

Risk of Sarcopenia and Its Association with Anthropometric Indicators Among Hemodialysis Patients

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ABSTRACT

Sarcopenia is increasingly recognised as a major complication among patients undergoing hemodialysis, largely driven by chronic inflammation, metabolic disturbances, and protein–energy wasting. However, evidence describing body composition–related indicators of sarcopenia among hemodialysis patients in Malaysia remains limited. This study aimed to determine the prevalence of sarcopenia risk and its associated factors among hemodialysis patients, with particular emphasis on anthropometric indicators of body composition. A cross-sectional study was conducted among 102 hemodialysis patients recruited from three dialysis centres in Kinta District, Perak. Risk of sarcopenia was assessed using the SARC-F questionnaire. Associations between variables and sarcopenia risk were examined using chi-square tests, correlations, and independent t-tests. The mean age of participants was 56.4 ± 12.4 years. Hypertension (83.3%) and diabetes (43.1%) were the most common comorbidities. Despite a mean BMI of 25.5 ± 4.0 kg/m², indicators reflecting muscle mass depletion were common, with more than half of the participants presenting with low mid-upper arm circumference (MUAC ≤ 22 cm) and reduced calf circumference. Overall, 38.2% of patients were identified as being at risk of sarcopenia. Significant associations were observed between sarcopenia risk and diabetes ($p < 0.001$). Anthropometric indicators reflecting muscle mass, including MUAC and calf circumference, were significantly associated with sarcopenia risk, whereas BMI showed no significant relationship. A substantial proportion of hemodialysis patients were at risk of sarcopenia despite having BMI values within the normal or overweight range. Simple anthropometric indicators reflecting muscle mass, particularly calf circumference and MUAC, may provide valuable tools for early detection of sarcopenia in dialysis settings.

Keywords: sarcopenia; body composition; hemodialysis; calf circumference; MUAC; chronic kidney disease

Introduction

Sarcopenia, as defined by Asian Working Group for Sarcopenia (AWGS 2025), is characterized by the coexistence of low muscle mass and low muscle strength that occurs during the ageing process [1], affecting numerous negative health outcomes and a reduced quality of life [2]. Although commonly associated with ageing, sarcopenia is also increasingly recognised in patients with chronic diseases, particularly chronic kidney disease (CKD).

Hemodialysis is a life-saving therapy for patients with end-stage renal disease (ESRD) that alleviates symptoms of kidney failure. However, long-term hemodialysis may contribute to or exacerbate complications, including the progression of sarcopenia [3]. Contemporary definitions have expanded beyond muscle mass loss to include declines in muscle strength and physical performance, such as reduced grip strength and slower gait speed [4]. While these diagnostic criteria are widely applied in geriatric populations, their applicability to patients with chronic kidney disease (CKD) remains uncertain, as profound muscle loss may occur in hemodialysis patients even at younger ages due to disease-related factors [5].

The prevalence of sarcopenia among hemodialysis patients has been reported to range from approximately 29% to 40%, which is comparable to or slightly higher than that observed in community-dwelling older adults [3]. In the CKD context, sarcopenia is associated with important clinical consequences, including increased risk of falls, reduced functional capacity, and higher cardiovascular risk [6, 7]. Moreover, CKD patients with sarcopenia have been reported to have a two- to five-fold higher risk of mortality compared with those without sarcopenia [8]. Given that sarcopenia may be partially reversible through appropriate nutritional and exercise interventions [9], early screening and identification of associated risk factors are essential for improving clinical outcomes among patients undergoing hemodialysis.

Muscle loss in hemodialysis patients is frequently accompanied by alterations in body composition, including reductions in skeletal muscle mass and changes in fat distribution. These changes may occur even when body mass index (BMI) remains within the normal or overweight range, a phenomenon sometimes referred to as “sarcopenic obesity.” Consequently, reliance on BMI alone may underestimate the presence of muscle depletion in this population. Anthropometric indicators reflecting muscle mass, such as calf circumference (CC) and mid-

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upper arm circumference (MUAC), have been proposed as practical screening tools for identifying sarcopenia in clinical and community settings. These measures are inexpensive, easy to perform, and have been shown to correlate with appendicular skeletal muscle mass. In dialysis populations, early identification of muscle loss is particularly important because sarcopenia is associated with reduced functional capacity, increased risk of falls, poorer quality of life, and higher mortality.

Despite the growing recognition of sarcopenia in CKD populations, research examining sarcopenia risk and its associated factors among hemodialysis patients in Malaysia remains limited. Moreover, few studies have explored the relationship between simple anthropometric indicators of body composition and sarcopenia risk in this population. Therefore, this study aimed to determine the prevalence of sarcopenia risk among hemodialysis patients and to examine its associated factors, with particular emphasis on anthropometric indicators of muscle mass such as MUAC and calf circumference.

Methods

Study Design and Setting

A cross-sectional study was conducted among patients undergoing maintenance hemodialysis in the Kinta district, Perak, Malaysia. Data collection was carried out between March and May 2021. Due to restrictions imposed during the COVID-19 pandemic, data were collected using self-administered questionnaires distributed through selected dialysis centres. Kinta district was selected as the study location because it has a relatively high number of dialysis centres and patient capacity within the state.

Study Participants and Sampling

Multistage sampling was employed in this study. First, the Kinta district was purposively selected due to logistical considerations during the pandemic. A list of dialysis centres in the district was obtained from the National Renal Registry, from which three centres were randomly selected. Patients receiving maintenance hemodialysis in the selected centres were invited to participate if they met the inclusion criteria.

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Eligible participants were Malaysian adults aged ≥ 18 years who had been undergoing hemodialysis for at least three months. Patients who were hospitalized within the previous three months or diagnosed with severe comorbid conditions such as hepatitis B or C, dementia, inflammatory illness, heart failure, lung disease, or liver disease were excluded from the study. A minimum sample size of 85 subjects was estimated based on correlation analysis from previous studies. After accounting for a potential 20% non-response rate, a total sample size of 102 participants was targeted.

