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Received: 11 January 2026

Accepted: 31 March 2026

Published online: 13 April 2026

Cite this article as: Lee B.C., Lee J., Cho K.H. *et al.* Identification of ultrasound predictors and development of a diagnostic scoring system for sarcopenia using LASSO regression: a cross-sectional study. *Sci Rep* (2026). <https://doi.org/10.1038/s41598-026-47400-1>

Byung Chan Lee, Juhyun Lee, Kang Hee Cho & Changwon Moon

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Identification of Ultrasound Predictors and Development of a Diagnostic Scoring System for Sarcopenia Using LASSO Regression: A Cross-Sectional Study

Running Title: Ultrasound in Sarcopenia Diagnosis

Byung Chan Lee¹, Juhyun Lee², Kang Hee Cho^{2,3}, Changwon Moon^{2,3*}

¹Department of Physical Medicine and Rehabilitation, College of Medicine, Chung-Ang University, Seoul, Republic of Korea

²Department of Biomedical Institute, Chungnam National University, Daejeon, Republic of Korea

³Department of Rehabilitation Medicine, Chungnam National University College of Medicine, Daejeon, Republic of Korea

***Corresponding author:** Changwon Moon

Department of Rehabilitation Medicine, Chungnam National University College of Medicine, 266 Munhwa-ro, Jung-gu, Daejeon, 35015, Korea

Telephone number: +82-42-338-2460; Fax number: +82-42-338-2461

E-mail: mcw0171@naver.com

ORCID: 0000-0003-4096-7470

Abstract: 200 words

Manuscript: 3,511 words

Number of Figures and Tables: 6

Number of References: 30

Abstract

Ultrasound-based muscle assessment has emerged as a practical and noninvasive tool for evaluating sarcopenia; however, the relative diagnostic value of individual ultrasound-derived muscle parameters and their integration into a simple scoring system remain unclear. This cross-sectional study included 145 community-dwelling women aged 65–80 years. Eight ultrasound-derived quadriceps muscle parameters were evaluated: rectus femoris thickness, cross-sectional area, and echo intensity; vastus intermedius thickness; vastus lateralis thickness, fascicle length, and pennation angle; and quadriceps femoris thickness, defined as the combined thickness of the rectus femoris and vastus intermedius. Sarcopenia was diagnosed in 8 participants (5.5%). Most ultrasound parameters demonstrated significant weak-to-moderate correlations with handgrip strength and skeletal muscle mass index. Least absolute shrinkage and selection operator regression identified quadriceps femoris thickness, vastus lateralis thickness, and rectus femoris cross-sectional area as the most informative predictors. Based on these variables, a simple preliminary ultrasound-based scoring system was developed using parameter-specific cutoff values. A cutoff score of ≥ 3 demonstrated high diagnostic performance, with an area under the receiver operating characteristic curve of 0.914, sensitivity of 0.875, and specificity of 0.861. This exploratory ultrasound-based scoring system may suggest a feasible approach for sarcopenia screening in older women, although further validation in larger populations is warranted.

