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IMPACT OF SARCOPENIA ON FUNCTIONAL RECOVERY IN ICU PATIENTS: PREVALENCE, CLINICAL OUTCOMES AND MANAGEMENT

Original Article (ID: 458)

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ABSTRACT

Background: Sarcopenia is increasingly recognised as a clinically important problem in critical care because immobility, systemic inflammation, inadequate nutritional intake, organ dysfunction, and mechanical ventilation can accelerate skeletal-muscle loss. Reduced muscle reserve may contribute to delayed mobilisation, prolonged dependence, and poorer recovery after intensive care. Bedside ultrasonography offers a practical method of assessing peripheral muscle status when conventional tests of strength and physical performance cannot be completed in unstable, sedated, or mechanically ventilated patients at admission.

Objective: To determine the prevalence of ultrasound-defined sarcopenia among critically ill adults and examine the relationships of quadriceps muscle thickness with age, sex, and place of residence.

Methods: This observational study included 93 critically ill adults admitted to an intensive care unit. Rectus femoris and vastus intermedius thicknesses were measured by bedside ultrasonography, and total quadriceps thickness was calculated from both measurements. Sarcopenia was classified using prespecified sex-specific rectus femoris thresholds. Data were analysed using descriptive statistics, the Mann–Whitney U test, Spearman's rank correlation, and multiple linear regression.

Results: The sample comprised 44 males (47.3%) and 49 females (52.7%), with a mean age of 32.71 ± 14.76 years; 78 participants (83.9%) were urban residents. No participant met the operational criteria for sarcopenia, yielding a prevalence of 0.0%. Mean rectus femoris, vastus intermedius, and total quadriceps thicknesses were 16.93 ± 5.00 mm, 13.28 ± 1.93 mm, and 30.22 ± 5.95 mm, respectively. Muscle thickness did not differ significantly by sex or residence. Age correlated inversely with vastus intermedius thickness ($\rho = -0.249$, $p = 0.016$) and independently predicted lower total quadriceps thickness ($B = -0.098$ mm/year, $p = 0.018$). The regression model explained 7.0% of the variance. Clinical-outcome associations could not be estimated because sarcopenia status was constant.

Conclusion: Ultrasound-defined sarcopenia was not identified in this relatively young ICU cohort. Increasing age predicted lower quadriceps thickness. Serial ultrasonography may detect emerging muscle loss and guide nutritional and rehabilitation strategies.

Keywords: Adult; Critical Illness; Intensive Care Units; Muscle, Skeletal; Quadriceps Muscle; Sarcopenia; Ultrasonography.

INTRODUCTION

Sarcopenia is a progressive skeletal muscle disorder characterised by reduced muscle mass, strength, and physical performance. Although traditionally associated with ageing, it is increasingly recognised as an important complication of critical illness. Patients admitted to intensive care units are frequently exposed to prolonged immobility, systemic inflammation, sepsis, inadequate nutritional intake, multiple-organ dysfunction, and mechanical ventilation. These factors can accelerate skeletal muscle breakdown and result in substantial muscle loss within a relatively short period (1–3). Advances in intensive care medicine have improved survival among patients with severe illnesses, including malignancies, haematological disorders, and multiple comorbidities. Nevertheless, survival does not always correspond to complete functional recovery. Many ICU survivors experience persistent muscle weakness, reduced mobility, dependence in activities of daily living, and impaired quality of life after discharge. Sepsis, prolonged immobilisation, nutritional deficiencies, and multiple-organ failure have consistently been identified as major contributors to unfavourable outcomes in critically ill populations (4–6).

Skeletal muscle wasting may begin soon after the onset of critical illness. Reduced mechanical loading during bed rest, combined with inflammatory and metabolic stress, promotes muscle protein breakdown and suppresses protein synthesis. Sedation, vasopressor therapy, mechanical ventilation, haemodynamic instability, and other forms of organ support may also delay mobilisation and rehabilitation, leaving patients with weakness, delayed functional improvement, and diminished post-discharge quality of life (6–8). The prevalence of sarcopenia among critically ill patients varies considerably according to the characteristics of the study population, the diagnostic criteria applied, the method of muscle assessment, and the timing of evaluation. A systematic review and meta-analysis reported a pooled prevalence of approximately 41%, whereas another study identified during the development of the current research protocol reported sarcopenia in 62.9% of ICU patients (8–10).