Socio-Demographic Characteristics

Socio-demographic information collected included age, sex, ethnicity, educational level, and smoking status. Smoking status was classified as non-smoker, former smoker, or current smoker. For current and former smokers, smoking intensity was estimated using pack-years, calculated as the number of packs smoked per day multiplied by the number of years of smoking.

Clinical Factors

Clinical information including comorbidities and medication use was obtained from patients' medical records. The presence of comorbidities such as diabetes mellitus, hypertension, and hyperlipidemia was recorded. Polypharmacy was defined as the concurrent use of five or more medications.

Anthropometric Measurements

Anthropometric indicators reflecting body composition were assessed in this study. Height and dry body weight were obtained from dialysis records. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). The subjects were divided into the respective categories: $< 23 \text{ kg}/\text{m}^2$ for protein-energy malnutrition (PEM); $23\text{--}29.9 \text{ kg}/\text{m}^2$ for ideal weight; and $\geq 30 \text{ kg}/\text{m}^2$ for obese [10]. On the other hand, weight change during the previous three months was assessed through self-report using the questionnaire. Unintentional weight loss was defined as a reduction in body weight without intentional dieting or lifestyle modification. As the data was collected during the COVID pandemic, mid-upper arm circumference (MUAC) and calf circumference (CC) of respondents were measured by respondents using a non-elastic measuring tape. Respondents were provided with written instructions and a QR code linking to instructional videos to guide the self-measurement

process. MUAC was measured at the midpoint between the acromion and olecranon process of the non-dominant arm. Calf circumference was measured at the widest part of the calf while the participant was seated with the knee at approximately 90° flexion.

ASSESSMENT OF SARCOPENIA RISK

Risk of sarcopenia among the respondents was assessed using the SARC-F questionnaire, a validated screening tool for sarcopenia. The SARC-F consists of five items assessing strength, assistance in walking, rising from a chair, climbing stairs, and history of falls [11]. Each item is scored from 0 to 2, giving a total score ranging from 0 to 10. Participants with a total SARC-F score ≥ 4 were classified as being at risk of sarcopenia, while those with scores < 4 were classified as not at risk.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 25. Continuous variables were presented as mean \pm standard deviation, while categorical variables were presented as frequencies and percentages. Associations between selected variables and sarcopenia risk were examined using Pearson correlation, Chi-square tests, or Fisher's exact tests where appropriate. A p-value of < 0.05 was considered statistically significant.

Results

A total of 102 hemodialysis patients were included in the study (Table 1). The mean age of participants was 56.4 ± 12.4 years (range 31–81 years), with 59.8% males and 40.2% females. Approximately 56.9% of participants were younger than 60 years. In terms of ethnicity, Malays constituted 45.1% of the sample, followed by Chinese (41.2%) and Indians (13.7%). Hypertension was the most prevalent comorbidity (83.3%), followed by diabetes mellitus (43.1%). Polypharmacy was highly prevalent, with 94.1% of participants taking five or more medications and an average of 7.9 ± 2.5 medications per patient.

Table 1 Distribution of subjects according to sociodemographic characteristics (n = 102)

Variables	n (%)	Mean \pm SD	Range
Age (years)		56.4 ± 12.4	31-81
<60 years old	58 (56.9)		
≥ 60 years old	44 (43.1)		

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Gender			
Male	61 (59.8)		
Female	41 (40.2)		
Ethnicity			
Malay	46 (45.1)		
Chinese	42 (41.2)		
Indian	14 (13.7)		
Education level			
No formal education	7 (6.9)		
Primary education	26 (25.5)		
Secondary education	58 (56.9)		
Tertiary education	11 (10.8)		
Smoking behavior			
Smoking status			
Non-smoker	79 (77.5)		
Past smoker	13 (12.7)		
Current smoker	10 (9.8)		
Smoking level			
No smoking	14 (13.7)		
Light smoking	9 (8.8)		
Medium smoking	0 (0)		
Heavy smoking			
Comorbidities *			
Hypertension	85 (83.3)		
Diabetes mellitus	44 (43.1)		
Cardiovascular Disease	4 (3.9)		
Dyslipidemia	3 (2.9)		
Anemia	1 (1.0)		
Bone disease	2 (2.0)		
Number of medications		7.9 ± 2.5	2-17
Polypharmacy (no. of medication used ≥5)			
Yes	6 (5.9)		
No	96 (94.1)		

*Multiple responses

As depicts on Table 2, the mean BMI of participants was 25.5 ± 4.0 kg/m². Approximately 29.4% of participants had BMI values below 23 kg/m², while 57.8% had BMI within the range of 23–29.9 kg/m². However, indicators reflecting muscle mass depletion were common. More than half of the participants had reduced mid-upper arm circumference (MUAC ≤ 22 cm) and low calf circumference. These findings suggest that muscle depletion may occur even among individuals with BMI values within the normal or overweight range. Sarcopenic obesity was

observed in approximately 4% of participants. Notably, nearly one-third of individuals with obesity were also classified as being at risk of sarcopenia.

Table 2 Distribution of subjects according to anthropometric parameters (n = 102)

Variables	n (%)	Mean ± SD	Range
BMI (kg/m²)		25.5± 4.0	16.3-39.4
Low (<23)	30 (29.4)		
Normal (23-29.9)	59 (57.8)		
High (≥ 30)	13 (12.7)		
Unintentional weight loss		0.39 ± 0.54	0-2.9
No weight loss	75 (73.5)		
weight loss 1-3 kg	27 (26.5)		
weight loss > 3kg	None		
Mid-upper arm circumference (MUAC)		21.3 ± 0.8	19.1 – 22.4
less than 21 cm	29 (28.4)		
21-22 cm	27 (26.5)		
>22 cm	46 (45.1)		
Calf circumference (CC)		32.4 ± 0.65	31.0 – 34.5
Normal	56 (54.9)		
Low (below 33 cm for female or below 34 for male)	46 (45.1)		

As shown in Table 3, based on SARC-F assessment, 38.2% of participants were classified as being at risk of sarcopenia. Difficulties in performing functional activities such as lifting weights and climbing stairs were commonly reported.

