Journal of Parenteral and Enteral Nutrition
Volume 44 Number 8
November 2020 1398–1406

DOI: 10.1002/jpen.1830
wileyonlinelibrary.com
WILEY

CE Role of Ultrasonography in Estimating Muscle Mass in Sarcopenic Obesity

Olgun Deniz, MD[1]; Alfonso Cruz-Jentoft, MD[2]; Gozde Sengul Aycicek, MD[1]; Pelin Unsal, MD[1]; Mert Esme, MD[1]; Yelda Ucar, MD[1]; Suna Burkuk, MD[1]; Ayse Sendur, MD[1]; Burcu Balam Yavuz, MD[1]; Mustafa Cankurtaran, MD[1]; and Meltem Halil, MD[1]

Abstract

Background: Sarcopenic obesity (SO) is the coexistence of sarcopenia and obesity in an individual. The present study is designed to define the usefulness of skeletal muscle ultrasonography (US) in the definition of SO. *Methods:* Eighty-nine participants aged ≥65 whose body mass index (BMI, kg/m^2) was ≥30 were consecutively enrolled in an outpatient clinic of geriatric medicine. All underwent comprehensive geriatric assessment. US measurements were obtained in 6 different muscles consisting of core and limb muscles. We defined SO as the presence of low muscle function (defined by a handgrip strength < 27 kg in males and <16 kg in females) and high BMI (≥30). *Results:* The median age of the participants was 72 (65–85) years; 81% were female, and 35% (n = 31) had SO. Anthropometric parameters that estimate muscle mass were lower in the sarcopenic group, but estimations of muscle mass with bioelectrical impedance analysis (BIA) did not differ between groups. All US estimations of muscle mass were lower in sarcopenic obese participants, albeit not all significantly. RF muscle cross-sectional area (RF CSA) and abdominal subcutaneous fat thickness were most strongly correlated with grip strength ($r = 0.477$ and $r = -508$, respectively). Receiver operating characteristic analysis suggested that the optimum cutoff point of RF CSA for SO was ≤5.22 cm^2, with 95.8% sensitivity and 46.7% specificity (area under the curve: 0.686). *Conclusions:* US evaluation of muscle mass may be more accurate than BIA-derived skeletal muscle index assessment for the diagnosis of SO. (*JPEN J Parenter Enteral Nutr.* 2020;44:1398–1406)

Keywords

bioimpedance analysis; geriatrics; obesity; sarcopenia; sarcopenic obesity; muscle; ultrasonography; ultrasound

Clinical Relevancy Statement

Sarcopenic obesity (SO) is a clinical and functional condition characterized by the co-occurrence of obesity and sarcopenia. Although many definitions have been proposed, at present, there are no unified diagnostic criteria for SO. It is crucial to estimate muscle mass for the diagnosis of SO. There are many relevant techniques for measuring muscle mass, of which ultrasonography (US) is the recently expanded tool in clinical practice. US is a simple, real-time, noninvasive, radiation-free, low-cost, and easily transportable, as well as valid and reliable, method to estimate muscle mass. There are clinical trials investigating

From the [1]Department of Internal Medicine, Division of Geriatrics, Hacettepe University Medical School, Ankara, Turkey; and the [2]Servicio de Geriatría, Hospital Universitario Ramón y Cajal (IRYCIS), Madrid, Spain.

Financial disclosure: None declared.

Conflicts of interest: None declared.

This study was scheduled to be presented during the ASPEN 2020 Nutrition Science & Practice Conference (Tampa, FL) and was a candidate for the Harry M Vars Award and the Promising Investigator Award. The conference was cancelled due to the coronavirus disease 2019 and neither of these annual Early Career Investigator awards were determined.

[This article was modified on 28 May 2020, after first online publication: The article category was updated, and the preceding footnote was added.]

Linked content: Please visit https://onlinelibrary.wiley.com/doi/10.1002/jpen.1951 for the related Letter to the Editor, and https://onlinelibrary.wiley.com/doi/10.1002/jpen.1950 for the related Response.

CE This is a continuing education article. Please see https://aspen.digitellinc.com/aspen/publications/8/view

accepted for publication March 4, 2020.

This article originally appeared online on April 28, 2020.

Corresponding Author:
Olgun Deniz, MD, Department of Internal Medicine, Division of Geriatrics, Hacettepe University Faculty of Medicine, Ankara 06100, Turkey.
Email: olgundeniz2001@yahoo.com

US assessment for the diagnosis of sarcopenia, but there is a lack of research on the role of skeletal muscle US in the diagnosis of SO. This study represents a first step toward the introduction of ultrasound imaging in the evaluation of SO.

Introduction

Sarcopenic obesity (SO) is the combination of sarcopenia and obesity.[1] SO was first introduced by Heber et al in 1996 and defined as a condition of co-occurrence of reduced lean mass and high body-fat mass.[2] Since then, many definitions have been proposed. Changes in body composition, such as body-fat increments, height reduction (due to vertebral compression), and muscle mass decline, are observed with aging.[3] Age-related reduction in lean mass or fat-free mass (FFM) results in a decline in total energy expenditure, reduced resting metabolic rates, and weight gain in particular, with an increase in visceral abdominal fat.[4,5] All these age-related changes contribute to increased fat mass and reduced muscle mass.

The prevalence of SO in older adults has been estimated to be about 5%–10%, which is significantly higher in adults age ≥80 compared with that in those age <80, with no sex differences.[6] SO is related to functional deficits and disabilities and may have an impact more than cases in which obesity or sarcopenia occur separately.[7]

Definitions of SO have been extremely variable in defining both terms of the condition: obesity and sarcopenia.[8] Obesity has been defined in different studies by body mass index (BMI, kg/m^2), fat mass, waist circumference (WC), and visceral fat area, using different cutoff points. Sarcopenia has been defined by different measures and adjustments of FFM or appendicular mass and muscle cross-sectional area (CSA); more recently, functional measures (gait speed and handgrip strength [HGS]) have been incorporated, using the modern definitions of sarcopenia.