Reduced skeletal muscle reserve may limit a patient's ability to tolerate the physiological and metabolic demands of severe illness, contributing to prolonged mechanical ventilation, restricted mobilisation, and increased dependence. Sarcopenia has been associated with longer hospitalisation, greater functional dependency, increased complications, and mortality, although findings have not been entirely consistent, reflecting variation in age, disease severity, comorbidities, nutritional status, and assessment technique (10–12). Accurate assessment of sarcopenia in critically ill patients remains challenging. Conventional diagnostic frameworks require the combined evaluation of muscle mass, strength, and physical performance — assessments that are often impractical in sedated, unconscious, mechanically ventilated, or haemodynamically unstable patients. CT and MRI can measure muscle mass but are limited by cost, radiation exposure, and the risk of transferring unstable patients (12–14).

Bedside ultrasonography provides a practical alternative for evaluating skeletal muscle in critical care. It is non-invasive, repeatable, relatively inexpensive, and can be performed without moving the patient. Measurements of the rectus femoris and vastus intermedius can provide an objective estimate of peripheral skeletal muscle status, assisting in identifying patients with reduced muscle reserve and supporting timely nutritional and rehabilitation strategies. The use of sex-specific rectus femoris thresholds may further improve classification. Despite increasing recognition of ICU-associated muscle wasting, uncertainty remains regarding the prevalence of sarcopenia and its relationship with major clinical outcomes in critically ill adults, and whether ultrasonographic muscle thickness varies by sex and residence, or whether age and residence predict total quadriceps thickness.

The primary research question was whether sarcopenia, assessed through bedside ultrasonographic measurements of the rectus femoris and vastus intermedius, was prevalent among critically ill adults and whether its presence was associated with adverse clinical outcomes. It was hypothesised that patients with sarcopenia would have a greater likelihood of prolonged ICU stay, mechanical ventilation, circulatory-support requirements, and in-hospital mortality than patients without sarcopenia. The secondary objectives were to evaluate this association; compare muscle thickness between males and females and between rural and urban residents; examine the relationship of age with ultrasonographic muscle measurements; and determine whether age and place of residence could predict total quadriceps muscle thickness.

METHODOLOGY

This was a longitudinal observational study conducted over a three-month period in the Intensive Care Unit of Jinnah Postgraduate Medical Centre (JPMC), Karachi, following approval from the Institutional Review Board (IRB). The study was designed to determine the prevalence of sarcopenia using bedside ultrasonographic measurement of quadriceps muscle thickness and to evaluate the relationships of muscle thickness with selected demographic characteristics and clinical outcomes. Adult patients aged 18 years or older who were admitted to the ICU and underwent bedside quadriceps ultrasonography were eligible for inclusion, and were enrolled using a non-probability consecutive sampling technique. Patients younger than 18 years, those with lower-limb amputation, major trauma or surgery involving the assessed limb, pre-existing neuromuscular disorders, local wounds or dressings that prevented adequate scanning, or incomplete demographic, clinical, or ultrasonographic records were excluded. A total of 93 eligible critically ill adults were included in the final analysis. Complete data were available for all participants, and no cases were excluded because of missing values.

Demographic and clinical information was recorded using a structured data-collection form, including age, sex, and place of residence (urban or rural). The primary outcome was the presence of sarcopenia according to prespecified ultrasonographic criteria. Additional

variables included rectus femoris thickness, vastus intermedius thickness, and total quadriceps muscle thickness. Planned clinical outcomes were an ICU length of stay exceeding seven days, requirement for mechanical ventilation, requirement for circulatory support, and in-hospital mortality. Quadriceps muscle thickness was assessed at the bedside using a portable ultrasound system equipped with a 12-MHz linear-array transducer. Measurements were obtained from the right thigh at the midpoint between the anterior superior iliac spine and the superior border of the patella, with each participant supine and the right lower limb relaxed and extended. The rectus femoris and vastus intermedius muscles were identified in the transverse plane; muscle thickness was measured in millimetres between the superficial and deep fascial boundaries, excluding overlying subcutaneous tissue and the femoral cortex. Total quadriceps muscle thickness was calculated as the sum of the two measurements. All assessments were performed by a single trained radiologist experienced in musculoskeletal ultrasonography to minimise inter-observer variation.