Table 3 Distribution of subjects according to risk of sarcopenia (n = 102)

Components	n (%)		
	None	Some difficulties	A lot or unable
Strength How much difficulty do you have in lifting and carrying 4.5 kg?	26 (25.5)	41 (40.2)	35 (34.3)
Assistance in walking How much difficulty do you have walking across a room?	66 (64.7)	32 (31.4)	4 (3.9)
Rise from a chair How much difficulty do you have transferring from a chair or bed?	66 (64.7)	34 (33.3)	2 (2.0)
Climb stair How much difficulty do you have in climbing a flight of 10 stairs?	31 (30.4)	37 (36.3)	34 (33.3)
Fall How much times have you fallen in the past year?	50 (49.0)	49 (48.0)	3 (2.9)
SARC-F total score (0-8) ^a, mean± sd		3.2 ± 2.3	
At risk of sarcopenia , n(%)		63 (61.8)	
No (score <4)		39 (38.2)	
At risk (score ≥ 4)			

^a Range

The associations between selected variables and sarcopenia risk are presented in Table 4 and 5. Age was not significantly correlated with sarcopenia risk ($r = 0.121$, $p > 0.05$). Similarly, no significant associations were observed between sarcopenia risk and other socio-demographic variables, including gender, educational level, and smoking status. However, ethnicity showed a significant association with sarcopenia risk ($\chi^2 = 8.540$, $p < 0.05$), with a higher proportion of Malays classified as being at risk compared with Chinese and Indian participants. Among the clinical variables examined, a significant association was observed between sarcopenia risk and the presence of diabetes mellitus ($\chi^2 = 14.252$, $p < 0.001$), whereas other clinical factors were not significantly associated with sarcopenia risk. Anthropometric indicators reflecting

muscle mass were significantly associated with sarcopenia risk. Participants at risk of sarcopenia had significantly lower mid-upper arm circumference (MUAC) ($t = 2.07$, $p < 0.05$) and calf circumference ($t = 2.12$, $p < 0.05$) compared with those not at risk. In contrast, BMI was not significantly associated with sarcopenia risk.

Table 4 Correlation between selected sociodemographic and clinical parameters and sarcopenia risk (n=102)

Variable	Sarcopenia risk		χ^2	<i>t value</i>	<i>p-value</i>
	No (n= 63)	At risk (n= 39)			
Age				0.121 ^c	0.226
< 60 years old	38 (37.3%)	20 (19.6%)	0.802 ^a		0.415
≥ 60 years old	25 (24.5%)	19 (18.6%)			
Gender			0.018 ^a		1.000
Male	38 (37.3%)	23 (22.5%)			
Female	25 (24.5%)	16 (15.7%)			
Ethnicity					
Malay	23 (22.5%)	23 (22.5%)	8.540 ^a		0.013*
Chinese	33 (32.4%)	9 (8.8%)			
Indian	7 (6.9%)	7 (6.9%)			
Educational level					
No formal education	5 (4.9%)	2 (2.0%)			0.985 ^b
Primary education	16 (15.7%)	10 (9.8%)			
Secondary education	35 (34.3%)	23 (22.5%)			
Tertiary education	7 (6.9%)	4 (3.9%)			
Smoking behavior					
Smoking status					
Non-smoker	47 (46.1%)	32 (31.4%)			0.557
Past smoker	10 (9.8%)	3 (2.9%)			
Current smoker	6 (5.9%)	4 (3.9%)			
Smoking level (pack-years)			1.994 ^a		0.368
No smoking	47 (46.1%)	32 (31.4%)			
Light smoking	11 (10.8%)	3 (2.9%)			
Medium smoking	5 (4.9%)	4 (3.9%)			
Comorbidities					
Diabetes mellitus	18 (17.6%)	26 (25.5%)	14.252 ^a		<0.001** *
Cardiovascular Disease	1 (1.0%)	3 (2.9%)			0.155 ^b
Hypertension	50 (49.0%)	35 (34.3%)	1.868 ^a		0.274
Dyslipidemia	2 (2.0%)	1 (1.0%)			1.000 ^b
Anemia	1 (1.0%)	0 (0.0%)			1.000 ^b
Bone disease	1 (1.0%)	1 (1.0%)			1.000 ^b

Data were presented as n (%)

^a Pearson Chi-square test

^b Fisher's Exact test

^c Pearson's Product-Moment Correlation

*Correlation is significant at $p < 0.05$

Table 5 Correlation between anthropometric parameters and sarcopenia risk of the subjects (n=102)

Variable	Sarcopenia risk		χ^2	<i>t value</i>	<i>p-value</i>
	Normal (n= 63)	At risk (n= 39)			
BMI (kg/m ²)	24.2	22.1		1.35 ^c	0.081
<23	19 (18.6)	11 (10.8)	0.487 ^a		0.174
23 – 29.9	35 (34.3)	24 (23.5)			
≥ 30	9 (8.8)	4 (3.9)			
Unintentional weight loss					
No weight loss	47 (46.1)	28 (27.5)	0.098		0.819
Weight loss (between 1 and 3 kg)	16 (15.7)	11 (10.8)	a		
Mid Upper Arm Circumference (cm)	23.1	20.8		2.07 ^c	0.034
less than 21 cm	5	24	9.85 ^b		0.021
21-22 cm	17	10			
>22 cm	33	15			
Calf Circumference (cm)	35.2	31.8		2.12 ^c	0.016
Normal (≥ 33 cm for female and ≥34 cm for male)	39	7	12.65 ^a		< 0.01
Low	43	13			

Note: Data were presented as n (%)

^a Pearson Chi-square test

^b F test

^c Student t test

Discussion

In the present study, approximately 60% of the participants were male. This distribution is consistent with national and global trends showing a higher proportion of men receiving hemodialysis for renal replacement therapy in end-stage renal disease [12]. In Malaysia, registry data similarly indicate that the proportion of male patients undergoing dialysis has consistently exceeded that of females, with a male-to-female ratio of approximately 55:45 over the past decade [13]. Several factors may contribute to this gender disparity. Previous studies have suggested that psychosocial and socioeconomic factors, including caregiving responsibilities and lower disease awareness, may delay treatment initiation among women [14]. Additionally, women undergoing maintenance hemodialysis have been reported to experience higher rates of hospitalization and 30-day readmission compared with men [15], which may also influence clinical decision-making regarding dialysis management.

