMI, unintentional loss of body weight (in the last three to six months), and acute disorders. Each section is scored between 0 and 2: 0 points for a BMI value of >20 kg/m², 1 point for BMI value of 18.5-20 kg/m², and 2 points for a BMI value of <18.5 kg/m². If the weight loss is <5%, the score is 0; if it is 5-10%, the score is 1, and if it is > 10%, the score is 2 points. If there is no acute illness and the possibility of not being able to take food for the next >5 days, the score is 0 points, or 2 points otherwise. At the end of the evaluation, those who score 0 are classified as low risk, those who score 1 are classified as medium risk, and those who score ≥ 2 are classified as "high risk." A care plan is created according to the risk level.[16]

The 7-point Subjective Global Assessment (7p-SGA) scale: Churchill developed the subjective global assessment as a seven-point tool (SGA-7P).[17] Eminsoy et al.[18] studied the Turkish reliability and validity of this measure. Scoring with SGA-7P is done according to a standard protocol. Patients are evaluated by questioning their weight loss, food intake, gastrointestinal problems, muscle loss, and functional capacity in the last six months using a standard form. Scores are interpreted as follows: 7-6, well-nourishment; 5-3, mild to moderate malnourishment; and 2-1 malnourishment. Patients' malnutrition status is evaluated based on this classification.[18]

The Nutritional Risk Screening-2002 (NRS-2002): NRS-2002 was developed by an ESPEN study group led by Kondrup[19] in 2003, and it was adapted to Turkish by Başak Bolayır.[20] It was developed to screen nutritional risk in inpatients and to classify those likely to get the benefits of nutritional support.[20] During the application of this tool, individuals are first given a preliminary screening test. In this test, they are asked about their BMI value, loss of weight in the past three months, decrease in food consumption in the past week, and whether their condition is severe. "Yes" response to any of these items triggers the main screening section, or the preliminary screening is repeated at certain intervals if all items are answered "no." In the main screening section of the scale, nutritional status irregularity is evaluated according to the percentage of weight loss as none (0 points), mild (1 point), moderate (2 points), and severe (3 points). Disease severity is evaluated similarly to nutritional irregularity as none (0 points), mild (1 point), moderate (2 points), and severe (3 points). At the end of the test, the scores obtained from the main screening section are summed, and if the individual is over seventy years old, an extra 1 point is added due to age to calculate the total score. It is concluded that the individual has a risk of nutrition and it is necessary to start a nutritional care scheme in cases where the score is ≥3. The screening test should be done again at a certain frequency in cases where the score is <3.[19,20]

Statistical Analysis

Descriptive tests, such as number (n), percentage (%), mean, standard deviation (±sd), minimum (min.), and maximum (max.) values, were utilized in analyses. Kolmogorov-Smirnov test was utilized to test normality. In the comparison of the means of two independent groups, Student's t-test was applied in parametric distributions, and the Mann-Whitney-U test was employed in nonparametric distributions. Kruskal-Wallis H test was utilized in nonparametric distributions to make three-or more-group comparisons. Dunn's test, one of the post hoc tests, was employed to examine the source of significant differences obtained from comparisons of three or more groups, and the results were presented by performing Bonferroni correction. The relationship between two numerical variables was examined with Pearson's correlation analysis in parametric distributions and with Spearman's correlation analysis in nonparametric distributions. Data were analyzed on Statistical Package for the Social Sciences 26.0 (SPSS 26.0) software. Significance was set at p<0.05. Daily dietary energy and protein values were analyzed using the 'computer-supported nutrition information system' (BeBis) full version 9".[14]

RESULTS

Table 1 shows factual characteristics of the individuals. As seen in the table, average age was 62.79±11.73 years, 57.0% were male, and 93.0% were married. The average duration of participants' kidney disease was 10.37±12.65 years. Findings showed that 81.0% of the adults had an accompanying disease, with the most prevalent ones being hypertension (69.1%), diabetes (30.9%), and cardiovascular disorders (CVD) (16.0%) (**Table 1**).

Table 1. Distribution of participants' descriptive characteristics

Variables	n	%
Gender		
Female	43	43.0
Male	57	57.0
Age (mean±SD: 62.79±11.73, min.:33, max.: 89)		
Marital status		
Married	93	93.0
Single	7	7.0
Duration of the kidney disease (mean±SD: 10.37±12.65, min.: 1, max.: 72)		
Presence of accompanying diseases		
Yes	81	81.0
No	19	19.0
Accompanying diseases* (n=81)		
Hypertension	56	69.1
Diabetes mellitus	25	30.9
Cardiovascular diseases	13	16.0
Gastrointestinal diseases	18	22.2
Respiratory diseases	7	8.6
Hypothyroidism	4	4.9
Cancer	5	6.2

*Multiple options were marked, SD: Standard deviation

Table 2 shows the distribution of participants' body composition and biochemical parameters by gender. BMI was 25.82±5.50 kg/m² in females and 24.65±5.20 kg/ m² in males in average. The BMI classification of the participants was as follows: underweight, 10.0%; normal weight, 48.0%; overweight, 22.0%; obese, 20.0% (not shown in the table). The mean PA value was 5.17±1.18° in females and 5.58°±1.02° in males (**Table 2**).