There are different methods to estimate muscle mass, such as dual energy x-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), anthropometry, creatine dilution test, ultrasonography (US), computed tomography (CT), and magnetic resonance imaging (MRI).[9] US is a simple, real-time, noninvasive, radiation-free, low-cost, and easily transportable method. It provides not only quantitative data but also qualitative data about skeletal muscles. US seems to be a valid and reliable method to estimate muscle mass, yielding results comparable to DXA, CT, and MRI.[10,11] In this context, US may play an essential role in the diagnosis of sarcopenia, as well as SO. There are clinical trials investigating US assessment for the diagnosis of sarcopenia, but there is a lack of research on the role of skeletal muscle US in the diagnosis of SO.

This study is designed to define the usefulness of skeletal muscle US to estimate muscle mass in obese, older persons. We hypothesized that SO is associated with lower muscle thickness (MT), smaller muscle CSA, and thicker subcutaneous fat tissue defined by US.

Methods

Participants

Community-dwelling participants age ≥65 whose BMI was ≥30 and who were admitted to the geriatric outpatient clinic for 6 months were consecutively enrolled in this cross-sectional study. A total of 112 patients were evaluated. Patients with hypervolumea (n = 6), severe dementia (n = 5), delirium (n = 4), end-stage kidney disease on dialysis (n = 3), rheumatologic disease using corticosteroid (n = 2), stroke history (n = 2), and uncontrolled hyperthyroidism (n = 1) were excluded from the study. As a result, 89 patients were included for analysis. The following variables were recorded: age, sex, educational level, anthropometric parameters, and living conditions. Comorbidities (such as diabetes mellitus, hypertension, coronary artery disease, chronic obstructive pulmonary disease, chronic heart failure, and hypothyroidism) and geriatric syndromes (such as osteoporosis, dementia, depression, urinary incontinence, fall, and polypharmacy) were defined by comprehensive geriatric assessment, laboratory tests, participants' self-reports, and a review of current medications.

Inclusion and Exclusion Criteria

Potential participants with a primary diagnosis of neuromuscular disease were excluded, along with those with moderate-severe dementia defined by a clinical dementia rating scale[12] and those with stroke history, systemic connective tissue disorders, myositis, chronic use of oral corticosteroids ≥ 5 mg/d for >3 months, uncontrolled hypothyroidism or hyperthyroidism, end-stage kidney disease on dialysis, and demyelinating diseases of the central nervous system. No participant had clinically detectable edema, which could influence the measure of resistance and reactance with BIA.[13] Those with chronic heart failure and chronic renal failure with hypervolemia, who were unable to stand for anthropometric measurements and who had skin conditions that preclude using ultrasound, were also excluded. Patients who met the inclusion criteria were included consecutively in the study from the outpatient clinic.

Comprehensive Geriatric Assessment

All participants underwent comprehensive geriatric assessment. Functional status was evaluated with the Katz Index of Independence in activities of daily living (ADL) (score 0–6)[14] and the Lawton-Brody instrumental ADL (IADL) (score 0–8).[15] Katz ADL measures 6 self-care tasks as listed: bathing, toileting, dressing, transferring to and from a chair,

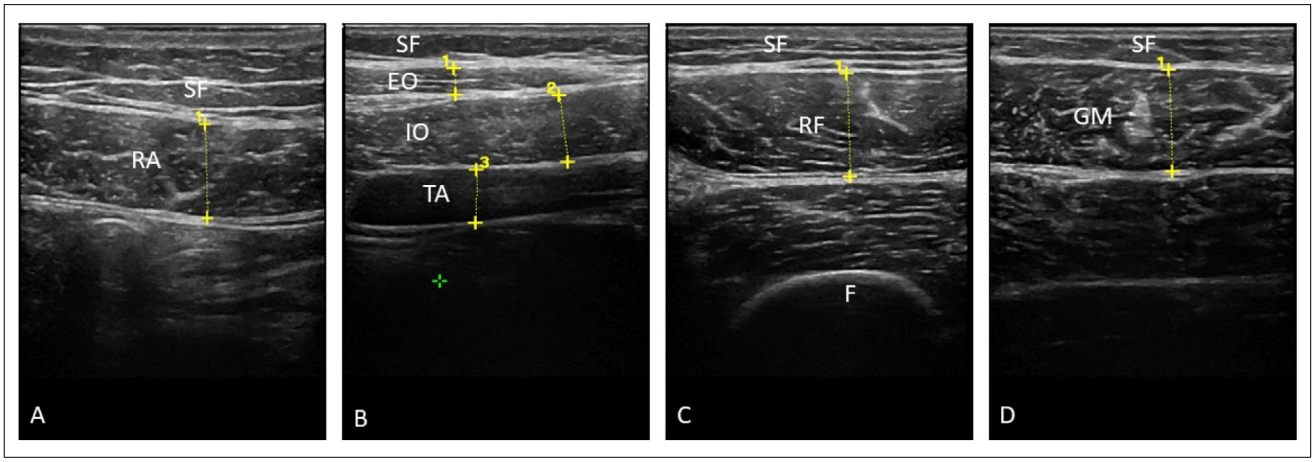

Figure 1. Axial ultrasound images. (A) Rectus abdominis; (B) external abdominal oblique, internal abdominal oblique, transversus abdominis; (C) rectus femoris; and (D) gastrocnemius medialis muscle thicknesses. Dotted yellow line represents the thickness. [1,2,3] indicates the number of measurements, for example in capture A,C and D there is one measurement albeit in capture B there are three differnet muscle US measurements. [+]symbol is the symbol of the US device which shows the distance between the layers to measure the thickness of the muscle. EO, external abdominal oblique; F, femur; GM, gastrocnemius medialis; IO, internal abdominal oblique; RA, rectus abdominis; RF, rectus femoris; SF, subcutaneous fat; TA, transversus abdominis.