Approximately 40% of our cohort aged above 60 years old. This finding was comparable to national data, where most hemodialysis patients were between 55 and 64 years old (National Renal Registry, n.d). In terms of ethnic composition, there was a slight over-representation of patients of Chinese ethnicity (41.2%), and an under-representation of patients who were of Malay ethnicity (45.1%). The apparent difference may be due to the uneven population distribution in Malaysia, where more Chinese residents are concentrated in Kinta, Perak [16]. Most participants in the present study were non-smokers, which is consistent with findings from previous local studies involving hemodialysis patients of similar age [17]. Among those who reported smoking, the majority were classified as light smokers (≤ 11.3 pack-years), while the remainder were moderate smokers (> 11.3 – 24.5 pack-years). Smoking is a well-established risk factor for adverse clinical outcomes in patients undergoing hemodialysis, including increased risk of cardiovascular complications and infection-related morbidity. Therefore, smoking cessation remains an important component of clinical management for patients receiving hemodialysis.

Hypertension and diabetes mellitus were the most prevalent comorbidity among the hemodialysis patients. This pattern is consistent with findings from previous local studies, where hypertension and diabetes were identified as the leading causes and comorbid conditions associated with end-stage renal disease [18, 19]. Polypharmacy was also highly prevalent in this study population, with patients taking an average of eight medications. This finding is comparable to previous reports on medication use among hemodialysis patients [20] and is

likely attributable to the high burden of comorbid conditions requiring multiple pharmacological treatments [21]. In addition, fragmented care and prescriptions from multiple healthcare providers may further contribute to the high prevalence of polypharmacy. Given the potential risks associated with polypharmacy, including adverse drug reactions and medication interactions, further research is warranted to optimize medication management strategies among hemodialysis patients.

The mean BMI of the participants was slightly higher than the mean BMI of 24.4 kg/m² reported in the 24th Malaysian Dialysis and Transplant Registry report (2016). Nevertheless, approximately one-third of the participants had a BMI below 23 kg/m², indicating that a considerable proportion of patients may still be at risk of undernutrition. Previous studies have described the “obesity paradox” in hemodialysis populations, whereby overweight or mild obesity (BMI 25–28 kg/m²) may be associated with improved short-term survival [22]. This phenomenon is thought to reflect the protective effects of greater energy reserves in the context of protein–energy wasting and chronic inflammation commonly observed in chronic kidney disease.

Although the average magnitude of weight loss was relatively small (0.39 kg), the fact that more than one-quarter of the respondents with unintentional weight loss within the previous three months deserve further attention. Among these individuals, most were within the normal BMI category, while only a small proportion had low or obese BMI. Unintentional weight loss in hemodialysis patients is clinically important because it has been associated with adverse outcomes, including increased morbidity and reduced survival. However, in certain clinical contexts, particularly among patients with severe obesity (BMI >30 kg/m²) or those awaiting kidney transplantation, intentional weight reduction may be recommended to improve transplant eligibility [23]. It should be noted that weight loss in this study was self-reported, which may limit the accuracy of the findings.

Beyond BMI, anthropometric indicators reflecting muscle mass revealed a substantial burden of potential muscle depletion among the participants. More than half of the patients had low mid-upper arm circumference (MUAC \leq 22 cm) and reduced calf circumference, both of which are commonly used surrogate indicators of skeletal muscle mass. Notably, approximately 40% of participants had both low MUAC and calf circumference simultaneously. These findings suggest that muscle depletion may be present even among individuals with relatively preserved

BMI. Interestingly, the prevalence of reduced MUAC and calf circumference observed in this study was higher than that reported in several local studies involving community-dwelling older adults [24], despite the hemodialysis patients in the present study being younger on average. This observation may reflect the impact of chronic kidney disease and dialysis-related factors on muscle mass and nutritional status, highlighting the importance of early nutritional and body composition assessment in this population.

Data on the risk of sarcopenia for patients undergoing hemodialysis in Malaysia are scarce. Approximately 4 out of 10 subjects were at risk of sarcopenia in the current findings, which was comparable to other studies among Asian HD patients [3, 7]. In local studies, there was not much difference in the prevalence of sarcopenia between dialysis and non-dialysis subjects, even if there were differences in socio-demographic characteristics and the diagnostic algorithm used [25, 26]. However, a majority of the subjects in the current study had lower functional capacity for daily activities (such as facing more difficulties in climbing stairs and carrying a weight of 4.5 kg) than the elderly without dialysis treatment [27]. The reported functional deficits may be partly due to the suboptimal readings of their mid-arm and calf circumference as these two parameters are always linked to appendicular muscle strength and mass [28]. It is also worth mentioning that 51% of the subjects had a fall in the past 12 months, which was higher than previous local cross-sectional study on the non-dialysis elderly population (aged ≥ 60 year old) [29]. This was in agreement with a cohort study that revealed a high risk of falls after the start of dialysis, which may be due to the kidney disease and the treatment itself that promotes muscle loss, lower blood pressure prior to dialysis session, as well as the higher number of medications and antidepressant use [30].

Although sarcopenia is commonly associated with ageing and its prevalence typically increases with advancing age, age was not significantly correlated with sarcopenia risk in the present study ($r = 0.121$, $p > 0.05$). This finding suggests that muscle loss in patients with chronic kidney disease may differ from age-related sarcopenia, as disease-related factors such as CKD progression, dialysis treatment, chronic inflammation, and disturbances in protein metabolism may contribute more substantially to muscle wasting in this population (Sabatino et al., 2020). In contrast, ethnicity was significantly associated with sarcopenia risk ($\chi^2 = 8.540$, $p < 0.05$), with Malays showing a higher proportion of individuals at risk compared with Chinese and Indians. This finding differs from previous studies conducted in non-CKD populations, which reported a higher prevalence of sarcopenia among Indians [31]. The discrepancy may be

attributable to differences in study populations and socio-demographic characteristics, as earlier studies primarily focused on community-dwelling older adults. In addition, CKD-related factors and dialysis treatment may influence lifestyle behaviours, dietary patterns, and psychological well-being differently across ethnic groups. The relatively small proportion of Indian participants in the present study may also have affected the observed distribution.