Sarcopenia was assessed according to prespecified sex-specific rectus femoris thickness thresholds stated in the approved study protocol, with participants classified as having normal muscle thickness or mild, moderate, or severe sarcopenia. As the operational assessment was based on ultrasonographic muscle thickness alone, it represented ultrasound-defined low muscle mass rather than a comprehensive diagnosis incorporating muscle strength and physical performance. Data were entered, checked for completeness and accuracy, and analysed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Categorical variables were presented as frequencies and percentages; continuous variables were summarised using means, standard deviations, medians, and ranges. Normality was assessed using the Kolmogorov–Smirnov test with Lilliefors correction and the Shapiro–Wilk test; as the continuous variables showed significant departures from normality, non-parametric tests were applied. The Mann–Whitney U test was used to compare muscle-thickness measurements between male and female participants and between urban and rural residents. Spearman's rank-order correlation coefficient was used to examine relationships between age and the three muscle-thickness measures.

Multiple linear regression analysis was performed to determine whether age and place of residence independently predicted total quadriceps muscle thickness, with total quadriceps thickness as the dependent variable and age and residence entered simultaneously (enter method; residence coded 1 = urban, 2 = rural). The model was reported using unstandardised and standardised coefficients, standard errors, 95% confidence intervals, t-statistics, p-values, R^2, adjusted R^2, and the overall F-statistic. Multicollinearity was assessed using tolerance and variance inflation factor values. All tests were two-tailed, with $p < 0.05$ considered statistically significant. Associations of sarcopenia with clinical outcomes were planned via chi-square or Fisher's exact test, as appropriate, but were not estimable because sarcopenia status showed no variation within the study population. Ethical approval was obtained before data collection began. Written informed consent was obtained from conscious, capable participants; for patients unable to consent because of sedation, unconsciousness, mechanical ventilation, or clinical instability, consent was obtained from a legally authorised representative in accordance with institutional policy. Confidentiality was maintained through coded data collection and restricted access to study records. The study was conducted in accordance with the Declaration of Helsinki.

RESULTS

A total of 93 critically ill adults were included in the analysis, and no participant had missing demographic or ultrasonographic data. The study population comprised 44 males (47.3%) and 49 females (52.7%). Most participants resided in urban areas (n = 78, 83.9%), whereas 15 (16.1%) were from rural areas. None of the participants met the prespecified ultrasonographic criteria for sarcopenia, resulting in a prevalence of 0.0% (0/93; exact 95% CI, 0.0%–3.9%). All 93 participants were therefore classified as having normal muscle thickness. Because sarcopenia status showed no variability, planned comparisons between participants with and without sarcopenia, and associations with prolonged ICU stay, mechanical ventilation, circulatory support, and in-hospital mortality, could not be estimated. The mean age of participants was 32.71 ± 14.76 years (median 28.00; range 18.00–71.00). Mean rectus femoris thickness was 16.93 ± 5.00 mm (median 16.98 mm), mean vastus intermedius thickness was 13.28 ± 1.93 mm (median 13.80 mm), and mean total quadriceps thickness was 30.22 ± 5.95 mm (median 30.90 mm).

Table 1. Participant characteristics (N = 93)

Characteristic	Category	n (%)
Sex	Male	44 (47.3)
	Female	49 (52.7)
Residence	Urban	78 (83.9)
	Rural	15 (16.1)
Sarcopenia	Present	0 (0.0)
	Absent	93 (100.0)
Sarcopenia severity	Normal (no sarcopenia)	93 (100.0)

Data are presented as count (percentage).

Age showed moderate positive skewness (skewness = 1.080; kurtosis = 0.252). Rectus femoris thickness was markedly right-skewed and leptokurtic (skewness = 7.042; kurtosis = 62.277), and total quadriceps thickness was also substantially right-skewed and leptokurtic (skewness = 4.001; kurtosis = 31.891). Vastus intermedius thickness showed a nearly symmetrical distribution (skewness = −0.484; kurtosis = 0.528). One participant had an extreme rectus femoris thickness of 60.20 mm and a corresponding total quadriceps thickness of 74.00 mm; this observation was retained because no source-data error or prespecified reason for exclusion had been documented. All continuous variables deviated significantly from a normal distribution (Table 2), so non-parametric tests were used for group comparisons and correlation analyses.