Keywords Sarcopenia, Diagnosis, Ultrasound, Quadriceps femoris, Vastus

lateralis, Rectus femoris

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List of abbreviations

AUC, area under the receiver operating characteristic curve

AWGS, Asian Working Group for Sarcopenia

BIA, bioelectrical impedance analysis

BMI, body mass index

CT, computed tomography

DXA, dual-energy X-ray absorptiometry

HGS, handgrip strength

LASSO, least absolute shrinkage and selection operator

MRI, magnetic resonance imaging

NPV, negative predictive value

OR, odds ratio

PPV, positive predictive value

QFT, quadriceps femoris thickness

RF, rectus femoris

RFEI, rectus femoris echo-intensity

RFCSA, rectus femoris cross-sectional area

RFT, rectus femoris thickness

ROI, region of interest

ROC, receiver operating characteristic

SMI, appendicular skeletal muscle mass index

SROC, summary receiver operating characteristic

VI, vastus intermedius

VIT, vastus intermedius thickness

VL, vastus lateralis

VLFL, vastus lateralis fascicle length

VLPA, vastus lateralis pennation angle

VLT, vastus lateralis thickness

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Introduction

Sarcopenia, a geriatric syndrome, is characterized by decreased muscle mass and strength, as well as impaired physical function¹. Despite the variance depending on the diagnostic criteria, the prevalence is generally estimated at 10%–27%². Sarcopenia is associated with an increased risk of falls, fractures, and mortality³⁻⁵, highlighting the importance of accurate diagnosis and appropriate management.

Dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) are the primary modalities used to assess muscle mass, with DXA traditionally considered the standard method^{6,7}. However, DXA has several limitations: measurements can be inaccurate in the presence of metallic implants, muscle quality parameters such as intramuscular fat infiltration cannot be evaluated, and trunk muscles cannot be directly measured; hence, appendicular muscle mass must be used instead⁸.

To overcome these limitations, alternative imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound have been proposed for evaluating individual muscles and assessing myosteatosis^{9,10}. Among these, ultrasound has emerged as a particularly suitable option for assessing frail older adults, as it does not expose patients to radiation, enables real-time assessment of multiple muscle sites, and can be performed at the bedside¹¹. Although various muscles can be examined for diagnostic purposes, current approaches remain focused on single-muscle assessments. Given that sarcopenia is a systemic condition characterized by the generalized loss of muscle mass, a diagnostic model incorporating multiple muscles may provide superior diagnostic accuracy.

Therefore, this study aims to investigate multiple ultrasound-derived muscle parameters in Korean women aged ≥ 65 years, identify candidate indices for diagnosing sarcopenia, and ultimately develop an exploratory scoring system.

Methods

This study was a cross-sectional investigation conducted at a single tertiary medical center. Participants were recruited between June 2024 and June 2025. The inclusion criteria were 1) women aged 65–80 years and 2) those who agreed to participate in the study. The exclusion criteria comprised 1) the use of systemic corticosteroids for >1 month within the past month; 2) current treatment for an active malignancy; 3) alcohol dependence; 4) cognitive impairment preventing comprehension of the study protocol; 5) presence of metallic implants; and 6) refusal to participate. Participants were recruited from local senior centers located in urban areas. The study was approved by the Institutional Review Board of our hospital (CNUH-2022-12-026). Written informed consent was obtained from all participants before enrollment.

Outcome analysis

Baseline characteristics, including age, sex, and previous medical history, were collected through patient interviews. Body composition was assessed using DXA (Hologic; Hologic Inc., USA) using commercially available software (version 13.4.1). Appendicular skeletal muscle mass was obtained and divided by height squared to calculate the skeletal muscle index. Handgrip strength (HGS) was measured using a handheld dynamometer (Jamar; Hoggan Scientific, USA). During the HGS measurement, participants were seated with their shoulder in

adduction and the elbow flexed at 90°. Measurements were taken three times for each hand, with a one-minute rest between the trials. The highest value among the six trials was used for analysis⁶.

Sarcopenia diagnosis

The diagnosis of sarcopenia was based on the 2025 criteria of the Asian Working Group for Sarcopenia (AWGS)⁶. According to the cutoff values for women aged ≥ 65 years, participants were classified as having sarcopenia if they had an appendicular skeletal muscle index (SMI) of $< 5.4 \text{ kg/m}^2$ and an HGS of $< 18 \text{ kg}$.

Ultrasound measurement

Ultrasound measurements were performed using an ACUSON S2000 ultrasound system (Siemens Healthineers, USA). An 11-MHz linear transducer was used for all examinations, which were performed by one of the authors (C.W.M.) with > 10 years of experience in musculoskeletal ultrasonography. The operator was blinded to the participants' sarcopenia status and clinical assessment results at the time of image acquisition and analysis. Participants were instructed to avoid exercise for at least 30 minutes before the ultrasound assessment. All measurements were performed with the participant in the supine position, ensuring complete relaxation of the target muscles. Ultrasound scans were obtained from the lower right limb of the participants (Supplemental figure 1).