No significant associations were observed between sarcopenia risk and other socio-demographic variables, including gender, educational level, and smoking status. These findings differ from some studies conducted among hemodialysis populations in Brazil and the United Kingdom [32, 33], which reported gender-related differences in sarcopenia prevalence. Such discrepancies may reflect variations in population characteristics and ethnic diversity across study settings. The absence of an association between smoking status and sarcopenia risk in this study is consistent with previous findings indicating no significant difference in smoking behaviour between sarcopenic and non-sarcopenic CKD patients [6]. Nevertheless, the relatively small sample size in the present study may have limited the statistical power to detect certain associations. Future studies with larger and more diverse populations are therefore warranted to further clarify the role of socio-demographic factors in the development of sarcopenia among hemodialysis patients.

Diabetes mellitus was significantly associated with sarcopenia risk. This finding was consistent with other studies [30], where a cohort study revealed that the presence of diabetes was an independent cause of sarcopenia in hemodialysis patients [3]. The relationship between diabetes and sarcopenia has been well documented in the past literature, of which the likelihood of sarcopenia increases as HbA1c increases [34]. The presence of diabetes is most likely to invoke some inflammatory processes, with an elevated level of oxidative stress, serum CRP and TNF- α and therefore, favoring the development of sarcopenia [35]. On the other hand, the correlation between polypharmacy (defined as taking at least five drugs) and sarcopenia risk was not evident in the current study. This finding was supported by the GLISTEN study on hospitalized elderly patients [36] but contradicted the study done by Tanaka et al. (2018)[37] and König et al. (2017)[38] which the elderly subjects studied were healthier with lower prevalence of polypharmacy and sarcopenia reported. It could be partially explained by the subjects in both the current and GLISTEN study had presented with more severe diseases and poorer nutritional status, thereby diluting the potential association between polypharmacy and sarcopenia risk. Since the previous three studies were only conducted in non-CKD elderly

residents, it can be postulated that the association may vary depending on the health status of the subjects, which addresses the need for more research.

Given that there was no significant correlation between BMI and sarcopenia risk ($t= 1.35$, $p=0.081$), whereby higher BMI may not protect hemodialysis subjects against sarcopenia, “obesity paradox” phenomenon is not valid in this case. The current results were inconsistent with previous studies that reported a significant negative correlation between BMI and sarcopenia in hemodialysis patients [39, 40]. The discrepancy may likely be explained by the differences in the classification of BMI and the tools used to identify sarcopenia. Besides, the use of BMI has its limitations in distinguishing the body composition including muscle mass. This was reiterated in a large-scale, population-based study (NHANES), reporting that obese CKD people with sarcopenia were 97% more likely to be misclassified by BMI as non-obese [41]. Therefore, BMI should be used with caution to draw conclusions about its impact on sarcopenia among CKD populations.

There was no significant correlation between unintentional weight loss and the risk of sarcopenia. This finding was inconsistent with previous studies that documented an association between unintentional weight loss and poor functional status. The disparity in finding may be explained by the differences in baseline characteristics of the subjects, of which none were on hemodialysis treatments in the previous studies. The small magnitude of weight changes in the current study may also limit the ability to establish a significant association. To date, this is the first study investigating the relationship between unintentional weight loss and the risk of sarcopenia among hemodialysis subjects. Further study is needed to draw a conclusion on this relationship.

The present findings highlight the importance of incorporating body composition-related indicators into routine clinical assessment of hemodialysis patients. In this study, participants with lower MUAC and calf circumference were significantly more likely to be at risk of sarcopenia, underscoring the relevance of simple anthropometric indicators as markers of muscle depletion. Calf circumference is widely recognised as a practical surrogate measure of skeletal muscle mass and has been used extensively in both clinical and research settings. Similarly, mid-upper arm circumference is commonly used in clinical nutrition assessment and has been endorsed by several clinical societies as a phenotypic indicator of reduced skeletal muscle mass, particularly in the context of undernutrition. Given their simplicity, low cost, and

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minimal equipment requirements, MUAC and calf circumference measurements may provide valuable alternatives for screening muscle depletion in dialysis settings where advanced body composition techniques, such as bioelectrical impedance analysis (BIA) or dual-energy X-ray absorptiometry (DXA), are not readily available. Incorporating these anthropometric indicators into routine assessment may facilitate early identification of sarcopenia risk and enable timely nutritional and functional interventions among hemodialysis patients.

Nevertheless, several limitations should be considered. The cross-sectional design limits causal inference, and some anthropometric data were obtained from existing records. Future studies should incorporate more precise body composition assessment methods, such as bioelectrical impedance analysis or dual-energy X-ray absorptiometry, to better characterise muscle and fat distribution in hemodialysis populations.

Conclusion

A substantial proportion of hemodialysis patients in this study were identified as being at risk of sarcopenia, despite many having BMI values within the normal or overweight range. These findings highlight the limitation of relying solely on BMI to detect muscle depletion in dialysis populations. Anthropometric indicators reflecting muscle mass, particularly mid-upper arm circumference and calf circumference, were significantly associated with sarcopenia risk and may serve as practical screening tools in routine dialysis care. In addition, diabetes mellitus was significantly associated with a higher risk of sarcopenia, suggesting the importance of targeted monitoring among patients with this comorbidity. Incorporating simple anthropometric measurements into routine clinical assessment may facilitate early identification of muscle depletion and enable timely nutritional and functional interventions to improve patient outcomes. Future studies using longitudinal designs and more precise body composition techniques are warranted to further elucidate the progression and management of sarcopenia in hemodialysis populations

Conflicts of Interest

The authors declare no conflict of interest.

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No.