maintaining continence, and feeding. The Lawton scale includes items, such as ability to use the telephone, mode of transportation, shopping, food preparation, household tasks, responsibility for medications, and ability to manage finances. Nutrition assessment was performed by the Mini Nutritional Assessment–Short Form (score 0–14).[16] Cognitive function and depressive symptoms were assessed with the Mini–Mental State Examination (score 0–30) and the short form of the Geriatric Depression Scale (score 0–15), respectively.[17,18] Muscle strength was assessed by HGS and measured using a calibrated hand-held dynamometer (T.K.K.5401; Takei Scientific Instruments, Tokyo, Japan) while the participants were standing with their arms at a position parallel to the floor. The highest of the 3 repeated measurements was used in the analysis. HGS < 16 kg and <27 kg, for women and men, respectively, were taken as cutoff values to assess muscle strength.[19] Low physical performance was defined as gait speed ≤ 0.8 m/s during a 4-m walking test using a manual stopwatch, in terms of its convenience to use and ability to predict sarcopenia-related outcomes.[19,20] Gait speed was calculated as the average of 2 measurements.

Anthropometric Measurements

Weight and height were measured using standard procedures with participants wearing light clothing without shoes. BMI was calculated by dividing body weight in kg by height in meters squared (kg/m^2). WC was measured by a tape measure on the level of the umbilicus; hip circumference was measured on a level parallel to the floor, at the largest circumference of the buttocks; mid-upper arm circumference (MAC) was measured from the midpoint between the acromial and olecranon protrusions in an upright, standing position while the arm was twisted by 90° from the elbow; and calf circumference (CC) was measured from the widest part of the legs by pressing the feet onto a hard and plain ground.

Assessment of Sarcopenic Obesity

Diagnosis of SO was based on the following parameters:

- Obesity was defined by a high BMI (≥30)
- Sarcopenia was diagnosed by a low muscle strength defined by low HGS (<27 kg for males and <16 kg for females). This is the current definition of probable sarcopenia recommended by the EWGSOP2 (the European Working Group on Sarcopenia in Older People) consensus.[19]

Afterward, participants were classified into 2 groups:

1. The nonsarcopenic obese group, defined as BMI ≥ 30 and HGS ≥ 16 kg and ≥27 kg, for women and men, respectively
2. The sarcopenic obese group, defined as BMI ≥ 30 and HGS < 16 kg and <27 kg, for women and men, respectively

Ultrasonographic Evaluations

Ultrasound is a reliable and valid tool for assessment of muscle size in older adults.[10] In 6 different types of muscle (gastrocnemius medialis [GM], rectus femoris [RF], rectus abdominis [RA], external abdominal oblique [EO], internal abdominal oblique [IO], and transversus abdominis [TA]) and abdominal subcutaneous fat tissue, US evaluation

Table 1. Demographic Data of the Participants.

Parameters	Sarcopenic obese (n = 31)	Nonsarcopenic obese (n = 58)	*P*-value
Age, median (min-max)	74 (65–85)	71 (65–84)	.05
Gender, female, n (%)	27 (87.1)	45 (77.6)	.28
Educational status			
≤5 years, n (%)	28 (90.3)	47 (81)	.36
>5 years, n (%)	3 (9.7)	11 (19)	
Comorbidities			
Diabetes mellitus, n (%)	17 (54.8)	39 (67.2)	.25
Hypertension, n (%)	30 (96.8)	48 (82.8)	.09
Coronary artery disease, n (%)	11 (35.5)	9 (15.5)	**.03**
Chronic obstructive pulmonary disease, n (%)	5 (16.1)	5 (8.6)	.31
Chronic heart failure, n (%)	4 (12.9)	3 (5.2)	.23
Geriatric syndromes			
Dementia, n (%)	4 (12.9)	2 (3.4)	.18
Polypharmacy,[a] n (%)	26 (83.9)	43 (74.1)	.30
Urinary incontinence, n (%)	20 (64.5)	28 (48.3)	.14
Osteoporosis, n (%)	10 (35.7)	8 (15.1)	**.03**
Falls,[b] n (%)	9 (29)	9 (15.5)	.13
4-meter gait speed, m/s	0.83 (0.33–1.16)	1.04 (0.32–2.00)	**<.01**
Katz Index ADL score	6 (1–6)	6 (5–6)	.10
Lawton-Brody IADL score	8 (0–8)	8 (5–8)	**<.01**
YDS score	3 (0–15)	1 (0–10)	.05
MMSE score[c]	27 (15–30)	28 (15–30)	**.03**
MNA-SF score	14 (6–14)	14 (9–14)	.08

Categorical variables were presented as n (%), whereas skew-distributed ones presented as median (min-max).
ADL, activities of daily living; IADL, instrumental activities of daily living; MMSE, Mini–Mental State Examination; MNA-SF, Mini Nutritional Assessment–Short Form; YDS, Yesevage Depression Scale.
Bold values denote statistical significance at the $p < 0.05$ level.
[a]Five or more medications.
[b]One or more per year.
[c]Patients with dementia (n = 6) excluded.