Table 2. Descriptive statistics and normality assessment (N = 93)

Variable	Mean ± SD	Median	Range	Skew.	Kurt.	K–S	S–W
Age (years)	32.71 ± 14.76	28.00	18.00–71.00	1.080	0.252	0.184 (<0.001)	0.861 (<0.001)
RF (mm)	16.93 ± 5.00	16.98	9.50–60.20	7.042	62.277	0.305 (<0.001)	0.403 (<0.001)
VI (mm)	13.28 ± 1.93	13.80	8.00–18.04	−0.484	0.528	0.111 (0.007)	0.970 (0.033)
Total (mm)	30.22 ± 5.95	30.90	17.50–74.00	4.001	31.891	0.213 (<0.001)	0.637 (<0.001)

K–S, Kolmogorov–Smirnov (with Lilliefors significance correction); S–W, Shapiro–Wilk; test statistics reported as statistic (p value), with 93 degrees of freedom. SD, standard deviation; Skew., skewness; Kurt., kurtosis; RF, rectus femoris; VI, vastus intermedius.

No statistically significant differences in muscle thickness were observed between male and female participants (Table 3). For RF thickness, mean ranks were 50.17 (male) vs 44.15 (female), U = 938.5, Z = −1.074, p = 0.283. For VI thickness, mean ranks were 43.92 (male) vs 49.77 (female), U = 942.5, Z = −1.043, p = 0.297. Total quadriceps thickness was comparable between sexes (mean ranks 46.26 vs 47.66; U = 1045.5, Z = −0.250, p = 0.803). Muscle-thickness measurements also did not differ significantly between urban and rural residents. Mean ranks for RF thickness were 49.11 (urban) vs 36.03 (rural), U = 420.5, Z = −1.719, p = 0.086; for VI thickness, 49.20 vs 35.57, U = 413.5, Z = −1.792, p = 0.073; and for total thickness, 49.15 vs 35.80, U = 417.0, Z = −1.755, p = 0.079.

Table 3. Mann–Whitney U comparisons of quadriceps muscle thickness by sex and residence

Variable	Mean rank (Group 1)	Mean rank (Group 2)	U	Z	p
By sex: Male (n=44) vs Female (n=49)					
RF (mm)	50.17	44.15	938.5	−1.074	0.283
VI (mm)	43.92	49.77	942.5	−1.043	0.297
Total (mm)	46.26	47.66	1045.5	−0.250	0.803
By residence: Urban (n=78) vs Rural (n=15)					
RF (mm)	49.11	36.03	420.5	−1.719	0.086
VI (mm)	49.20	35.57	413.5	−1.792	0.073
Total (mm)	49.15	35.80	417.0	−1.755	0.079

U, Mann–Whitney U statistic; Z, standardised test statistic (corrected for ties); p, asymptotic two-tailed significance. RF, rectus femoris; VI, vastus intermedius.

Age had a weak inverse correlation with vastus intermedius thickness (Spearman's ρ = −0.249, p = 0.016); correlations with rectus femoris (ρ = −0.080, p = 0.446) and total quadriceps thickness (ρ = −0.188, p = 0.071) were not statistically significant. The muscle-thickness measurements were strongly and positively correlated with one another: RF with VI (ρ = 0.601, p < 0.001), RF with total (ρ = 0.856, p < 0.001), and VI with total (ρ = 0.879, p < 0.001).

Table 4. Spearman rank-order correlation matrix between age and muscle thickness of quadriceps (N = 93)

Variable	Age	RF	VI	Total
Age	1.000			
RF	−0.080	1.000		

VI	−0.249*	0.601***	1.000	
Total	−0.188	0.856***	0.879***	1.000

*Values are Spearman's correlation coefficient (ρ). *p < 0.05; ***p < 0.001 (two-tailed). RF, rectus femoris; VI, vastus intermedius.*