Author Contributions

S.J.L. worked on data curation, methodology, formal analysis and prepared the original draft writing. Y.M.C. contributed on study conception, data curation, methodology, review, editing and supervision. M.X.Y. contributed methodology and review.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Association Between Dietary Acid Load, Anthropometric Indices and Body Fat Percentage in Malaysian Chinese Postmenopausal Women

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Abstract

This study aimed to examine the association between dietary acid load (DAL), anthropometric indices, and body fat percentage (BF%) among Malaysian Chinese postmenopausal women. This cross-sectional study included 211 postmenopausal women recruited from the National Council of Senior Citizens Organizations Malaysia. Habitual dietary intake over the past month was assessed using a validated semi-quantitative food frequency questionnaire. DAL was estimated using Potential Renal Acid Load (PRAL) and Net Endogenous Acid Production (NEAP) equations. Anthropometric measurements, including body mass index (BMI), waist circumference, BF%, were obtained using standard procedures. Participants were categorized into tertiles of DAL, and differences across tertiles were assessed using ANOVA. Participants had a mean age of 66.7 ± 6.6 years and a mean duration of menopause of 16.1 ± 7.8 years. Across PRAL tertiles, participants in the highest tertile had significantly higher intakes of energy, carbohydrates, protein, fat, and phosphorus, but lower potassium and magnesium intakes (all $p < 0.001$). Similar trends were observed across NEAP tertiles for energy, protein, fat, phosphorus, potassium, and magnesium intake ($p < 0.05$). However, no significant differences were observed in body weight, BMI, waist circumference, or BF% across DAL tertiles ($p > 0.05$). Higher DAL was not associated with anthropometric indices or BF% among Malaysian Chinese postmenopausal women. Further longitudinal studies are needed to clarify the potential role of dietary acid load in body composition and metabolic health.

Keywords: dietary acid load; PRAL; NEAP; anthropometric indices; body fat percentage; postmenopausal women

Introduction

Menopause is a biological process characterized by the cessation of menstrual cycles resulting from a significant decrease in estrogen production, typically begins around the age of 45-55 in women [1]. This hormonal transition leads to various changes in metabolic, musculoskeletal, and cardiovascular health, with its effects often influenced by genetics, dietary patterns, and lifestyle factors [1]. During this transition, many women experience symptoms such as hot flashes, sleep disturbances, and mood swings, which can adversely affect their quality of life and mental well-being [2, 3]. In the postmenopausal period, women experience physiological changes primarily driven by declining estrogen levels, which can lead to significant alterations in body composition, including increased central adiposity and reduced lean muscle mass. Central adiposity or visceral fat is metabolically active and is associated with increased systemic inflammation, insulin resistance, and higher risks of cardiovascular disease and type 2 diabetes [4, 5]. The hormonal decline also exacerbates bone loss and reduces muscle strength, and thus increasing the risk of osteoporosis and frailty [6]. These changes make anthropometric measurements critical for assessing health outcomes during this life stage.

Anthropometric indices such as body mass index (BMI) and waist circumference (WC) are commonly used in epidemiological studies to assess overall and central obesity. BMI provides a general measure of body weight relative to height, often used as a basic screening tool for obesity. However, it does not distinguish between fat and lean mass, limiting its accuracy in older adults, including postmenopausal women who experience changes in body composition [7]. WC reflects abdominal fat accumulation, which has been strongly associated to cardiometabolic risk [5]. However, these anthropometric indicators do not directly measure body composition. In contrast, body fat percentage (BF%) provides a more direct assessment of adiposity by quantifying the proportion of fat mass relative to total body weight. Previous studies showed that increased BF% in postmenopausal women contributes to higher risks of metabolic syndrome and impaired physical function [4].

In recent years, dietary acid load (DAL) has received increasing attention as potential factor for metabolic health. DAL is defined as the acid-producing and base-producing nutrients in the diet. Emerging evidence also suggests that higher DAL associated with diets rich in animal protein and

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processed foods, may promote mild metabolic acidosis and lead to negatively impact body composition by increasing fat accumulation and reducing muscle mass [8]. Conversely, alkaline diets comprising plant-based foods and adequate water intake can promote healthier body composition and mitigate inflammatory effects [3].

Despite growing interest in DAL, evidence regarding its relationship with adiposity indicators remains inconsistent. Furthermore, most studies have been conducted in Western populations, with limited data available among Asian populations. The differences in genetics and cultural dietary habits, body composition, and metabolic responses highlight the importance of examining these associations in specific populations. Therefore, this study aimed to examine the association between DAL, anthropometric indices, and BF% among Malaysian Chinese postmenopausal women.

Methods

Study Design and Participants

This analytical cross-sectional study was conducted among 217 healthy postmenopausal Chinese women recruited from the National Council of Senior Citizens Organizations Malaysia (NACSCOM) in Kuala Lumpur and Selangor, Malaysia. The required sample size was calculated using G*Power software, which indicated that a sample of 217 participants would sufficient to provide a statistical power of 95%. The inclusion criteria were Malaysian Chinese women who had experienced menopause for at least five years. Participants were excluded if they had taken medications that could affect bone health within the past year. Written informed consent was obtained from all participants prior to the commencement of the study. Ethical approval for the study was granted by the Ethics Committee for Research Involving Human Subjects, Universiti Putra Malaysia, with the project reference number FPSK (FR16) P019.

Sociodemographic And Dietary Assessment

Information on sociodemographic characteristics, including age, years of menopause, marital status, education level, was collected using a pre-tested structured questionnaire. Habitual dietary

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intake over the past month was assessed using a validated semi-quantitative food frequency questionnaire (FFQ) [9], adapted from the Malaysian Adult Nutrition Survey 2003 [10]. The FFQ comprised 121 food items commonly consumed by Malaysians. Daily energy and nutrient intakes were analysed using Nutritionist Pro™ Diet Analysis software (Axxya Systems, Stafford, TX, USA). DAL was estimated using the Potential Renal Acid Load (PRAL) [11] and Net Endogenous Acid Production (NEAP) equation [12]:

$$\text{Estimated PRAL (mEq/d)} = 0.49 \text{ protein (g/d)} + 0.037 \text{ phosphorus (mg/d)} - 0.021 \text{ Potassium (mg/d)} - 0.026 \text{ Magnesium (mg/d)} - 0.013 \text{ Calcium (mg/d)}$$
$$\text{Estimated NEAP (mEq/d)} = 54.5 \times \text{protein intake [g/d]} / \text{potassium intake [mEq/d]} - 10.2$$

Anthropometric and Body Composition Measurements

Body weight and standing height were measured using a TANITA digital weighing scale and a SECA portable stadiometer to the nearest 0.1 kg and 0.1 cm, respectively. These measurements were used to calculate BMI. Waist circumference was measured to the nearest 0.1 cm using a non-elastic SECA measuring tape following standard measurement procedures. Body fat percentage of participants was measured using OMRON portable body fat analyzer.