was carried out according to the recommendations of the European Union Geriatric Medicine Society Sarcopenia Special Interest Group[11] and in accordance with the previous literature.[21] Measurements were performed using a 8–10-MHz linear probe of 5 cm width (LOGİQ 200 PRO, General Electrics Medical Systems). To avoid interindividual variability, all measurements were performed by the same physician—blinded to the study results—who had 10 years of experience in musculoskeletal US. All measurements were obtained with minimal pressure applied by the US probe on the right side of the body at the selected sites. The images of the trunk muscles (RA, EO, IO, and TA) were captured at the end of a normal exhalation to control for the influence of respiration.[22] For MT, transversal images of the distance between the superficial and the deep fascia at the widest distance were captured. Pennation angle (PA) was measured between muscle fibers and the deep fascia of the muscle in the longitudinal ultrasound image. Fascicle length (FL) was defined as the length of the fascicular path between the insertions of the fascicle into the superficial and deep aponeuroses. If feasible, CSA was also measured and defined as the area of the cross section of a muscle perpendicular to its longitudinal axis. Abdominal subcutaneous fat thickness was measured between the internal skin layer and the linea alba of the RA muscle. Studies have confirmed the intraobserver and interobserver reliability of US for abdominal subcutaneous fat thickness measurement.[23] The US measurement sites and positions for each muscle are shown in Table S1. US images of the measurements are shown in Figure 1. To assess intraobserver reliability, we evaluated intraclass correlation coefficients (ICCs) using 2 images taken on 2 separate days on 15 healthy participants. The ICCs were 0.92, 0.96, 0.92, and 0.98 for MT of the GM, RF, EO, and IO, respectively; 0.98 for RF CSA; and 0.94 for abdominal subcutaneous fat tissue.

Muscle Mass Measurement Using Bioimpedance Analysis

All participants without a cardiac pacemaker or peripheral edema underwent body composition analysis via a Body Stat Quadscan 4000 bioimpedance analyzer (BodyStat Ltd,

Table 2. Muscle Mass Measurements by Different Methods and Anthropometric Parameters.

Parameters	Sarcopenic Obese (n = 31)	Nonsarcopenic Obese (n = 58)	*P*-value
BIA parameters			
Fat (%), median (min-max)	51.1 (24.2–64)	49.7 (32.9–61.7)	.73
SMI, kg/m^2, median (min-max)	9.79 (7.24–17.21)	10.41 (5.82–14.66)	.42
Ultrasonographic parameters			
Gastrocnemius muscle thickness, mm	14.9 + 1.82	16.21 ± 2.42	**.02**
Gastrocnemius fascicle length, mm	26.9 ± 4.63	28.6 ± 4.46	.14
Gastrocnemius pennation angle (°)	28 (24–39)	28.5 (22–35)	.20
Gastrocnemius subcutaneous fat thickness, mm	7.8 (3.9–16.7)	9.1 (3.6–18)	.75
Rectus femoris muscle thickness, mm	12.7 ± 2.01	13.89 ± 2.87	**.03**
Rectus femoris cross-sectional area, mm^2, median (min-max)	3.99 (2.38–6.56)	5.37 (2.14–9.01)	**.01**
Rectus abdominis muscle thickness, mm	6.56 ± 1.33	6.86 ± 1.51	.34
Abdominal subcutaneous fat thickness, mm	24.01 ± 6.62	20.4 ± 6.52	**.04**
EO muscle thickness, mm, median (min-max)	4.2 (2.3–7.5)	4.4 (3.1–6.1)	**.03**
IO muscle thickness, mm	5.21 ± 0.94	6.25 ± 1.32	**<.01**
TA muscle thickness, mm	3.73 ± 0.96	4.13 ± 1.18	.12
Anthropometric parameters			
CC, cm	37.1 ± 3.19	40.4 ± 3.51	**<.01**
MAC, cm	30.5 (24–36)	33 (29–44)	**<.01**
WC, cm	113.5 (99–141)	111 (104–140)	.72
HC, cm	111.5 (102–133)	113 (102–155)	.35
BMI, kg/m^2	35.3 (30.5–47.9)	35.6 (30.1–51.8)	.63
Waist-hip ratio	1.01 ± 0.07	0.99 ± 0.06	.33

Normally distributed variables were presented as mean ± standard deviation, where as skew-distributed ones presented as median (min-max).
BIA, bioimpedance analysis; BMI, body mass index; CC, calf circumference; EO, external abdominal oblique; HC, hip circumference; IO, internal abdominal oblique; MAC, mid-upper arm circumference; SMI, skeletal muscle index; TA, transversus abdominis; WC, waist circumference.
Bold values denote statistical significance at the $p < 0.05$ level.

Douglas, Isle of Man, British Isles), using a multifrequency and tetrapolar technique while the participants were lying in a supine position after overnight fasting. FFM was measured by BIA and then skeletal muscle mass (SMM) was calculated with the following validated equation:[24] SMM (kg) = FFM × 0.566. Skeletal muscle index (SMI) (SMM divided by height squared) was used for estimating muscle mass.

Ethical Approval

The study was approved by the local ethics committee of Hacettepe University School of Medicine (#2019/08-21, 07.03.2019). Informed consent was provided by all participants after providing verbal and written information about the study. The study protocol was in compliance with the Declaration of Helsinki.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 21.0 was used for the statistical analyses. The categorical variables are presented as frequencies and percentages. The continuous variables were assessed by Kolmogorov-Smirnov test and histograms to determine whether their distributions were normal. The normally distributed numerical parameters were compared by Student *t*-test in 2 groups, whereas those with nonnormal distributions were analyzed by Mann-Whitney *U* test. The categorical variables were compared by χ^2 or Fisher exact tests where appropriate. Correlation analyses were performed by Spearman or Pearson correlation tests based on the distributions of the variables. A *P*-value < .05 was considered as statistically significant. The accuracy of the ultrasound measurement of the muscle, subcutaneous fat thickness, and muscle CSA in assessing the presence of sarcopenia was evaluated by receiver operating characteristic (ROC) analysis. The accuracy of the test was measured by the area under the ROC curve (AUC). An AUC close to 1 represents a perfect diagnostic test, whereas an area of 0.5 represents a worthless test. Intraobserver reliabilities for US muscle and subcutaneous fat tissue measurements were described using ICC. A 5% type I error level was used to infer statistical significance.