Table 3 shows the comparison of participants' PA values according to the GLIM, MUST, 7p-SGA, and NRS-2002 criteria. According to the GLIM criteria, malnutrition was determined at stage 1 (moderate malnutrition) in 15.0% of the participants and stage 2 (severe malnutrition) in 11.0%. According to the MUST criteria, 9.0% of the participants were found to have a moderate risk and 21.0% a high risk. According to the 7p-SGA criteria, 10.0% of the participants were determined to have mild and moderate malnutrition. According to the NRS-2002 criteria, 16.0% of the participants had a nutritional risk, and therefore a nutritional plan needed to be initiated (**Table 3**).

The GLIM criteria and the PA yielded a statistically significant difference (p=0.000). When the source of the difference was examined, it was found that those with stage 1 malnutrition had statistically significantly lower mean PA values than those who were not at risk of malnutrition (p=0.001). The MUST criteria and the PA yielded a statistically significant difference (p=0.004). According to the source of this difference, those at high risk had statistically significantly lower PA values than those at low risk (p=0.008). According to the SGA-7P criteria, the mean PA values of those with mild and moderate malnutrition were statistically significantly lower than the mean values of those who were well-nourished (p=0.004). The mean PA values of the participants who had a nutritional risk according to the NRS-2002 criteria and who needed a nutritional plan were statistically significantly lower than the values of those who required weekly NRS-2002 evaluation (p=0.017) (**Table 3**).

The relationship between certain parameters and PA values is shown in **Table 4**. A positive weak or very weak statistically significant relationship was observed between PA and lean body mass (r=0.257, p=0.010), muscle mass (r=0.264, p=0.008), TSF thickness (r=0.259, p=0.009), and albumin (r=0.313, p=0.002) (**Table 4**).

DISCUSSION

The relationship of PA with nutritional status and blood biochemical parameters in patients receiving hemodialysis was investigated in the present research. The main findings revealed that PA was lower in individuals with or at risk of malnutrition and showed significant relationships with certain indicators of nutritional status.

In the current study, the mean PA value was found to be 5.17±1.18° in female and 5.58±1.02° in male patients on hemodialysis treatment. These values varied in the relevant literature.[7,21] These differences may have been due to confounding factors affecting the PA, characteristics of the study population (e.g., age, gender, ethnicity, nutritional status, presence of comorbidities), and the variety of BIA devices used.[22,23]

According to previous studies, PA is a valuable indicator reflecting hemodialysis nutritional status.[3,7] It is also thought

Table 2. Distribution of participants' body composition and biochemical parameters by gender

	Female (n=43)		Male (n=57)	
	Mean±SD	**Min.-max.**	**Mean±SD**	**Min.-max.**
BMI (kg/m²)	25.82±5.50	15.6-38.5	24.65±5.20	16.3-41.9
Lean body mass (kg)	45.34±7.90	28.7-69.0	58.73±7.88	43.8-77.9
Body fat mass (kg)	19.36±9.02	5.70-37.60	14.07±9.22	1.70-42.10
TSF thickness (mm)	27.78±6.01	15-39	27.45±5.90	10-37
PA (°)	5.17±1.18	1.8-7.7	5.58±1.02	3.4-7.8
HGS (kg)	16.91±6.83	2.8-30.0	28.90±12.22	7.8-49.7
Total protein (g/dl)	6.78±0.55	5.30-8.40	6.65±0.52	5.80-8.20
Albumin (g/dl)	3.82±0.34	2.90-4.60	3.92±0.36	3.00-4.70
CRP (mg/L)	14.33±23.81	0.30-122.00	11.23±13.65	0.30-59.60
Daily protein intake (g/kg/day)	0.67±0.37	0.14-1.98	0.80±0.41	0.23-2.16
Daily energy intake (kcal/kg/day)	17.63±8.76	5.40-47.25	20.67±8.93	5.80-54.89

*BMI: Body-mass index, TSF: Triceps skinfold, PA: Phase angle, HGS: Hand grip strength, CRP, C-reactive protein, SD: Standard deviation, Min: Minimum, Max: Maximum

