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Determinants of muscle mass in hemodialysis patients: the role of BMI, MUAC, and MAMC

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ABSTRACT

Background: Previous experimental research on oral nutritional support formulas made from snails, tempeh, and moringa leaves, which are high in protein and calcium, has been reported to increase muscle mass in hemodialysis patients. However, further research is needed to analyze the factors that influence muscle mass in hemodialysis patients.
Objective: To analyze factors that influence muscle mass in hemodialysis patients.
Materials and Methods: This study was an observational study with a cross-sectional design. The study was conducted at Panembahan Senopati Bantul Hospital. The research sample was taken using a purposive sampling technique. The inclusion criteria for the study included being 18 years of age or older, undergoing routine hemodialysis 2 times a week, having received nutritional counseling, patients being able to stand, and being able to be measured anthropometrically. The exclusion criteria of the study were patients with anasarca edema, and patients whose muscle mass and bone mass could not be measured using bioelectrical impedance analysis (BIA). Independent variables suspected of influencing muscle mass included body mass index, mid-upper arm circumference (MUAC), triceps skinfold, mid-arm muscle circumference (MAMC), duration of hemodialysis, duration of hemodialysis, energy intake, protein intake, fat intake, carbohydrate intake, vitamin C intake, iron intake, and zinc intake. Research instruments include BIA/Bioelectrical Impedance Analysis to measure muscle mass, digital body scales with a scale of 0.1 kg, microtoise, metline, informed consent questionnaire, SQ-FFQ (Semi-Quantitative Food Frequency Questionnaire), CRF (Case Report Form), and research activity recording form. Data were analyzed univariately, bivariately, and multivariately.
Results: The analysis showed that the relationship between BMI, MUAC, and MAMC with muscle mass showed P values=0.025; p values <0.05.
Conclusion: BMI, MUAC, and MAMC factors have a significant relationship with muscle mass. The higher the BMI, MUAC, and MAMC, the higher the muscle mass.

Keywords: Body mass index; hemodialysis patients; mid-upper arm circumference (MUAC); mid-arm muscle circumference (MAMC); muscle mass

BACKGROUND

Malnutrition in routine hemodialysis patients can cause decreased body immunity, resulting in problems with wound healing, prolonged recovery period, impaired quality of life, fatigue, malaise, increased length of hospitalization, and reduced muscle mass.[1,2,3] Muscle mass, along with bone mass and water mass, is part of the lean body mass that correlates with body mass index.[4] The body composition of hemodialysis patients is reported to be better measured using muscle mass indicators, which represent lean mass. Better survival of hemodialysis patients is reported to be largely due to a higher percentage of lean body mass.[5]

Long-term routine hemodialysis can cause muscle wasting or muscle shrinkage.[6,7] Muscle loss in hemodialysis patients is associated with protein hypercatabolism, systemic inflammation, decreased protein synthesis, and decreased oxygen extraction, causing disruption of protein homeostasis in the body.[8,9]

The previous study reported that the provision of an oral nutritional support formula made from modified field snails, tempeh, and moringa leaves can significantly increase muscle mass in the intervention group subjects by 2.5% compared to the control group. The oral nutritional support formula has a high protein and high calcium content.[10] Consumption of foods high in animal protein in hemodialysis patients can prevent and reduce the incidence of protein energy wasting (PEW).[11] However, the results of this study were reported to have limitations, namely that they were not accompanied by mid-upper arm circumference (MUAC) and mid-arm muscle circumference (MAMC) measurements. Higher MUAC values in hemodialysis patients were

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reported to be associated with lower mortality.[12] Additionally, lower limb lean area (LLA) was reported to have a significant impact on mortality, but MAMC measurements were reported to be an accurate predictor of mortality in hemodialysis patients.[13,14] This study aimed to determine the factors affecting muscle mass in hemodialysis patients.