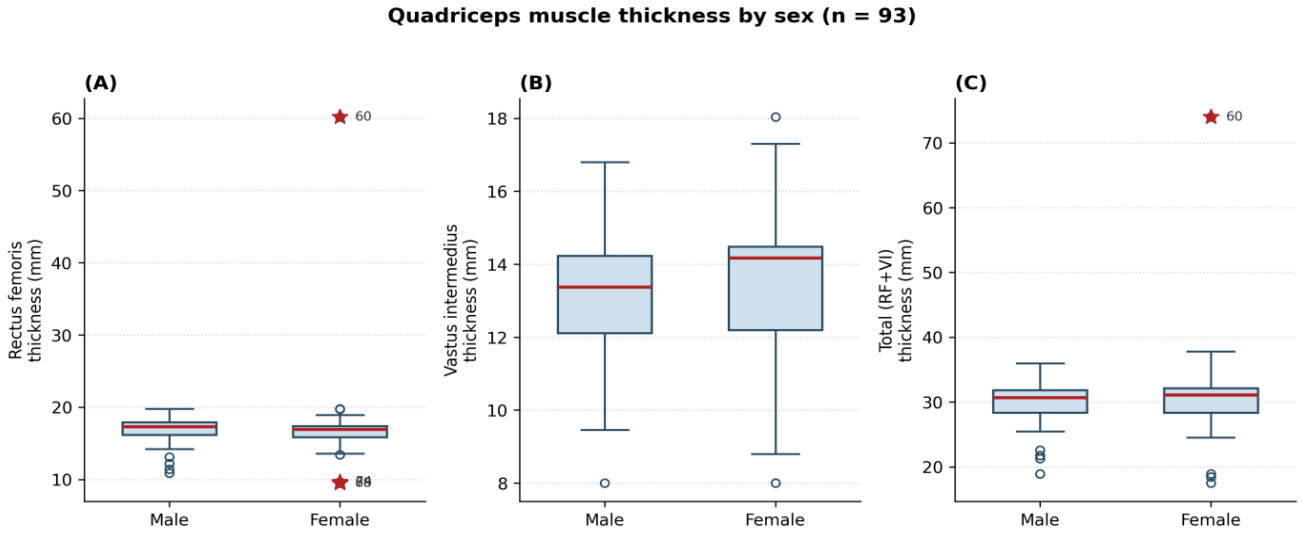
A multiple linear regression model incorporating age and residence explained 7.0% of the variance in total quadriceps thickness (R = 0.265, R^2 = 0.070, adjusted R^2 = 0.050). The overall model was statistically significant (F[2, 90] = 3.403, p = 0.038; standard error of the estimate = 5.799 mm). After adjustment for residence, age was independently associated with total quadriceps thickness: each additional year of age corresponded to a reduction of 0.098 mm in total thickness (B = −0.098; SE = 0.041; β = −0.244; 95% CI, −0.180 to −0.017; t = −2.400, p = 0.018). Residence was not an independent predictor (B = 1.904; SE = 1.638; β = 0.118; 95% CI, −1.350 to 5.158; t = 1.162, p = 0.248). Tolerance (0.997) and VIF (1.003) for both predictors indicated no evidence of multicollinearity.

Table 5. Multiple linear regression model predicting total quadriceps muscle thickness (N = 93)

Predictor	B (95% CI)	SE	β	t	p	VIF
(Constant)	31.234 (26.582, 35.886)	2.342	—	13.339	<0.001	—
Age (years)	−0.098 (−0.180, −0.017)	0.041	−0.244	−2.400	0.018	1.003
Residence	1.904 (−1.350, 5.158)	1.638	0.118	1.162	0.248	1.003

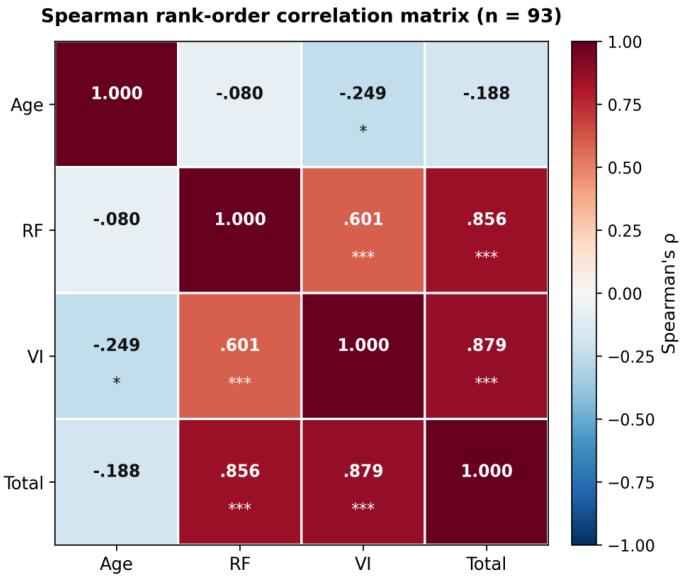
Dependent variable: total (RF + VI) muscle thickness (mm). Model summary: R = 0.265, R^2 = 0.070, adjusted R^2 = 0.050; F(2,90) = 3.403, p = 0.038. Residence coded 1 = urban, 2 = rural.