For quadriceps assessment, a transverse image was acquired at the midpoint between the greater trochanter and the proximal border of the patella (50% of the femur length)¹², ensuring that both the rectus femoris (RF) and vastus

intermedius (VI) were fully included in the field of view. For the RF, muscle thickness (RFT), cross-sectional area (RFCSA), and echo-intensity (RFEI) were measured¹³. RFEI was quantified using ImageJ software (National Institutes of Health, Bethesda, USA). All images were converted to 8-bit grayscale, in which pixel intensity ranges from 0 (black) to 255 (white). A region of interest (ROI) was manually selected while avoiding fascia and bone interfaces, and the mean grayscale value within the ROI was recorded as the RFEI¹⁴. VI muscle thickness (VIT) was measured from the same transverse view. Quadriceps femoris thickness (QFT) was defined as the sum of RFT and VIT.

The probe was placed at the distal third between the greater trochanter and the proximal border of the patella to obtain a clear transverse view of the vastus lateralis (VL)¹⁵. Then, the probe was rotated to obtain a longitudinal view. In this view, VL muscle thickness (VLT; measured from the superficial to the deep aponeurosis) and the pennation angle (VLPA; defined as the angle between the deep aponeurosis and the muscle fascicles) were recorded. Fascicle length (VLFL) was measured directly when the entire fascicle was visible within the image. When this was not possible, fascicle length was estimated using the following equation: $VLFL = VLT / \sin(VLPA)$ ¹⁵. Each ultrasound parameter was measured three times, using the mean value for analysis.

In total, the following ultrasound parameters were collected from the two imaging views: RFT, VIT, QFT, RFEI, RFCSA, VLT, VLPA, and VLFL.

Sample size estimation

The sample size required for evaluating the diagnostic performance of the ultrasound-based scoring system was calculated using the area under the receiver

operating characteristic (ROC) curve (AUC)-based method proposed by Hajian-Tilaki¹⁶.

Previous studies on ultrasound-measured rectus femoris for sarcopenia typically reported AUC values of 0.74–0.82^{11,17}. To adopt a conservative assumption, the expected AUC was set at 0.75. A two-sided α of 0.05, power of 0.80, and a case-control ratio of 1:10 (reflecting the estimated prevalence of sarcopenia in the target population) were applied. Based on these parameters, the required number of participants was computed, providing the estimated minimum sample size of 90 participants (9 cases and 81 controls). The final study sample of 145 participants exceeded this requirement and provided sufficient statistical power for ROC-based diagnostic accuracy analysis.

Statistical analysis

All statistical analyses were performed using R software (version 4.3.0; R Foundation for Statistical Computing). Continuous variables are presented as means and standard deviations, whereas categorical variables are presented as frequencies and percentages.

First, Pearson correlation analysis was conducted to evaluate the associations between ultrasound parameters and HGS and SMI. A logistic least absolute shrinkage and selection operator (LASSO) regression was performed to identify candidate ultrasound variables associated with sarcopenia¹⁸. The optimal λ -value was determined using 10-fold cross-validation, and variables with non-zero coefficients at $\lambda_{\min}$ were selected as candidate predictors. ROC analysis was performed to calculate the AUC, sensitivity, specificity, positive and negative predictive values (PPV and NPV), and accuracy for each variable selected by

LASSO. The optimal cut-off value for each variable was determined at the point maximizing the Youden index¹⁹.

Subsequently, a multivariable logistic regression model including all selected variables was constructed. Regression coefficients (β), standard errors (SEs), p-values, odds ratios (ORs), and 95% confidence intervals were reported.