MATERIALS AND METHODS

This study was an observational study with a cross-sectional design. The study was conducted in March-August 2024 at Panembahan Senopati Bantul Hospital. The study population was patients undergoing routine hemodialysis at the Hemodialysis Unit of Panembahan Senopati Bantul Hospital, totaling 350 people. The study samples were taken using a purposive sampling technique. The inclusion criteria for the study included a willingness to be a respondent, aged 18 years or older, undergoing routine hemodialysis 2 times a week, having received nutritional counseling, patients being able to stand, and being able to be measured anthropometrically. The inclusion criteria for selecting respondents with twice-weekly hemodialysis were created to minimize bias related to the hemodialysis process. The exclusion criteria for the study were patients with anasarca edema, and patients whose muscle mass and bone mass could not be measured using BIA. The minimum sample size was 78 people, calculated using the Slovin formula, with a significance level of 90%.

The research variables consisted of independent variables and dependent variables. Independent variables that were suspected of affecting muscle mass include BMI, MUAC, triceps skinfold, MAMC, duration of hemodialysis, duration of hemodialysis, energy intake, protein intake, fat intake, carbohydrate intake, vitamin C intake, iron intake, and zinc intake. Research instruments include BIA/Bioelectrical Impedance Analysis with the TANITA brand to measure muscle mass, digital body scales with a scale of 0.1 kg, microtoise, metlin, informed consent questionnaire, SQ-FFQ (Semi-Quantitative Food Frequency Questionnaire), CRF (Case Report Form), and research activity recording form.

The muscle mass variable is defined as the amount of muscle mass of respondents measured using the TANITA brand BIA. The percentage of muscle mass category is based on the Instruction Manual-Body Composition Monitor Model HBF-375 Karada Scan, the percentage of muscle mass is categorized based on gender and age. The normal muscle mass category in women aged 18–38 years is 24.3–30.3%, 40–59 years is 24.1–30.1%, 60–80 years is 23.9–29.9%. The normal muscle mass category in men aged 18–38 years is 33.3–39.3%, 40–59 years is 33.1–39.1%, 60–80 years is 32.9–38.9%.[15] The muscle mass variable in this study used a ratio scale with % parameters. Body mass index was defined as body weight in kilograms divided by height squared in meters, the body weight used is post-hemodialysis body weight, with a ratio scale. MUAC was defined as the magnitude of the respondent's MUAC measurement results measured during post-hemodialysis, with a ratio scale. Triceps skinfold was defined as the magnitude of the respondent's triceps fat thickness measurements measured during post-hemodialysis, with a ratio scale. MAMC was defined as the magnitude of the respondent's MAMC calculated using the formula MAMC = MUAC – (3.14 x triceps skinfold). The hemodialysis period was the length of time the respondent underwent hemodialysis since the first hemodialysis, with a ratio scale. Duration of hemodialysis was the length of time the respondent undergoes one hemodialysis process, with a ratio scale. Intake was defined as the average amount of daily intake consumed by the respondent from food and drink, taken using the Semi-quantitative Food Frequency Questionnaire (SFFQ) method, compared to individual needs and presented. Intake data in this study was presented using % parameters and a ratio scale. The intake analyzed in this study included energy, protein, fat, carbohydrate, vitamin C, iron, and zinc intake.

The data of this study used primary data and secondary data. Primary data taken through direct measurement process to patients include post-hemodialysis weight, height, MUAC, triceps fat thickness, MAMC, duration of hemodialysis, duration of hemodialysis, energy intake, protein intake, fat intake, carbohydrate intake, vitamin C intake, iron intake, zinc intake, and muscle mass. Informed consent, Case Report Form data collection, and SQ-FFQ were carried out during the hemodialysis process. Anthropometric measurements were carried out after the hemodialysis process was completed (post-hemodialysis). Secondary data used in this study were taken from medical records, including respondent identity data, and hemodialysis history.