Statistical Analyses

Statistical analysis was conducted using SPSS version 29.0 (IBM Corp., Armonk, NY, USA) with statistical significance set at p-value <0.05. Participant characteristics, anthropometric indices and body compositions were compared across NEAP and PRAL tertiles using one-way analysis of variance (ANOVA) for continuous variables. The results were presented as mean ± standard deviation (SD) for continuous variables and as percentages for categorical variables.

Results

Table 1 presents the socioeconomic and demographic characteristics of the participants. A total of 211 postmenopausal women were included in the analysis. The mean age of the participants was 66.7 ± 6.6 years, and the mean duration of menopause was 16.1 ± 7.8 years. Most participants were classified as young-old (60–74 years) (74.9%). The majority were married (76.8%). In terms of educational attainment, primary and upper secondary education were the most commonly reported levels.

Table 1 Socioeconomic and demographic characteristics of participants (n = 211)

Variable	n (%)	Mean ± SD	Range
Age (years)		66.7 ± 6.6	51-85
Older adult (<60)	27 (12.8)		
Young-old (60 – 74)	158 (74.9)		
Old-old (75 – 84)	26 (12.3)		
Years of menopause (years)		16.1 ± 7.8	5-43
Marital Status			
Single	21 (10.0)		
Married	162 (76.8)		
Divorced	6 (2.8)		
Widowed	22 (10.4)		
Education level			
No formal education	27 (12.8)		
Primary school	68 (32.2)		
Lower secondary school	30 (14.2)		
Upper secondary school	57 (27.0)		
Pre-university (Diploma / A Level)	20 (9.5)		
Bachelor degree	9 (4.3)		

Table 2 shows the daily dietary intake of participants across tertiles of dietary acid load based on PRAL and NEAP scores. Across PRAL tertiles, significant differences were observed for energy and most nutrient intakes. Participants in the highest PRAL tertile had significantly higher intakes of energy, carbohydrates, protein, fat, and phosphorus compared with those in the lower tertiles (all $p < 0.001$). In contrast, potassium and magnesium intakes were significantly lower in the higher PRAL tertiles ($p < 0.001$). Calcium intake also differed significantly across PRAL tertiles ($p = 0.032$).

Similarly, across NEAP tertiles, energy, protein, fat, phosphorus, potassium, and magnesium intakes differed significantly between groups ($p < 0.05$). Participants in the highest NEAP tertile had higher energy, protein, fat, and phosphorus intakes, but lower potassium and magnesium intakes. No significant difference in carbohydrate or calcium intake was observed across NEAP tertiles.

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Table 2 Daily dietary intakes of participants among tertiles of dietary acid load

Variables	Tertiles of PRAL			Total (n=211)	P value	Tertiles of NEAP			Total (n=211)	P value
	1 (<58.68 ; n=69)	2 (58.68 – 84.30; n=70)	3 (>84.30 ; n=72)			1 (<58.68 ; n=69)	2 (58.68 – 84.30; n=70)	3 (>84.30 ; n=72)		
Energy (kcal)	1314.55 ± 498.77	1369.1 4 ± 470.19	1749.92 ± 495.04	1481.2 2 ± 523.57	< 0.00 1	1369.01 ± 506.85	1466.6 7 ± 533.93	1602.91 ± 510.13	1481.2 2 ± 523.57	0.02 8
CHO (g)	207.18 ± 83.33	197.17 ± 78.60	244.85 ± 75.14	216.71 ± 81.34	< 0.00 1	215.55 ± 85.95	208.79 ± 82.56	225.52 ± 75.66	216.71 ± 81.34	0.46 9
Protein (g)	56.19 ± 22.43	60.73 ± 18.22	86.29 ± 28.73	67.96 ± 27.01	< 0.00 1	57.62 ± 22.83	67.94 ± 22.36	77.89 ± 31.12	67.96 ± 27.01	< 0.00 1
Fat (g)	25.58 ± 13.44	28.23 ± 12.05	44.06 ± 31.71	32.77 ± 22.67	< 0.00 1	26.72 ± 13.46	32.04 ± 16.73	39.27 ± 31.54	32.77 ± 22.67	0.00 4
Phosphorus (mg)	763.37 ± 296.75	772.54 ± 234.83	1157.51 ± 348.75	900.91 ± 349.34	< 0.00 1	809.37 ± 309.42	887.96 ± 332.71	1001.22 ± 378.38	900.91 ± 349.34	0.00 4
Potassium (mg)	2194.54 ± 835.53	1685.7 8 ± 745.72	1744.91 ± 684.04	1872.3 3 ± 786.29	< 0.00 1	2312.64 ± 871.92	1848.2 4 ± 637.50	1473.78 ± 596.21	1872.3 3 ± 786.29	< 0.00 1
Magnesium (mg)	260.82 ± 94.64	200.44 ± 71.01	214.82 ± 77.78	225.09 ± 85.21	< 0.00 1	268.06 ± 92.34	219.05 ± 74.04	189.77 ± 596.21	225.09 ± 85.21	< 0.00 1
Calcium (mg)	688.84 ± 386.60	599.34 ± 338.41	757.30 ± 344.48	682.51 ± 361.09	0.03 2	727.45 ± 375.48	637.66 ± 300.88	683.04 ± 398.36	682.51 ± 361.09	0.34 3

Table 3 presents the anthropometric indices and BF% across tertiles of dietary acid load based on PRAL and NEAP scores. No significant differences were observed in body weight, height, body mass index (BMI), waist circumference, or BF% across tertiles of PRAL or NEAP (all $p > 0.05$).