A simplified scoring system was then developed by assigning weights proportional to the absolute values of the regression coefficients. Scores were assigned based on variable-specific cut-off values, and a total score was calculated. The construct validity of this scoring system was evaluated by examining the correlations between the total calculated score and HGS and SMI.

Finally, the diagnostic performance of the scoring system was assessed using ROC analysis. Furthermore, AUC, sensitivity, specificity, PPV, NPV, and accuracy were calculated. The optimal cut-off values were determined using the Youden index. To assess potential overfitting, internal validation was performed using bootstrap resampling with 1,000 iterations. In each bootstrap sample, the logistic regression model was refitted, and optimism-corrected AUC was calculated. A two-sided p-value < 0.05 indicated statistical significance.

Results

Baseline demographics

A total of 145 older women were included in the analysis. The mean participant's age was 72.3 ± 5.3 years. The average body weight and height were 58.1 ± 8.3 kg and 154.9 ± 5.3 cm, respectively. The mean body mass index (BMI) was 24.2 ± 3.0 kg/m². The mean lean body mass was 15.5 ± 1.5 kg, with an average SMI

of $6.1 \pm 0.7 \text{ kg/m}^2$. Mean HGS was $22.4 \pm 4.3 \text{ kg}$.

Of all participants, 8 individuals (5.5%) met the diagnostic criteria for sarcopenia. Compared with the non-sarcopenia group, participants with sarcopenia were older (75.5 ± 5.2 vs. 72.1 ± 5.3 years, $p = 0.069$, Mann-Whitney U test) and had lower body weight (49.5 ± 5.8 vs. $58.6 \pm 8.2 \text{ kg}$, $p = 0.002$) and BMI (21.12 ± 2.28 vs. $24.35 \pm 2.93 \text{ kg/m}^2$, $p = 0.003$). SMI (4.96 ± 0.39 vs. $6.17 \pm 0.67 \text{ kg/m}^2$) were also significantly lower in the sarcopenia group (both $p < 0.001$). Additionally, HGS was markedly reduced in individuals with sarcopenia (16.18 ± 2.17 vs. $22.75 \pm 4.11 \text{ kg}$, $p < 0.001$) (Table 1).

Correlation between ultrasound parameters and muscle strength/SMI

Eight ultrasound-derived parameters were significantly correlated with both HGS and SMI. Despite their statistical significance, the correlations with HGS were generally weak across most ultrasound variables, including RFT, VIT, QFT, VLT, VLPA, and RFCSA (RFT: 0.290, VIT: 0.283, QFT: 0.322, VLT: 0.335, VLPA: 0.215, and RFCSA: 0.357). In contrast, no significant correlations were observed between HGS and VLFL or RFEI.

For SMI, moderate and significant correlations were found for RFT, QFT, VLT, and RFCSA (RFT: 0.465, QFT: 0.472, VLT: 0.465, and RFCSA: 0.544). VIT, VLPA, VLFL, and RFEI showed weak correlations (VIT: 0.379, VLPA: 0.202, VLFL: 0.201, and RFEI: -0.204) (Table 2).

Diagnostic performance of individual ultrasound parameters

LASSO regression was performed to identify the most relevant predictors of

sarcopenia, selecting three variables: QFT, VLT, and RFCSA. ROC analyses for each selected variable demonstrated the following diagnostic performance: cut-off of 24.52 mm, AUC of 0.866, sensitivity of 1.000, specificity of 0.642, PPV of 0.140, NPV of 1.000, and accuracy of 0.662 for QFT; cut-off of 14.97 mm, AUC of 0.817, sensitivity of 0.875, specificity of 0.730, PPV of 0.159, NPV of 0.990, and accuracy of 0.738 for VLT; cut-off of 3.11 cm², AUC of 0.838, sensitivity of 0.625, specificity of 0.920, PPV of 0.312, NPV of 0.977, and accuracy of 0.903 for RFCSA (Table 3, Supplemental figure 2).