Results

The median age of the participants was 72 (range 65–85) years; 81% were females. The main sociodemographic and

Table 3. Correlation Between Handgrip Strength and Other Parameters.

Parameters	Handgrip strength	
	Correlation coefficient	*P*-value
Anthropometric measurements		
CC	0.148	.19
Waist circumference	−0.046	.67
Hip circumference	−0.153	.15
BIA parameters		
Fat (%)	−0.389	**<.01**
SMI	0.290	**<.01**
BMI	−0.184	.10
Waist-hip ratio	0.113	.32
Ultrasonographic parameters		
Gastrocnemius muscle thickness	0.211	**.04**
Gastrocnemius muscle fascicle length	0.059	.64
Gastrocnemius muscle pennation angle	0.308	**.02**
Rectus femoris muscle thickness	0.315	**<.01**
Rectus femoris muscle cross-sectional area	0.477	**<.01**
Rectus abdominis muscle thickness	0.337	**<.01**
Abdominal subcutaneous fat thickness	−0.508	**<.01**
External abdominal oblique muscle thickness	0.085	.46
Internal abdominal oblique muscle thickness	0.251	**.02**
Transversus abdominis muscle thickness	0.092	.40

BIA, bioimpedance analysis; BMI, body mass index; CC, calf circumference; SMI, skeletal muscle index.
Bold values denote statistical significance at the $p < 0.05$ level.

clinical characteristics of the participants are presented in Table 1. Thirty-five percent (n = 31) of the participants were considered to have SO. The sex distributions were similar between the 2 groups. The sarcopenic participants were older, with a slightly higher prevalence of coronary artery disease (CAD) and osteoporosis and poorer physical and cognitive function (Table 1).

Anthropometric parameters that estimate muscle mass (CC and MAC) were lower in the sarcopenic group, but measures of obesity and estimations of muscle mass with BIA did not significantly differ between the groups (Table 2).

With respect to US measurements, all US estimations of muscle mass were lower in the sarcopenic participants than in the nonsarcopenic participants with obesity, albeit not all significantly. Thickness of GM, RF, EO and IO muscles (but not of other abdominal muscles), as well as RF CSA, were significantly lower in sarcopenic patients with obesity (Table 2). Abdominal subcutaneous fat tissue was found to be thicker in the participants with sarcopenia than the nonsarcopenic patients with obesity.

We assessed correlations between HGS and BIA and US measurements (Table 3). Weak correlations were found with BIA estimations of muscle and fat and with many US measurements. The strongest positive correlation was found with RF CSA ($r = 0.477$) and the strongest negative correlation with RA subcutaneous fat thickness ($r = -508$).

We analyzed the optimal cutoff points of GM MT, RF MT, EO MT, and RF CSA predicting SO. ROC analysis results on the optimum cutoff point of GM MT, RF MT, EO MT, IO MT, RF CSA, and abdominal subcutaneous fat tissue for SO are presented in Table 4. ROC analysis curves are shown in Figure 2. In general, US had good sensitivity but low specificity, thus having a better negative than positive predictive value.

Discussion

In accordance with our hypothesis, we showed that US measurement of muscle mass is an accurate method for the assessment of muscle mass in SO when sarcopenia was defined using muscle function. US assessment showed that participants with SO had significantly lower values in different muscle size measurements (CSA and MT) and higher value in subcutaneous fat tissue in comparison with those without SO. This difference was not found using a more conventional estimation of muscle mass—BIA. This is the first study, to our knowledge, to report on the US evaluation of muscle mass in SO.

There is, at present, no universally adopted definition of SO and much confusion in this field.[8] In this study, we used a definition of SO consisting of high BMI and low muscle strength. Recent studies have shown that there is a decrease in muscle strength before a decrease in muscle mass, and a decrease in muscle strength affects functionality and survival more than muscle mass.[25,26] Therefore, new recommendations of EWGSOP2 for sarcopenia emphasize functionality and have highlighted the role of muscle strength, whereas muscle mass assessment has been recommended to confirm the diagnosis. The optimal measure for obesity, whether central (ie, waist-hip ratio or WC) or general (ie, BMI), is debated. In this study, all participants' BMIs were ≥30, and all had WCs > 102 and 88 cm, in men and women, respectively.

SO is associated with physical limitation, increased risk of disability, and lower physical function.[26] It portends poor outcomes, as well as increased mortality. A recent meta-analysis demonstrated that SO is associated with increased all-cause mortality in comparison with persons without SO.[27] Because of physiological changes throughout their lifespan, older people are at a higher risk of SO. In our study, SO was shown to be related to physical limitations, impaired IADL, and cognitive impairment (after excluding

Table 4. Receiver Operating Characteristic Analysis for Muscle Ultrasonographic Measurements to Detect Sarcopenic Obesity.

Parameters	AUC (95% CI)	Cutoff	Sensitivity	Specificity	Positive predictive value (%)	Negative predictive value (%)	*P*-value
GM muscle thickness, mm	0.652 (0.544–0.750)	≤15	58.1	70.7	51.4	75.9	**.01**
RF muscle thickness, mm	0.604 (0.494–0.707)	≤15.9	96.7	32.8	42.6	95	.08
RF muscle cross-sectional area, mm^2	0.686 (0.563–0.793)	≤5.22	95.8	46.7	48.9	95.5	**<.01**
EO muscle thickness, mm	0.645 (0.534–0.745)	≤4.4	79.3	52.6	46	83.3	**.02**
IO muscle thickness, mm	0.734 (0.628–0.824)	≤5.6	79.3	61.4	51.1	85.4	**<.01**
Abdominal subcutaneous fat thickness, mm	0.681 (0.551–0.794)	>21.4	79.2	71.1	63.3	84.4	**.02**

AUC, area under the curve; EO, external abdominal oblique; GM, gastrocnemius medialis; IO, internal abdominal oblique; RF, rectus femoris. Bold values denote statistical significance at the $p < 0.05$ level.