Data were processed according to the variable scale. Categorical variable data were edited, scored, entered, tabulated, and then analyzed. Numerical scale data were tested for data normality first using the Kolmogorov-Smirnov test, then analyzed univariately and bivariately. All data in this study were not normally distributed, so bivariate analysis used the Spearman Rank Test. The analysis was continued multivariately using multiple linear regression tests, for variables with significant bivariate analysis results. This research has obtained Ethical Clearance from the Health Research Ethics Commission, Faculty of Health Science, Universitas Respati Yogyakarta No: 055.3/FIKES/PL/V/2024 dated 31 May 2024.

RESULTS

The study involved 78 patients as respondents selected using a purposive sampling technique. Researchers selected prospective respondents who met the inclusion and exclusion criteria based on medical records. Researchers approached prospective respondents one by one to provide explanations related to the study and conduct informed consent. A total of 78 respondents were interviewed during the hemodialysis process to fill out the case report form. Anthropometric measurements were taken post-hemodialysis, approximately 30 minutes after the hemodialysis process was complete. Anthropometric data measured included body weight, height, MUAC, triceps skinfold, and muscle mass. The distribution of respondents based on research characteristics is shown in Table 1.

Table 1. Distribution of Respondents Based on Research Characteristics

Characteristics	Category	n	%
Gender	Man	41	52.6
	Woman	37	47.4
Total		**78**	**100.0**
Age	18-59 years	59	75.6
	≥60 years	19	24.4
Total		**78**	**100.0**
Education	College Graduate	8	10.3
	Secondary education graduate	67	85.9
	No school	3	3.8
Total		**78**	**100.0**
Job	Working	39	50.0
	Not working	39	50.0
Total		**78**	**100.0**
Etiology of hemodialysis	Hypertension	51	65.4
	Diabetes mellitus	12	15.4
	Kidney stones	4	5.1
	Kidney trauma	1	1.3
	Cyst	2	2.6
	Gout	1	1.3
	Consume herbal medicine or energy drinks	3	3.8
	Urinary tract infection	2	2.6
	Dehydration	2	2.6
Total		**78**	**100.0**
Consumption of albumin supplement	Yes	7	9.9
	No	71	91.0
Total		**78**	**100.0**

Based on Table 1, it can be reported that most of the respondents in this study were male, aged 18-59 years, and had attended elementary school to high school. The number of respondents who worked was the same as the respondents who did not work. The cause of hemodialysis in most respondents in this study was hypertension, followed by diabetes mellitus as the second cause. Most respondents did not consume albumin supplements.

Researchers analyzed the factors that affect muscle mass in hemodialysis patients, by first conducting univariate analysis on each variable, followed by bivariate analysis and multivariate analysis. Factors suspected of affecting muscle mass in hemodialysis patients in this study include body mass index, MUAC, triceps fat thickness, MAMC, duration of hemodialysis, duration of hemodialysis, energy intake, protein intake, fat intake, carbohydrate intake, vitamin C intake, iron intake, zinc intake. The results of the univariate analysis are shown in Table 2.

Table 2. Results of Data Normality Analysis for Each Variable (n=78)

Variable	Mean ± SD	Med (min-max)	p-value
BMI (kg/m^2)	-	21.75 (16.00-33.80)	0.040
MUAC (cm)	-	25.00 (19.00-32.00)	0.001
Triceps skinfold (cm)	-	0.80 (0.40-1.90)	0.000
MAMC (cm)	-	22.80 (15.90-30.10)	0.006
Hemodialysis period (years)	-	4.00 (1.00-15.00)	0.000
Hemodialysis duration (hour)	-	4.00 (3.00-5.00)	0.000
Energy intake (%)	-	63.93 (24.90-223.30)	0.001
Protein intake (%)	-	70.83 (18.90-227.40)	0.001
Fat intake (%)	-	81.12 (15.60-326.60)	0.001
Carbohydrate intake (%)	-	53.94 (29.10-216.10)	0.000
Vitamin C intake (mg)	-	17.10 (0.30-169.00)	0.000
Iron intake (mg)	-	7.00 (1.70-28.50)	0.000
Zinc intake (mg)	-	5.50 (2.40-23.40)	0.000
Muscle mass (%)	39.80 ± 7.40	-	0.200*

Based on Table 2, data normality was tested using the Kolmogorov-Smirnov test. Muscle mass was normally distributed (p=0.200), while other variables were not (p<0.05). Non-parametric tests were used accordingly, by using the Spearman Rank test. The results of the bivariate analysis are shown in Table 3.