Logistic regression and scoring system based on LASSO-selected variables

Table 4 presents the logistic regression including the three selected variables. Although none of the predictors reached statistical significance, higher QFT, VLT, and RFCSA were consistently associated with lower odds of sarcopenia (β : -0.157, SE: 0.113, p = 0.165, OR: 0.855 [0.686-1.067] for QFT; β : -0.320, SE: 0.175, p = 0.068, OR: 0.727 [0.516-1.023] for VLT; β : -0.194, SE: 0.590, p = 0.742, OR: 0.824 [0.259-2.616] for RFCSA) (Supplemental Table 1). The apparent discriminative performance of the logistic regression model yielded an AUC of 0.871. To assess potential overfitting, internal validation was performed using bootstrap resampling (1,000 iterations). The optimism-corrected AUC was 0.846, indicating a modest degree of overestimation (Supplementary Table 2).

A point-based scoring system was constructed by assigning points proportional to the absolute beta coefficients. One point was given for QFT <24.52 mm, two points for VLT <14.97 mm, and one point for RFCSA <3.11 cm², resulting in a total score ranging from 0 to 4 points (Table 4).

Correlation between the scoring system and muscle strength/muscle mass

Correlations between the total score and HGS or SMI were examined to assess the physiological validity of the scoring system. The score showed a significant negative correlation with HGS ($r = -0.352$) and SMI ($r = -0.468$) (Supplemental Figure 3).

ROC analysis was performed to evaluate the diagnostic utility of the scoring system. The optimal cut-off was 2.5 points, yielding an AUC of 0.914, sensitivity of 0.875, specificity of 0.861, PPV of 0.269, NPV of 0.992, and accuracy of 0.862 (Table 5, Figure 1).

Discussion

This study investigated the diagnostic utility of ultrasound for sarcopenia in 145 community-dwelling Korean women. The ultrasound-derived parameters demonstrated significant weak-to-moderate correlations with SMI, as well as HGS, except for RFEI and VLFL, which did not exhibit significant associations. Among the related variables, LASSO regression identified three key predictors of sarcopenia (QFT, VLT, and RFCSA). A multivariable logistic regression model was constructed using these predictors, and an exploratory scoring system ranging from 0 to 4 points was subsequently developed. The score showed an inverse relationship with both muscle strength and muscle mass. Using Youden's index, the optimal cut-off value was 2.5 points, and a threshold of ≥ 3 points yielded favorable apparent diagnostic performance (AUC 0.914).

Sarcopenia is clinically important due to its association with adverse health outcomes³⁻⁵. Despite its significance, discrepancies exist across diagnostic criteria²⁰. Conventional methods such as DXA and BIA primarily focus on muscle

mass quantification^{6,7,21}, but have limitations, including the inability to assess muscle quality and susceptibility to measurement variability^{10, 22}. To overcome these shortcomings, CT, MRI, and ultrasound have been proposed as alternative assessment tools⁹⁻¹¹. Ultrasound offers several advantages, including the ability to measure various muscle sites, real-time imaging, and bedside applicability. However, its limitations include operator dependency and the need for an adequate level of training²³. To address these issues, groups such as SARCUS have proposed standardization strategies for the acquisition of diagnostic ultrasound measures for sarcopenia¹³.

In the present study, the prevalence of sarcopenia was lower than previously reported. One possible explanation is the use of the updated AWGS 2025 diagnostic criteria. Compared with earlier definitions such as AWGS 2019 or EWGSOP2, the AWGS 2025 criteria do not include certain physical performance measures, such as the Short Physical Performance Battery (SPPB), in the diagnostic algorithm⁶. These differences in diagnostic components may result in variations in prevalence estimates and may partly explain the lower prevalence observed in our cohort. Therefore, comparisons with previous studies should consider differences in diagnostic criteria.