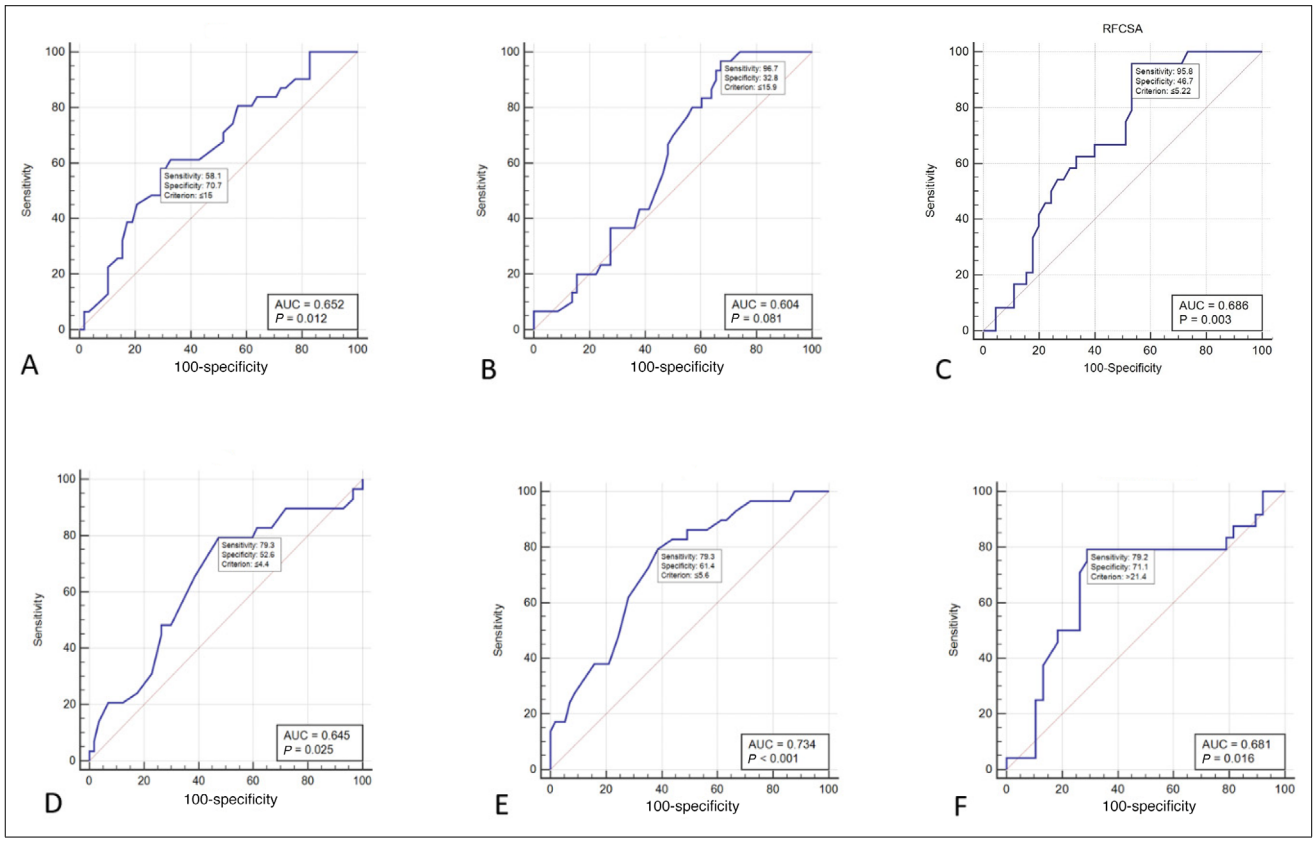

Figure 2. Receiver operating characteristic (ROC) analysis curves. ROC curve images of measurements of (A) gastrocnemius medialis muscle, (B) rectus femoris muscle, (C) rectus femoris cross-sectional area, (D) external abdominal oblique muscle, (E) internal abdominal oblique muscle, and (F) abdominal subcutaneous fat thickness. AUC, area under the curve.

6 patients with dementia). These findings were compatible with those reported by previous studies.[28–30] Toleo et al, in a recent study, showed that SO was associated with higher risk of mental disability and reduced performance on global cognition in comparison with obesity or sarcopenia alone.[28] In parallel to our results, Baumgartner et al found that persons with obesity and sarcopenia were more likely to have a decline in IADL, suggesting that SO is independently associated with and precedes the onset of disability.[29] Moreover, our data showing association with abnormalities in walking speed were in line with the study conducted in older patients by Stenholm et al.[30] These findings need to be evaluated further.

Conventional techniques being used for estimating muscle mass or lean body mass, such as CT, MRI, DXA, and BIA, have some disadvantages and limitations consisting of

lack of reference value, high cost, exposure to radiation, and access difficulty. Both BIA and DXA have cutoff points for diagnosis of sarcopenia; however, there is a lack of qualitative data on muscle mass. Furthermore, in individuals with obesity, (especially morbid obesity due to relatively high amounts of extracellular water and total body water, which may overestimate FFM and underestimate fat mass), BIA measurement might not be appropriate.[31] Similarly, DXA may overestimate FFM by an underestimation of trunk fat mass and, therefore, is not an appropriate standard for body composition in obesity.[32] CT and MRI provide both qualitative and quantitative data, but they lack cutoff points, are expensive, and may not be feasible in daily practice. There are many relevant measurement techniques for measuring muscle mass. On the other side, US is a valid, portable, inexpensive, noninvasive, and an easily interpreted technique, which also has a strong positive correlation with these aforementioned conventional techniques.[10] A protocol of performing muscle ultrasound in sarcopenia, has been used for the last few years.[11] This protocol requires a minimum level of ultrasound training (level 1, according to the European Federation of Societies for Ultrasound in Medicine and Biology [EFSUMB]).[33] However, there is currently a lack of a clear definitive agreement on which muscle group should be measured or which cutoff values should be defined for low muscle-mass identification in sarcopenia. In this study, we evaluated the GK, RA, RF, EO, IO, and TA muscles. It has previously been reported that lower limb and abdominal muscles are the first affected muscles with aging, associated with sarcopenia.[34]

With respect to our results, there were differences between the groups in ultrasound measurements of the muscles that BIA-derived SMI was unable to detect. On the other hand, the sarcopenic participants with obesity had lower anthropometric parameters (CC and MAC) that estimate muscle mass. It may be that BIA equations do not estimate muscle mass well in individuals with obesity, but CC (in a place where little fat exists) allows for a better measurement.