Table 3. Analysis of Factors Related to Muscle Mass in Hemodialysis Patients Using Spearman Rank Test

Dependent variable	Independent variable	Correlation coefficient	p-value
Muscle mass	BMI	0.267	0.018*
	MUAC	0.348	0.002*
	Triceps skinfold	0.158	0.168
	MAMC	0.317	0.005*
	Hemodialysis period	0.044	0.703
	Hemodialysis duration	0.117	0.308
	Energy intake	0.007	0.954
	Protein intake	-0.005	0.968
	Fat intake	-0.029	0.799
	Carbohydrate intake	0.029	0.799
	Vitamin C intake	0.018	0.873
	Iron intake	0.055	0.631
	Zinc intake	0.219	0.054

*Significant at p-value <0.05

Based on Table 3, BMI, MUAC, and MAMC factors have a significant relationship with muscle mass. The correlation coefficient of the three factors is positive, meaning that each factor is positively correlated with muscle mass. The higher the BMI, MUAC, and MAMC, the higher the muscle mass. Multivariate analysis in this study was conducted using multiple linear tests. The results of the multivariate analysis are shown in Table 4.

Table 4. Results of Multivariate Analysis of Factors Related to Muscle Mass

Model	*Sig	R Square	[a]Unstandardized Coefficients		[a]Standardized Coefficients	T	p-value
			B	Std. Error	Beta		
(Constant)	0.025	0.118	19.894	6.380		3.118	0.003
BMI			0.010	0.338	0.005	0.029	0.977
MUAC			0.665	1.090	0.293	0.611	0.543
MAMC			0.117	1.077	0.049	0.109	0.913

a. Dependent Variable: Muscle_mass

* Sig was analyzed using the F test (ANOVA)

Based on the ANOVA output table, it is known that the significance value (Sig) in the F test is 0.025. Because Sig 0.025 <0.05, it can be concluded that the BMI, MUAC, and MAMC factors simultaneously (together) affect muscle mass.

The coefficient of determination or R Square value is reported at 0.118 or equal to 11.8%. This means that the BMI, MUAC, and MAMC factors simultaneously (together) affect muscle mass by 11.8%. This indicates that 88.2% of other factors influencing muscle mass were not analyzed in this study.

The results showed a significant correlation between body mass index, upper arm circumference, and upper arm muscle circumference with muscle mass. The higher the BMI, MUAC, and MAMC, the higher the muscle mass.

DISCUSSION

The results of the study showed a significant correlation between BMI, MUAC, and MAMC with muscle mass, while the other variables were not significant, including intake factors. Several previous studies have demonstrated a correlation between energy and nutrient intake, such as protein and fat, and muscle mass in hospitalized patients. High protein intake is associated with less muscle mass loss.[16-20] However, in this study, nutritional factors such as protein, fat, carbohydrate, and micronutrient intake did not show a significant relationship with muscle mass in this study. This can be caused by other potential contributors to muscle mass, such as physical activity levels, inflammatory status, and patient's metabolic conditions. These factors are likely to influence the muscle mass of hemodialysis patients in this study, with a probability of 88.2%. Researchers also did not analyze the effects of other supplements such as brain chain amino acid (BCAA), β-Hydroxy β-Methylbutyrate (HMB), or vitamins and minerals that can affect muscle mass, and this is a limitation of this study.