The ultrasound parameters evaluated in this study showed weak-to-moderate correlations with both SMI and HGS, which is consistent with previous reports^{24,25}. Given that the updated AWGS diagnostic criteria emphasize low muscle mass combined with reduced HGS⁶, exploring combinations of ultrasound parameters that simultaneously reflect both components is a logical and clinically meaningful approach toward establishing new diagnostic tools for sarcopenia. Previous studies using diagnostic ultrasound have demonstrated varying degrees of diagnostic accuracy. Compared with previously reported ultrasound-based

diagnostic criteria for sarcopenia, the diagnostic performance of the individual indices in our study was largely consistent. Prior meta-analytic evidence demonstrated that RFT yielded a pooled summary receiver operating characteristic (SROC)-AUC of 0.78, with a sensitivity and specificity of 72% for each. For QFT, a pooled SROC-AUC of 0.64, sensitivity of 63%, and specificity of 77% were reported. Additionally, the pooled sensitivity and specificity of RFCSA were 84% and 69%, respectively¹¹. Beyond muscle size parameters, RFEI provided relatively limited diagnostic value, with reported AUCs ranging from 0.61 to 0.67, indicating poor discriminatory capacity^{26,27}.

Muscle selection in this study was guided by feasibility and measurement standardization. To minimize positional changes and improve consistency, ultrasound assessments were performed in a standardized supine position, focusing on anterior thigh muscles. In addition, echo intensity (EI) analysis was limited to the rectus femoris, as this parameter has been the most widely used and validated in previous studies and allows relatively consistent image acquisition. In our study, LASSO regression identified three ultrasound-derived variables (QFT, VLT, and RFCSA) as key predictors. These variables demonstrated consistent trends in their associations with sarcopenia, and their combination into a composite score showed good discriminative performance. RFT, which has been widely investigated in previous studies¹⁹, was not retained in the model, likely due to multicollinearity with RFCSA. The inclusion of VLT is physiologically plausible, as the VL plays a central role in lower extremity function, and its morphological characteristics may reflect overall quadriceps adaptation²⁸.

This finding suggests that integrating multiple ultrasound parameters may provide a more robust representation of sarcopenia than individual indices alone.

However, given the limited number of events and the data-driven nature of the model, the proposed scoring system should be interpreted as a preliminary, hypothesis-generating approach rather than a definitive diagnostic tool. These findings suggest that ultrasound may have potential utility in the assessment of muscle mass and in the diagnosis of sarcopenia and may contribute to its future integration into diagnostic frameworks.

Although researchers proposed protocols to evaluate the VL using ultrasound²⁹, to the best of our knowledge, no prior study has directly applied VL-based ultrasound measurements for the diagnosis of sarcopenia. Thus, our study is the first to propose and examine these VL-derived indices in a diagnostic context, highlighting their potential value. Moreover, our findings suggest that ultrasound assessment of VL may represent a potentially important parameter for sarcopenia diagnosis and should be considered in future research frameworks. Taken together, the present findings support the potential role of ultrasound as a feasible tool for assessing sarcopenia-related muscle changes. However, further studies with larger sample sizes, diverse populations, and external validation are required before ultrasound-based approaches can be integrated into routine diagnostic frameworks.

Limitations

This study has several limitations. First, it was a small cross-sectional study conducted at a single tertiary center, and all participants were Asian women residing in an urban area. Therefore, the generalizability of our findings to broader populations, including different ethnic groups, sexes, and community settings, may be limited. In particular, sex-specific differences in muscle