Figure 1.



Box-and-whisker plots of quadriceps muscle thickness in male vs female patients (n = 93): (A) rectus femoris (RF), (B) vastus intermedius (VI), (C) total thickness (RF + VI). Boxes show the interquartile range (25th–75th percentile); the horizontal line is the median; whiskers extend to values within 1.5 × IQR. The extreme outlier (case 60) is marked with a star and was retained in all analyses as no documented reason for exclusion was found. No significant differences were found between males and females on any measure (all p > 0.05).

Figure 2.



*Heatmap of the Spearman rank-order correlation matrix of age and quadriceps muscle thickness (N = 93). Cell colour reflects the size and sign of the correlation coefficient (ρ): red indicates positive correlations, blue indicates negative correlations, per the scale shown. Numbers show ρ values; asterisks denote significance (*p<0.05, **p<0.01, ***p<0.001, two-tailed). Muscle-thickness measures were strongly inter-correlated; age showed weak, mostly non-significant, negative associations with muscle thickness. RF, rectus femoris; VI, vastus intermedius.*

DISCUSSION

The present study evaluated sarcopenia among critically ill adults through bedside ultrasonographic measurement of rectus femoris and vastus intermedius thickness. The principal finding was that none of the 93 participants met the prespecified sex-specific criteria for sarcopenia, resulting in an observed prevalence of 0.0%. This finding differed markedly from previous critical-care literature, in which sarcopenia had frequently been reported as a common condition. Earlier systematic evidence indicated a pooled prevalence of approximately 41%, whereas another investigation conducted in an ICU population reported a prevalence of 62.9% (8–10). The absence of identified cases in the present cohort therefore required cautious interpretation and could not be considered evidence that sarcopenia was absent from critically ill populations more broadly. Several characteristics of the study population may have contributed to the low observed prevalence. The mean age was 32.71 years, indicating that the cohort was considerably younger than populations in which sarcopenia is most frequently reported. Advancing age is associated with progressive reductions in skeletal muscle mass, strength, regenerative capacity, and physiological reserve. Younger critically ill patients may enter intensive care with greater baseline muscle stores and may therefore be less likely to fall below diagnostic thresholds during the early phase of admission. Previous investigations have shown that the prevalence and prognostic importance of sarcopenia vary according to age, disease severity, nutritional status, comorbid conditions, case mix, and the method used to assess skeletal muscle (10–14).

The diagnostic approach represented another important explanation for the contrast with previous studies. Contemporary definitions of sarcopenia generally incorporate muscle strength as a primary component, supported by evidence of reduced muscle quantity or quality and, in more severe cases, impaired physical performance. Such assessments are difficult to perform in patients who are sedated, unconscious, mechanically ventilated, or haemodynamically unstable. Bedside ultrasound was therefore used as a practical surrogate measure of peripheral muscle quantity. Although this approach was feasible and clinically convenient, muscle thickness alone did not provide a complete assessment of sarcopenia. The findings were consequently more accurately interpreted as an absence of ultrasound-defined low quadriceps muscle thickness according to the selected thresholds rather than definitive exclusion of sarcopenia in every participant. Differences in ultrasound methodology may also have affected case classification. Estimates of muscle thickness vary according to the anatomical measurement site, patient positioning, transducer pressure, probe orientation, limb selected, operator experience, timing of assessment, and the cut-off values applied. Measurements obtained shortly after ICU admission may predominantly reflect pre-existing muscle status, whereas later measurements may capture muscle loss acquired during critical illness. Cross-sectional studies based on a single measurement may therefore fail to identify patients who develop substantial muscle wasting during a prolonged ICU stay. In addition, thresholds derived from older populations, other ethnic groups, or different ultrasound techniques may not perform adequately in a young local population. These methodological differences may partly explain why studies using computed tomography, magnetic resonance imaging, bioelectrical impedance, or combined functional criteria have reported considerably higher prevalence rates.