Previous research has shown a positive relationship between physical activity and muscle mass in hemodialysis patients. Physical activity during or between hemodialysis sessions can enhance the muscle protein synthesis response to protein ingestion. Muscle mass in hemodialysis patients is maintained through a combination of physical activity and nutritional interventions.[21,22] Metabolic conditions such as malnutrition, inflammation, and acidosis can also significantly impact muscle mass, often leading to sarcopenia (muscle loss) in hemodialysis patients. Both sarcopenia and PEW are associated with functional loss and increased morbidity and mortality in these patients. However, muscle loss can also be caused by inflammation and fluid overload. The body composition of hemodialysis patients needs to be monitored.[23]

Body composition often changes in patients with chronic kidney disease. Obesity and muscle wasting are reported to occur frequently in patients with chronic kidney disease and sometimes occur simultaneously. BMI cannot accurately differentiate fat composition, both visceral and subcutaneous fat. Visceral fat is associated with adverse outcomes while subcutaneous fat is associated with beneficial outcomes. Subcutaneous fat can protect the body from wasting and catabolism, especially when accompanied by comorbidities.[24] The use of BMI as an indicator of nutritional status needs to be complemented by muscle mass measurements. The 2020 KDOQI recommendation on body composition assessment combined with body weight or BMI in routine hemodialysis patients. Monitoring of changes in body weight or BMI and body composition in hemodialysis patients is carried out every month.[25]

BMI can be used to see changes in fat deposits but cannot show changes in muscle mass in hemodialysis patients.[26] Muscle wasting is often experienced by hemodialysis patients.[6] Muscle wasting and dysfunction in CKD are caused by systemic inflammation, decreased protein synthesis, and decreased oxygen extraction.[8]

BIA and DXA (Dual X-ray Absorptiometry) can both be used to measure muscle mass in hemodialysis patients. Hemodialysis patients are reported to have significantly lower muscle mass than healthy people. Measurement of muscle mass in hemodialysis patients is carried out using BIA and DXA.[26]

The 2020 KDOQI recommendations on the use of bioimpedance and multi-frequency bioelectrical impedance (MF-BIA) to assess body composition. Bioimpedance assessment should ideally be performed at least 30 minutes or more after the end of a hemodialysis session to allow for redistribution of body fluids.[25] In this study, the appropriate thing was also done, namely anthropometric measurements were taken post-hemodialysis, approximately 30 minutes after the hemodialysis process was complete.

Hemodialysis patients can experience complications of PEW, which can be seen from excessive muscle loss. Many hemodialysis patients experience a continuous decrease in muscle mass.[27] PEW in hemodialysis patients can be caused by excessive energy and protein consumption. This is caused by a combination of factors, including inadequate dietary intake, protein loss during dialysis, and the effects of chronic kidney disease itself. Furthermore, inflammation in hemodialysis patients can decrease protein anabolism, increase protein catabolism, or both, which can exacerbate PEW in these patients.[28] Muscle loss can reduce the quality of life of hemodialysis patients, worsen daily activities, and reduce physical function.[29] Significant atrophy and increased noncontractile tissue occur in the muscles of hemodialysis patients. Muscle atrophy is associated with poor physical activity.[30] Interventions need to be carried out related to improving muscle mass in hemodiaysis patients, such as protein intake optimization or supplementation to improve the nutritional intake, and physical activity. The choice of exercise for hemodialysis patients should be based on available resources and individual preferences. Walking has been shown to provide significant health benefits for hemodialysis patients.[31]

CONCLUSIONS

BMI, MUAC, and MAMC factors have a significant relationship with muscle mass. The higher the BMI, MUAC, and MAMC, the higher the muscle mass. BMI, MUAC, and MAMC factors simultaneously (together) affect muscle mass by 11.8%, while the remaining 88.2% is influenced by other variables. Further research in the form of interventions needs to be carried out related to improving muscle mass by improving the nutritional intake and physical activity of hemodialysis patients.

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