distribution and morphological characteristics may influence the selection and performance of ultrasound-derived parameters. Future studies including male participants, diverse populations, and broader clinical subgroups are warranted to further improve generalizability. Second, the prevalence of sarcopenia within our cohort was lower than expected, with only eight cases identified, resulting in a low events-per-variable (EPV) ratio of less than 3 in the multivariable model. This is substantially below commonly recommended thresholds and may increase the risk of model overfitting and unstable estimates. Although LASSO regression was applied to mitigate overfitting, this approach does not fully eliminate bias in small-sample settings. Third, although the scoring system was developed based on variables selected through LASSO regression, none of these predictors reached statistical significance in the subsequent multivariable logistic regression model. This discrepancy may reflect the limited number of sarcopenia cases, which reduces statistical power and complicates the establishment of independent associations for each variable. Furthermore, the diagnostic performance of the model and scoring system was primarily based on apparent estimates. Internal validation using bootstrap resampling demonstrated a modest degree of optimism, with the AUC decreasing from 0.871 to 0.846 after correction. This finding suggests that the observed performance may be overestimated and should be interpreted with caution, highlighting the need for external validation. Fourth, muscle selection in this study was guided by feasibility and measurement standardization, with the aim of minimizing positional changes during ultrasound examination by focusing on anterior thigh muscles in a supine position. In addition, EI analysis was limited to the RF, as this parameter has been the most widely used and validated in previous studies and allows relatively consistent image acquisition. However, restricting the assessment to selected lower limb muscles and a single EI measurement site may limit the comprehensiveness of muscle

evaluation. Sarcopenia does not affect all muscle groups uniformly, and upper extremity or trunk muscles were not included in this study. In particular, upper limb muscles may be relatively preserved or demonstrate compensatory adaptations in response to declining lower extremity function, which may result in different patterns of muscle change³⁰. In addition, physical activity was not quantitatively assessed. Although it is not included in the AWGS 2025 diagnostic criteria, it may influence ultrasound-derived muscle parameters and should be considered in future studies. In addition, all ultrasound measurements were performed by a single experienced operator, and inter- and intra-rater reliability were not assessed. Given the operator-dependent nature of ultrasound, this may limit the reproducibility of the measurements. Nevertheless, despite the lack of statistical significance at the individual predictor level, combining the selected variables into a point-based scoring system yielded favorable overall diagnostic performance, supporting the potential clinical utility of the composite score rather than its individual components. However, given the data-driven derivation and limited number of events, the proposed scoring system should be considered exploratory rather than a definitive clinical tool. Consequently, future research involving larger sample sizes, more balanced event distributions, and multicenter validation studies is necessary to confirm the robustness, reproducibility, and external validity of this ultrasound-based scoring system.

Conclusion

In conclusion, we identified three ultrasound parameters (QFT, VLT, and RFCSA) that together provide favorable diagnostic performance for sarcopenia. Using these predictors, we developed an exploratory 4-point scoring system with high accuracy. Notably, the incorporation of VLT represents a novel and

physiologically meaningful contribution. Although further validation in larger and more diverse cohorts is required, this ultrasound-based score offers a practical and noninvasive approach to sarcopenia diagnosis.

Declarations

Acknowledgment

We thank Chungnam National University Hospital and the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health and Welfare, Republic of Korea, for providing grants to support this clinical trial.

Author contributions

Byung Chan Lee - Conceptualization, Methodology, Data curation, Formal analysis, Writing-original draft; Juhyun Lee - Investigation, Data curation; Kang Hee Cho - Supervision, Writing-review and editing; Changwon Moon - Conceptualization, Methodology, Writing-review and editing, Funding acquisition.

Competing interests

The authors declare no competing interests

Data availability

The datasets used and/or analyzed in the current study are available from the

corresponding author upon reasonable request.

Ethics declarations

The ethical validity of the trial was assessed and approved by the Institutional Review Board of Chungnam National University Hospital (CNUH-2022-12-026). All methods were performed in accordance with the relevant guidelines and regulations, including the Declaration of Helsinki. All the participants provided written informed consent before the trial and agreed to participate.

Consent for publication

Not Applicable.

Funding

This research was supported by A grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health and Welfare, Republic of Korea (grant number: HR22C1734). The funders had no role in the design, data collection, data analysis, and reporting of this study. The research team was autonomous in all aspects of the study.