No significant differences in rectus femoris, vastus intermedius, or total quadriceps thickness were found between male and female participants. Males generally possess greater skeletal muscle mass than females in healthy populations; however, this expected difference was not evident in the present cohort. The lack of statistical significance may have reflected the modest sample size, relatively young

age distribution, clinical heterogeneity, and the influence of an extreme muscle-thickness observation. Critical illness may also alter the usual relationship between sex and skeletal muscle through inflammation, inactivity, nutritional deficits, fluid shifts, and variable exposure to organ-support therapies. Previous ICU research has similarly indicated that muscle depletion is influenced by several interacting clinical factors rather than by sex alone (14–18). Quadriceps thickness was consistently higher among urban residents than among rural residents, although none of the differences reached statistical significance. Variations in nutritional intake, occupational activity, socioeconomic conditions, healthcare access, and pre-admission functional status could plausibly contribute to differences in muscle reserve between residential groups. Nevertheless, these factors were not directly measured, and the results did not support an independent relationship between residence and total quadriceps thickness. The rural subgroup contained only 15 participants, which reduced statistical power and produced an imbalanced comparison. Residence should therefore not be interpreted as biologically protective or harmful on the basis of the present findings.

Age demonstrated a weak inverse relationship with muscle thickness. The association was statistically significant for vastus intermedius thickness, whereas the correlations with rectus femoris and total quadriceps thickness were not significant in the unadjusted analyses. In the multivariable model, increasing age remained independently associated with lower total quadriceps thickness after adjustment for residence. Each additional year of age corresponded to an estimated reduction of approximately 0.10 mm in total quadriceps thickness. This finding was consistent with the established age-related decline in skeletal muscle quantity and supported the biological plausibility of bedside ultrasound as an indicator of peripheral muscle status (18). However, age and residence explained only 7.0% of the variation in total quadriceps thickness, indicating that most of the observed variability was attributable to factors not included in the model. Potential determinants not evaluated in the regression analysis included sex, height, body weight, body mass index, nutritional status, pre-existing physical activity, comorbidities, severity of acute illness, fluid balance, sepsis, corticosteroid exposure, duration of immobilisation, and mechanical ventilation. These factors may have had stronger effects on quadriceps thickness than age or residence. Fluid accumulation was particularly relevant because oedema and tissue hydration may alter ultrasonographic measurements and potentially obscure true muscle depletion. Future predictive models should therefore include clinically relevant anthropometric, nutritional, and disease-related variables where the sample size permits.

Rectus femoris, vastus intermedius, and total quadriceps thickness were strongly correlated with one another. Total thickness showed very strong positive correlations with both individual muscle measurements, while rectus femoris and vastus intermedius thickness were also strongly related. These findings were expected because total quadriceps thickness was mathematically derived from the sum of the two component measurements. The observed correlations therefore confirmed internal consistency but should not be interpreted as independent validation of the ultrasound method. Validation would require comparison with an established reference technique, such as computed tomography-derived muscle area, magnetic resonance imaging, dual-energy X-ray absorptiometry, or a validated functional measure. Bedside ultrasonography nevertheless retained several practical advantages in critical care. It could be performed without transporting unstable patients, avoided ionising radiation, was repeatable, and allowed serial assessment during admission. Previous research has emphasised its potential role in monitoring peripheral muscle loss among patients who cannot participate in conventional strength or performance testing (19–21). Its greatest clinical value may lie in repeated measurement rather than a single cross-sectional assessment. A patient with muscle thickness above a diagnostic cut-off at admission may still experience clinically important muscle loss over subsequent days because of inflammation, catabolism, immobility, inadequate nutritional intake, sedation, mechanical ventilation, and multiple-organ support.