Table 3. Comparison of participants' PA values according to GLIM, MUST, SGA-7P, and NRS-2002 criteria

	n	%	Phase angle	
			Mean±SD	**p-value**
GLIM[#]				
Not at risk[a]	74	74.0	5.64±1.08	0.000***
Stage 1 malnutrition (moderate malnutrition)[b]	15	15.0	4.57±0.84	
Stage 2 malnutrition (severe malnutrition)	11	11.0	4.95±0.92	
MUST[#]				
Low risk (routine clinical care)[c]	70	70.0	5.64±1.10	**0.004****
Moderate risk (monitoring)	9	9.0	4.94±0.87	
High risk (treatment)[d]	21	21.0	4.83±0.95	
7p-SGA[#]				
Well-nourishment	90	90.0	5.51±1.09	**0.004****
Mild to moderate malnutrition	10	10.0	4.48±0.77	
NRS-2002[##]				
NRS assessment weekly	84	84.0	5.50±1.08	**0.017***
Nutritional risk; nutrition plan should be started	16	16.0	4.88±1.13	

Kruskal-Wallis H test; ## Mann-Whitney U test; Post Hoc Dunn's test. Phase angle: b<a, d<c; *p<0.05, **p<0.01, ***p<0.001. PA: Phase angle, GLIM: Global Leadership Initiative on Malnutrition, MUST: Malnutrition Universal Screening Tool, 7p-SGA: 7-point Subjective Global Assessment, NRS-2002: Nutritional Risk Screening Scale-2002, SD: Standard deviation

Table 4. Correlation between participants' certain parameters and PA values

Parameters	Phase angle (PA)	
	r	**p**
BMI (kg/m²)[1]	0.158	0.116
Lean body mass (kg)[2]	0.257	**0.010***
Muscle mass (kg)[2]	0.264	**0.008****
Body fat mass (kg)[1]	0.076	0.225
Body fat percentage (%)[2]	0.159	0.114
TSF thickness (mm)[2]	0.259	**0.009****
HGS (kg)[1]	0.164	0.103
Total protein(g/dl)[1]	0.055	0.587
Albumin(g/dl)[1]	0.313	**0.002****
CRP (mg/L)[1]	-0.095	0.345
Mean daily protein intake (g/kg/day)[1]	0.038	0.705
Mean daily energy intake (kcal/kg/day)[2]	0.126	0.210

*BMI: Body-mass index, TSF: Triceps skinfold, PA: Phase angle; HGS: Hand grip strength, CRP: C-reactive protein,[1]Spearman's correlation analysis; [2]Pearson's correlation analysis; r: Correlation coefficient; *p<0.05, **p<0.01, ***p<0.001.

that fluid and electrolyte imbalances in hemodialysis patients may affect BIA readings, leading to a false diagnosis of malnutrition, whereas PA calculations involving normalization of reactance by resistance may be less affected by excess fluid. Therefore, it has been suggested that PA has the potential to be a screening norm for diagnosing malnutrition in this patient group.[7] Composite or non-composite nutritional indices have been used in previous studies to examine the connection of PA with nutritional condition in hemodialysis patients.[3,21] However, it has been suggested that the lack of a standard definition of malnutrition and the use of different indices to assess nutritional status may affect the variability of PA and nutritional condition associations.[24] In this context, in the present study, we examined the relationship between PA and malnutrition assessment criteria, such as GLIM, MUST, NRS-2002, and SGA-7P, as well as the relationship of PA with other indicators, such as body composition, anthropometric measurements, biochemical parameters, dietary intake, and HGS, which is a functional measurement.

In the present study, the mean PA values of individuals determined to be at risk of malnutrition or malnourished based on the NRS-2002, the GLIM, and SGA-7P criteria were lower than the values of those not at risk or not malnourished. In addition, individuals in the high-risk group evaluated with MUST had lower mean PA values than those in the low-risk group. These findings were consistent with previous studies in the literature. Some studies have shown that PA values are lower in individuals with malnutrition and PEW, these lower values are associated with increased malnutrition and PEW risk, and that PA is an independent predictor for these conditions.[7,9] It is known that PA has a positive relationship with lean body mass and a negative one with extracellular/intracellular fluid ratio. Malnutrition is characterized by the premature transfer of fluids from the intracellular to the extracellular space, an increase in the extracellular/intracellular fluid ratio, and a concomitant decrease in body cell mass, with these changes emerging as a decrease in the PA.[25] This provides a potential explanation for why the PA may be an indicator of malnutrition.