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Figure legends

Figure 1. A receiver operating characteristic (ROC) curve for the developed scoring system. The ROC curve demonstrating the diagnostic performance of the ultrasound-based scoring system for identifying sarcopenia, with an AUC of 0.914, sensitivity of 0.875, and specificity of 0.861 at the optimal cut-off score of 2.5.

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Table 1. Baseline demographics of participants

	Total	Non- sarcopenia	Sarcopenia	p-value
Age	72.3±5.3	72.1 ± 5.3	75.5 ± 5.2	0.069 [†]
Weight (kg)	58.1±8.3	58.6 ± 8.2	49.5 ± 5.8	0.002
Height (cm)	154.9±5.3	155.0 ± 5.2	153.0 ± 7.1	0.303
BMI (kg/m ²)	24.2±3.0	24.35 ± 2.93	21.12 ± 2.28	0.003
Body fat percent (%)	31.2±4.9	31.18 ± 4.95	31.62 ± 4.26	0.804
Lean body mass (kg)	15.5±1.5	15.63 ± 1.45	13.50 ± 0.76	<0.001
SMI (kg/m ²)	6.1±0.7	6.17 ± 0.67	4.96 ± 0.39	<0.001 [†]
HGS (kg)	22.4±4.3	22.75 ± 4.11	16.18 ± 2.17	<0.001 [†]

BMI, body mass index; SMI, appendicular skeletal muscle index; HGS, hand grip strength

[†]Mann-Whitney test

Table 2. Correlation with ultrasound parameters and HGS or SMI

	HGS	p-value	SMI	p-value
RFT	0.290	<0.001	0.465	<0.001
VIT	0.283	<0.001	0.379	<0.001
QFT	0.322	<0.001	0.472	<0.001
VLТ	0.335	<0.001	0.465	<0.001
VLPA	0.215	<0.001	0.202	0.015
VLFL	0.140	0.093	0.201	0.015
RFCSA	0.357	<0.001	0.544	<0.001
RFEI	−0.065	0.43	−0.204	0.014

HGS, handgrip strength; SMI, appendicular skeletal muscle mass index; RFT, rectus femoris thickness; VIT, vastus intermedius thickness; QFT, quadriceps femoris thickness; VLT, vastus lateralis thickness; VLPA, vastus lateralis pennation angle; VLFL, vastus lateralis fascicle length; RFCSA, rectus femoris cross-sectional area; RFEI, rectus femoris echo-intensity

Table 3. Diagnostic utility of LASSO-selected ultrasound parameters for identifying sarcopenia

	Cut-off	AUC	Sensitivity	Specificity	PPV	NPV	Accuracy
			y	y			cy
QFT	24.52	0.866	1.000	0.642	0.140	1.000	0.662
	mm						
VLT	14.97	0.817	0.875	0.730	0.159	0.990	0.738
	mm						
RFCS	3.11	0.838	0.625	0.920	0.312	0.977	0.903
A	cm ²						

LASSO, least absolute shrinkage and selection operator; QFT, quadriceps femoris thickness; VLT, vastus lateralis thickness; RFCSA, rectus femoris cross-sectional area; AUC, area under the receiver operating characteristic curve; PPV, positive predictive value; NPV, negative predictive value

Table 4. Scoring system based on LASSO-selected ultrasound parameters for identifying sarcopenia

	Cut-off	Score
QFT (mm)	24.52	1
VLT (mm)	14.97	2
RFCSA (cm ²)	3.11	1

LASSO, least absolute shrinkage and selection operator; QFT, quadriceps femoris thickness; VLT, vastus lateralis thickness; RFCSA, rectus femoris cross-sectional area

Table 5. Diagnostic performance of the developed scoring system for sarcopenia diagnosis

	Cut-off	AUC	Sensitivity	Specificity	PPV	NPV	Accuracy
Score	2.5	0.914	0.875	0.861	0.269	0.992	0.862

AUC, area under the receiver operating characteristic curve; PPV, positive predictive value; NPV, negative predictive value

ROC Curve for Total Score (AUC = 0.914)