The absence of sarcopenia at one assessment did not therefore exclude the possibility of subsequent ICU-acquired muscle wasting or weakness. Serial ultrasonography could identify reductions in quadriceps thickness before functional deterioration becomes clinically apparent, potentially supporting earlier nutritional optimisation, physiotherapy, mobilisation, minimisation of unnecessary sedation, and structured rehabilitation planning. However, the present study did not evaluate changes in muscle thickness over time or the effects of specific management strategies, and therefore provided no direct evidence that ultrasound-guided intervention improved functional recovery or clinical outcomes. The study had several strengths. Bedside ultrasonography permitted objective evaluation of muscle thickness in patients who might not have been able to perform strength or mobility tests. Complete data were available for all 93 participants, eliminating bias related to missing observations. The analysis included sex- and residence-based comparisons, correlations with age, and an adjusted assessment of predictors of total quadriceps thickness. The use of non-parametric tests was appropriate for the skewed distribution of the ultrasound measurements.

The findings were subject to important limitations. The study was conducted in a relatively small and predominantly young sample, which restricted statistical power and limited generalisability to older or more severely debilitated ICU populations. The unequal distribution of urban and rural participants weakened residential comparisons. No participant met the operational criteria for sarcopenia, preventing the planned evaluation of associations with prolonged ICU stay, mechanical ventilation, circulatory support, and mortality; the prognostic effect of sarcopenia could therefore not be determined. Sarcopenia was classified using ultrasound-derived muscle thickness without concurrent assessment of strength, physical performance, pre-admission function, or muscle quality, so the study did not meet all components of widely accepted diagnostic frameworks. The validity and population appropriateness of the selected sex-specific cut-offs also remained a critical consideration. The use of a single measurement prevented evaluation of the rate of muscle loss during ICU admission. Information on nutritional status, body size, illness severity, comorbidities, sepsis, oedema, ventilation duration,

medications, and rehabilitation exposure was not incorporated into the principal analyses. An extreme rectus femoris measurement of 60.20 mm and total quadriceps thickness of 74.00 mm may also have influenced the descriptive statistics and regression model. Although the observation was retained because no documented data-entry error was identified, its marked separation from the remaining distribution warranted verification against the original ultrasound image and data-collection record. Sensitivity analyses excluding this observation would have helped determine whether the association between age and total quadriceps thickness remained stable.

Future studies should recruit larger and more diverse populations, particularly older adults and patients with prolonged ventilation, sepsis, malnutrition, multiple comorbidities, or extended ICU stays. Ultrasound assessment should be standardised with respect to anatomical site, patient position, transducer pressure, limb selection, assessor training, and timing. Repeated measurements from admission to ICU discharge would permit estimation of the rate of muscle loss and its relationship with clinical events. Where feasible, ultrasonography should be combined with strength testing, functional assessment, nutritional screening, and validated measures of illness severity. Further research should also evaluate whether early nutritional support, adequate protein provision, progressive mobilisation, neuromuscular stimulation, and structured rehabilitation reduce muscle loss or improve independence after critical illness. Overall, the study did not identify ultrasound-defined sarcopenia in the examined ICU population, despite substantially higher prevalence estimates in previous literature. The finding was most plausibly related to the young study population, the use of a single muscle-thickness-based definition, and methodological differences from earlier investigations. Age remained independently associated with lower total quadriceps thickness, while sex and residence were not significantly related to the measured muscle parameters. Bedside ultrasound appeared feasible for evaluating quadriceps muscle status, but longitudinal and multimodal assessment would be required to establish its diagnostic accuracy and clinical relevance in critically ill patients.

CONCLUSION

The study found no cases of ultrasound-defined sarcopenia among the critically ill adults assessed, which limited evaluation of its relationship with prolonged ICU stay, mechanical ventilation, circulatory support, and mortality. Nevertheless, increasing age was associated with lower quadriceps muscle thickness, while sex and place of residence showed no significant influence. Bedside ultrasonography appeared to be a practical and non-invasive method for assessing peripheral muscle status in critically ill patients, particularly when conventional strength and functional tests were not feasible. Its clinical value may be greater when used repeatedly during ICU admission to detect emerging muscle loss and to guide timely nutritional, mobilisation, and rehabilitation interventions. Future studies should include older and more clinically diverse populations, serial ultrasound measurements, and complementary assessments of muscle strength and physical function.

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