In some publications, it was suggested that the percentage of fat should be considered in the evaluation of SO.[8] Our study showed that abdominal subcutaneous fat tissue thickness measured with US was significantly higher in sarcopenic participants with obesity, and also, it was negatively correlated with HGS. However, the percentage of fat measured by BIA was not significantly different between the groups.

Once US has been found to be reliable for the estimation of muscle mass, it is important to establish cutoff values to be used in the diagnosis of SO. The high negative predictive value, especially for RF CSA, indicated that sonographic imaging may be a promising screening test for detecting SO.

Our study has several strengths. We used an easy and applicable tool to define SO in a geriatric population. For the first time, we used US for the evaluation of SO. We performed muscle US evaluation for multiple regions, and we determined the cutoff values. The other strength was the similarity between the 2 groups in age, sex, and comorbidities, except for osteoporosis and coronary artery disease, which were slightly more frequent in the sarcopenic obese group than in the nonsarcopenic obese group.

Some limitations should also be acknowledged. Firstly, the method used to define SO was relatively arbitrary, as there are still no standardized definitions of SO for community-dwelling older adults. Albeit, in the literature, the SO definition based on BMI and HGS measurements was used in 4 epidemiological studies with an estimated prevalence between 4% and 9%.[35–39] Our study was not an epidemiological study, and thus, it does not provide information about either incidence or prevalence of SO. More recently, Hamer and O'Donovan used BMI and HGS (the same parameters of our study) to define SO.[40] Secondly, our sample size was relatively small, and the study was carried out at a single center. Larger samples from different regions and countries are needed to define appropriate diagnostic cutoff values for SO diagnosis. We evaluated both the qualitative and quantitative measurements of the skeletal muscles. For muscle quality, FL, PA, and echogenicity may be measured. We were not able to measure echogenicity because of technical issues. The PA and FL values were lower in the sarcopenic obese group, whereas they did not reach statistical significance. It was found that the PA of the GM muscle were positively correlated with HGS.

Conclusions

Our results suggest that US evaluation of muscle mass may be more accurate than BIA-derived SMI assessment for estimating muscle mass in SO. The US assessment of skeletal muscles, especially the CSA of RF muscle, may be useful as a convenient approach for predicting SO. This study represents a first step toward the introduction of ultrasound imaging in the evaluation of SO. Further investigations on the use of muscle US in follow-up and intervention studies in diagnosis of SO need to be carried out.

Statement of Authorship

O. Deniz and M. Halil equally contributed to the conception and design of the research; O. Deniz, G. Sengul Aycicek, and P. Unsal equally contributed to the acquisition and analysis of the data; O. Deniz, M. Esme, Y. Ucar, S. Burkuk, A. Sendur, B. Balam Yavuz, and M. Cankurtaran equally contributed to the interpretation of the data; A. Cruz-Jentoft and M. Halil critically revised the manuscript; O. Deniz, M. Halil, and A. Cruz-Jentoft drafted the manuscript. All authors agree to be fully accountable for ensuring the integrity and accuracy of the work and read and approved the final manuscript