In the present study, PA was identified to have a positive correlation with muscle percentage and lean body-mass in hemodialysis patients. It also had a significant positive relationship with TSF thickness, an indicator of body fat mass. However, the positive relationships between PA and fat mass and fat percentage assessed by BIA did not reach statistical significance. In the literature, the relationships between PA and muscle percentage and lean body mass were similar to the findings of our study.[23,26] Muscle cells conduct electricity well as they have high levels of electrolyte and fluid content, while showing above average reactance because of the capacitive properties of their cell membranes. These properties cause reactance to increase and resistance to decrease with increasing muscle mass, which is reflected as a higher PA value.[27] On the other hand, body fat mass, which is a poor conductor of electricity due to its low water content and leads to higher resistance, might be expected to cause a decrease in PA. However, the direction and strength of the relationships between PA and body fat mass appear to depend on population characteristics (age, sex, health status, etc.).[28] Taken together, these findings suggest that PA may reflect nutritional status through lean body mass rather than body fat mass.

A positive relationship was found between PA and albumin in the present study. Most previous studies also showed results consistent with these findings.[3,21] A decrease in albumin levels is considered an important indicator of malnutrition and may contribute to changes in PA. However, it should be kept in mind that low albumin levels may reflect not only nutritional status but also factors such as inflammation and fluid overload, which may also affect PA.[29] Consistent with previous studies, no significant relationship was found between PA and CRP.[9,21,25]

The association between BMI and PA was not meaningful in this study. Similar results were shown in previous study.[26] This suggests that BMI may be an inadequate indicator of cell health due to its limited ability to distinguish between lean body mass and body fat mass.[30] However, contrary to our study, some studies indicated a positive relationship between PA and BMI.[3,7,9] It has been suggested that increasing BMI may an increase the number of fat or muscle cells and that this increase in cellular mass may affect the reactance associated with the amount of cell membrane, resulting in higher PA values.[9]

To our surprise, the findings of this study revealed that PA did not have a significant correlation with dietary energy and protein intake. These results were consistent with the results of a previous study, in which it was claimed that daily dietary intake variances might have weakened these relationships. It was seen that PA was less successful in revealing dietary energy and protein intake, but it could still detect PEW.[31]

Many previous studies have shown a positive relationship between HGS an indicator of muscle strength, and PA.[3,23] However, despite the positive correlation between muscle percentage and PA, the association of HGS with PA was not meaningful in the present study. This suggests that increases in body muscle mass and therefore PA do not always increase in parallel with muscle strength. In fact, similar results were shown in a previous study involving peritoneal dialysis patients. The authors stated that muscle strength was affected not only by body muscle percentage but also by a number of factors, such as electrolyte imbalances, anemia, heart diseases, neurological problems, and mental status. They also emphasized that the annual decline rates between muscle strength and body muscle percentage were different and that the relationship between HGS and PA was the result of a complex and multifactorial interaction.[27]

Limitations

This study has several limitations that should be noted. First, despite including all institutions/centers providing dialysis services in the Edirne province of Turkiye, it had a relatively small sample size. This limits the generalizability of the findings to larger hemodialysis patient populations. Multicenter studies with larger sample sizes are needed to ensure the generalizability of our findings to larger patient populations. Additionally, the exclusion of patients with clinical factors that were likely to have an impact on nutritional status was intended to reduce the potential impact of these factors on the results. However, this may limit the applicability of the study findings to larger hemodialysis populations. In future studies, doing subgroup analyses by including larger and more heterogeneous patient groups to overcome the limiting effects of the exclusion criteria and controlling the effects of clinical factors may increase the generalizability of the findings. Second, the cross-sectional design of our study limits the determination of causal relationships between PA and the indicators of nutritional status. Longitudinal studies are needed to better understand these relationships. Finally, confounding factors that may affect PA (e.g., age, gender, ethnicity, nutrition, and presence of comorbidities) may have influenced our results. In future studies, careful control and statistical modeling of such factors will increase the validity of the results.

CONCLUSION

This study revealed that PA may be an important biomarker in the assessment of nutritional status in hemodialysis patients. The results showed that patients classified as malnourished or at risk of malnutrition according to various assessment tools (GLIM, MUST, NRS-2002, and SGA-7P) had lower PA values. This suggests that PA may serve as a potential indicator for the early detection of nutritional deficiencies in this patient population. In addition, PA was found to be associated with some indicators related to albumin and body composition. However, the fact that it did not show a significant relationship with other biochemical and functional nutritional parameters suggests that PA focuses on aspects different from traditional measures in the assessment of nutritional status and can be used as a complementary tool. In conclusion, PA may serve as a valuable biomarker in determining nutritional status-related risks and supporting nutritional management in hemodialysis patients. It is recommended that future studies with larger samples take into account the effects of confounding factors, the effect of PA on clinical outcomes be further examined, the potential use of this measure be expanded, and its importance in clinical practice be increased.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was approved by the Ethics Committee of Trakya University Faculty of Medicine (Date: 13.11.2023, Decision No: 17/37).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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