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Overall, the mean BMI of the participants was 24.41 ± 4.02 kg/m², the mean waist circumference was 80.38 ± 9.25 cm, and the mean body fat percentage was $35.15 \pm 5.18\%$.

Table 3 Anthropometric indices among tertiles of dietary acid load

Variables	Tertiles of PRAL			Total (n=211)	P value	Tertiles of NEAP			Total (n=211)	P value
	1 (<58.68 ; n=69)	2 (58.68 – 84.30; n=70)	3 (>84.30 ; n=72)			1 (<58.68 ; n=69)	2 (58.68 – 84.30; n=70)	3 (>84.30 ; n=72)		
Weight (kg)	57.41 ± 9.46	59.38 ± 9.73	56.79 ± 9.25	57.85 ± 9.50	0.24 3	58.13 ± 10.35	57.75 ± 8.18	57.69 ± 9.96	57.85 ± 9.50	0.95 8
Height (cm)	154.51 ± 4.92	153.8 3 ± 5.78	153.72 ±5.62	154.01 ± 5.44	0.65 4	154.74 ± 4.66	153.5 0 ± 5.95	153.81 ± 5.62	154.01 ±5.44	0.37 8
BMI (kg/m²)	24.05 ± 3.79	25.17 ± 4.47	24.02 ± 3.71	24.41 ± 4.02	0.15 6	24.22 ±4.38	24.55 ± 3.64	24.39 ± 4.06	24.41 ± 4.02	0.92 7
Waist circumferenc e (cm)	79.81 ± 8.88	81.73 ± 9.54	79.62 ± 9.30	80.38 ± 9.25	0.32 7	80.83 ± 10.20	79.63 ± 8.09	80.69 ± 9.45	80.38 ± 9.25	0.70 6
Body fat %	35.18 ± 5.22	35.58 ± 5.06	34.72 ± 5.29	35.15 ± 5.18	0.60 9	35.15 ± 5.45	35.31 ± 4.69	35.00 ± 5.42	35.15 ± 5.18	0.93 8

Discussion

The present study examined the association between dietary acid load (DAL), anthropometric indices, and body fat percentage among Malaysian Chinese postmenopausal women. Overall, higher DAL, assessed using Potential Renal Acid Load (PRAL) and Net Endogenous Acid Production (NEAP), was associated with differences in dietary nutrient intake but not with anthropometric indices or body fat percentage. Participants in the higher DAL tertiles had significantly higher intakes of energy, protein, fat, and phosphorus, while potassium and

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magnesium intakes were lower compared with those in the lower DAL tertiles. However, no significant differences were observed in body weight, BMI, waist circumference, or body fat percentage across DAL tertiles.

Dietary patterns significantly influence the acid-base balance in the human body, with specific food groups affecting dietary acid load (DAL) due to their metabolic byproducts [13]. High DAL diets, predominantly comprising animal protein and cereal-based foods, lead to greater production of acidic compounds such as sulfuric and phosphoric acids. On the other hand, diets rich in fruits and vegetables contribute to lower DAL due to their high levels of alkali-forming minerals, such as potassium, bicarbonate, and magnesium [14, 15]. These minerals help neutralize the acidic metabolites in the body and maintain a balance acid-base condition.

In the present study, participants in the higher DAL tertiles had greater intakes of protein and phosphorus but lower potassium and magnesium intakes. This finding indicated that participants' habitual diet is more on acid-forming foods. This finding was in contrast with the current belief that Chinese's cultural dietary habits are more on rice and vegetable consumption, which should lead towards lower DAL [16, 17]. This dietary transition from traditional Chinese food towards westernized diet among Malaysian Chinese women, has the potential to raise DAL and adversely impact bone health and metabolic risk [18, 19].

Despite the observed differences in dietary intake across DAL tertiles, no significant associations were found between DAL and anthropometric indices or BF%. This finding suggests that DAL may not have a direct influence on adiposity among postmenopausal women in this population. However, this finding is inconsistent with the current research. A study assessing DAL's relationship with abdominal adiposity and anthropometric indices (BMI and WC) found that a higher DAL may contribute to an increased risk of abdominal obesity [5]. Another study also showed that DAL is inversely associated to skeletal muscle mass index among overweight or obese women [6].

In this study, we propose few factors that might explain the insignificant association between DAL and anthropometric indices in Malaysian postmenopausal women. First, the effects of DAL might

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be overshadowed by other dietary factors such as macronutrient composition, caloric intake, and nutritional diversity. Second, postmenopausal women may exhibit highly individualized responses to DAL influenced by genetic factors, estrogen deficiency, and lifestyle patterns. This complexity may explain mixed results across different populations, including inconsistencies in the relationship between DAL and anthropometry [5, 20]. Lastly, physical activity levels are pivotal in regulating fat distribution, lean muscle mass, and central adiposity [21]. However, this study does not include physical activity might limit the findings.

The present study has several strengths. To our knowledge, this is among the few studies examining DAL and body composition among Malaysian postmenopausal women. The use of both PRAL and NEAP estimates provided a comprehensive assessment of DAL. However, several limitations should be acknowledged. The cross-sectional design limits the ability to establish causal relationships between DAL and anthropometric outcomes. Furthermore, other factors that may influence body composition, such as physical activity level and hormonal status, were not comprehensively assessed in the present analysis.

Conclusion

In conclusion, higher DAL was associated with higher energy, protein, fat, and phosphorus intake and lower potassium and magnesium intake among Malaysian Chinese postmenopausal women. However, no significant associations were observed between DAL and anthropometric indices or BF%. Given the physiological and dietary diversity of this population, further longitudinal studies incorporating robust analysis methods are required to elucidate DAL's role within a broader metabolic and dietary framework.

Conflicts of Interest

The authors declare no conflict of interest.

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Author Contributions

S.Y.L. worked on data curation, methodology, formal analysis and prepared the original draft writing. Y.M.C. contributed on funding acquisition, data curation, methodology, review, editing and supervision.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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