Supplementary Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

References

1. Zamboni M, Rubele S, Rossi AP. Sarcopenia and obesity. *Curr Opin Clin Nutr Metab Care*. 2019;22(1):13-19.
2. Heber D, Ingles S, Ashley JM, Maxwell MH, Lyons RF, Elashoff RM. Clinical detection of sarcopenic obesity by bioelectrical impedance analysis. *Am J Clin Nutr*. 1996;64(3):472S-477S.
3. Batsis JA, Villareal DT. Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. *Nat Rev Endocrinol*. 2018;14(9):513-537.
4. Zamboni M, Mazzali G, Fantin F, Rossi A, Di Francesco V. Sarcopenic obesity: a new category of obesity in the elderly. *Nutr Metab Cardiovasc Dis*. 2008;18(5):388-395.
5. Gallagher D, Belmonte D, Deurenberg P, et al. Organ-tissue mass measurement allows modeling of REE and metabolically active tissue mass. *Am J Physiol*. 1998;275(2):E249-E258.
6. Lee D-c, Shook RP, Drenowatz C, Blair SN. Physical activity and sarcopenic obesity: definition, assessment, prevalence and mechanism. *Future Sci OA*. 2016;2(3):FSO127.
7. Roubenoff R. Sarcopenic obesity: the confluence of two epidemics. *Obes Res*. 2004;12(6):887-888.
8. Donini LM, Busetto L, Bauer JM, et al. Critical appraisal of definitions and diagnostic criteria for sarcopenic obesity based on a systematic review. *Clin Nutr*. Published online November 27, 2019. http://doi.org/10.1016/j.clnu.2019.11.024
9. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. *Age Ageing*. 2010;39(4):412-423.
10. Nijholt W, Scafoglieri A, Jager-Wittenaar H, Hobbelen JS, van der Schans CP. The reliability and validity of ultrasound to quantify muscles in older adults: a systematic review. *J Cachexia Sarcopenia Muscle*. 2017;8(5):702-712.
11. Perkisas S, Baudry S, Bauer J, et al. Application of ultrasound for muscle assessment in sarcopenia: towards standardized measurements. *Eur Geriatr Med*. 2018;9(6):739-757.
12. Hughes CP, Berg L, Danziger W, Coben LA, Martin RL. A new clinical scale for the staging of dementia. *Br J Psychiatry*. 1982;140(6):566-572.
13. Wu T, Huang J, Lin C. Effects of fluid retention on the measurement of body composition using bioelectric impedance. *J Formos Med Assoc*. 1994;93(11-12):939-943.
14. Arik G, Varan HD, Yavuz BB, et al. Validation of Katz index of independence in activities of daily living in Turkish older adults. *Arch Gerontol Geriatr*. 2015;61:344-350.
15. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist*. 1969;9(3 Part 1):179-186.
16. Rubenstein LZ, Harker JO, Salvà A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the short-form mini-nutritional assessment (MNA-SF). *J Gerontol A Biol Sci Med Sci*. 2001;56(6):M366-M372.
17. Güngen C, Ertan T, Eker E, Yaşar R, Engin F. Reliability and validity of the standardized Mini Mental State Examination in the diagnosis of mild dementia in Turkish population. *Turk Psikiyatri Derg*. 2002;13(4):273-281.
18. Durmaz B, Soysal P, Ellidokuz H, Isik AT. Validity and reliability of geriatric depression scale-15 (short form) in Turkish older adults. *North Clin Istanb*. 2018;5(3):216.
19. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing*. 2018;48(1):16-31.
20. Cesari M, Kritchevsky SB, Newman AB, et al. Added value of physical performance measures in predicting adverse health-related events: results from the Health, Aging and Body Composition Study. *J Am Geriatr Soc*. 2009;57(2):251-259.
21. Wilson A, Hides JA, Blizzard L, et al. Measuring ultrasound images of abdominal and lumbar multifidus muscles in older adults: a reliability study. *Man Ther*. 2016;23:114-119.
22. Shahtahmassebi B, Hebert JJ, Hecimovich MD, Fairchild TJ. Associations between trunk muscle morphology, strength and function in older adults. *Sci Rep*. 2017;7(1):10907.
23. Bazzocchi A, Filonzi G, Ponti F, et al. The Role of ultrasonography in the evaluation of abdominal fat. *Acad Radiol*. 2013;20(10):1278-1285.
24. Deurenberg P, Pietrobelli A, Wang Z, Heymsfield SB. Prediction of total body skeletal muscle mass from fat-free mass or intra-cellular water. *Int J Body Compos Res*. 2004;2:107-114.
25. Manini TM, Clark BC. Dynapenia and aging: an update. *J Gerontol A Biol Sci Med Sci*. 2011;67(1):28-40.
26. Schaap LA, Koster A, Visser M. Adiposity, muscle mass, and muscle strength in relation to functional decline in older persons. *Epidemiol Rev*. 2012;35(1):51-65.
27. Tian S, Xu Y. Association of sarcopenic obesity with the risk of all-cause mortality: a meta-analysis of prospective cohort studies. *Geriatr Gerontol Int*. 2016;16(2):155-166.
28. Tolea MI, Chrisphonte S, Galvin JE. Sarcopenic obesity and cognitive performance. *Clin Interv Aging*. 2018;13:1111-1119.
29. Baumgartner RN, Wayne SJ, Waters DL, Janssen I, Gallagher D, Morley JE. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. *Obes Res*. 2004;12(12):1995-2004.
30. Stenholm S, Alley D, Bandinelli S, et al. The effect of obesity combined with low muscle strength on decline in mobility in older persons: results from the InCHIANTI Study. *Int J Obes*. 2009;33(6):635.
31. Coppini LZ, Waitzberg DL, Campos AC. Limitations and validation of bioelectrical impedance analysis in morbidly obese patients. *Curr Opin Clin Nutr Metab Care*. 2005;8(3):329-332.
32. Jensen B, Braun W, Geisler C, et al. Limitations of fat-free mass for the assessment of muscle mass in obesity. *Obesity Facts*. 2019;12(3):307-315.
33. Education and Practical Standards Committee, European Federation of Societies for Ultrasound in Medicine and Biology. Minimum training recommendations for the practice of medical ultrasound. *Ultraschall Med*. 2006;27(1):79-105.
34. Abe T, Sakamaki M, Yasuda T, et al. Age-related, site-specific muscle loss in 1507 Japanese men and women aged 20 to 95 years. *J Sports Sci Med*. 2011;10(1):145.
35. Shock NW, Greulich RC, Andres R, et al. Normal human aging: the Baltimore Longitudinal Study of Aging. National Institutes of Health publication No. 84-2450. Washington, DC: US Government Printing Office; 1984.
36. Ferrucci L. Sarcopenic obesity: definition, cause and consequences. *Curr Opin Clin Nutr Metab Care*. 2008;11(6):693-700.
37. Ferrucci L, Bandinelli S, Benvenuti E, et al. Subsystems contributing to the decline in ability to walk: bridging the gap between epidemiology and geriatric practice in the InCHIANTI Study. *J Am Geriatr Soc*. 2000;48(12):1618-1625.
38. Sonnenberg C, Deeg D, Comijs H, Van Tilburg W, Beekman AJ. Trends in antidepressant use in the older population: results from the LASA-study over a period of 10 years. *J Affect Disord*. 2008;111(2-3):299-305.
39. Deeg DJ, van Tilburg T, Smit JH, de Leeuw ED. Attrition in the Longitudinal Aging Study Amsterdam. The effect of differential inclusion in side studies. *J Clin Epidemiol*. 2002;55(4):319-328.
40. Hamer M, O'Donovan G. Sarcopenic obesity, weight loss, and mortality: the English Longitudinal Study of Ageing. *Am J Clin Nutr*. 2017;106(1):125-129.