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The Relationship Between Ultrasonography-Measured Abdominal Subcutaneous Fat Thickness with Sarcopenia/Sarcopenic Obesity and Anthropometric Measurements

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Abstract

Objective: Abdominal subcutaneous fat thickness (ASFT) is an ultrasonography (USG)- based measurement that has been shown to accurately predict segmental or total fat-mass (FM) in previous studies. Since there is limited data on the relationship of ASFT with anthropometric measurements (AM) and sarcopenia, sarcopenic obesity (SO) parameters, we aimed to assess these relationships.

Materials and Methods: One hundred thirty-nine geriatric outpatients were enrolled. AMs [calf circumference (CC), mid-arm circumference (MC), hip circumference (HC), waist circumference (WC), and body mass index (BMI)], handgrip strength (HGS) via the Takei grip strength dynamometer, body composition analysis with bioelectrical impedance analysis (BIA) [FM, fat-percentage (FP), fat-free mass (FFM) and phase angle (PA)], thicknesses of rectus-abdominis (RA), external oblique (EO), internal oblique and transversus abdominis (TA) muscles via USG were assessed.

Results: The median (interquartile range) age was 71 (67-76) years, and 65.5% (n=91) of participants were female. ASFT was significantly correlated with CC (r=0.315, p<0.001), MC (r=0.432, p<0.001), HC (r=0.354, p<0.001), WC (r=0.199, p=0.019), BMI (r=0.334, p=0.001), FM (r=0.466, p<0.001), FP (r=0.443, p<0.001), PA (r=0.336, p<0.001), RA (r=0.175, p=0.039), EO (r=0.137, p=0.021), and TA (r= 0.209, p=0.014). Regression analysis showed that ASFT was associated with CC, MC, HC, WC, BMI, FM, FFM, PA, HGS, the thickness of RA and EO muscles, and the SO independently of sex, frailty, and age.

Conclusion: Our study is the first to comprehensively examine the relationship between the ASFT and body composition analysis of BIA, abdominal muscle thicknesses, and SO. Prospective studies on the role of ASFT in predicting sarcopenia/SO parameters are warranted.

Keywords: Sarcopenia, sarcopenic obesity, abdominal subcutaneous fat thickness, ultrasonography, anthropometric measurements, older adults

Introduction

Sarcopenia is a geriatric giant defined as widespread and progressive loss of skeletal muscle mass, strength, quality, and function (1). The evaluation of body composition in older adults, particularly fat and muscle distribution, has gained more importance, especially with the recent definition of both sarcopenia and sarcopenic obesity (SO) in the literature (1,2).

Rising obesity rates have become evident as a significant global public health issue (3). Obesity is related to an elevated risk of mortality and morbidity (4). With the rise in life expectancy,

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obesity is likely to become a significant clinical concern for the aging population (5). Obesity and aging contribute significantly to severe health issues, elevating the risk of disease and death. Recently, Barazzoni and Gortan Cappellari (6) explored how obesity affects skeletal muscle mass. SO combines sarcopenia and obesity, a syndrome that is becoming more common among older individuals and is related to adverse clinical outcomes, including mortality (2).

Contrary to previous evidence, particularly in the geriatric population, current studies argue that measuring body mass index (BMI) is insufficient for evaluating conditions associated with various adverse outcomes, such as obesity and SO. Using BMI is still an acceptable practice during the screening stage for conditions such as SO, while acknowledging the significant limitations of BMI in identifying fat distribution and body composition (2,7,8). Besides BMI, anthropometric measurements (AM), particularly waist circumference (WC), are suggested for obesity screening due to their superiority to BMI for predicting obesity-related outcomes (2,9). Moreover, recommendations for body composition analysis via validated tools such as dual-energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA) have become prominent in defining SO and sarcopenia (1,2).

Abdominal subcutaneous fat thickness (ASFT) is a parameter measured from the abdominal region with ultrasonography (USG), and recent studies have shown that it accurately predicts segmental and total fat-mass (FM) measured with DXA (10,11). Unlike DXA, USG is a radiation-free, easily accessible and applicable method, and evaluating ASFT with this method provides advantages. US can also measure muscle mass, which is an important component of the evaluation of sarcopenia and SO (12,13). However, there is limited data on the association between ASFT and sarcopenia parameters, such as muscle strength and mass, other AM.

Since there is no data on the relationship of ASFT with sarcopenia parameters, namely AM, muscle strength [handgrip strength (HGS)], body compositions by BIA, and US-measured abdominal muscle thicknesses, this study aimed to evaluate these relationships.

Materials and Methods

Participants

One hundred and thirty-nine geriatric outpatients were included in this 6-month cross-sectional study. Exclusion criteria were defined as any cause resulting in severe lower extremity edema, severe dehydration, the presence of an implant or pacemaker, amputation, or systemic atrophies mainly affecting the central nervous system. Informed consent was gained from the participants. Demographic characteristics of the patients, chronic diseases, drugs and polypharmacy (using five or more drugs) were also recorded.

Comprehensive Geriatric Assessment

We used validated tools to perform an objective comprehensive geriatric assessment. Functionality was assessed using the Katz activities of daily living (ADL) scale for basic ADL. It assesses the independence of patients in handling daily activities and basic care; the score increases as independence grows. The Lawton Brody Scale for instrumental ADL (14-16). It evaluates independence in instrumental ADLs. Its total score ranges from 0 to 8, and, similar to the Katz scale, higher scores indicate independence in these activities. Cognitive status was screened with the Mini-Mental State Examination (17,18). Mini Nutritional Assessment-short form, was used to evaluate nutritional status (19,20)

Anthropometric Measurements

After an overnight fast, anthropometric measures (AM) were performed. The BMI was calculated (kg/m^2). Using a tape measure on the umbilicus level, the WC was determined by the largest diameter of the buttocks. Mid-arm circumference (MC) was measured with the elbow flexed at 90 degrees. The body roundness index (BRI) was calculated using the related formula (21). Online calculators are available for BRI calculation, which allow users to enter height, hip and/or WC measurements (22). All measurements were performed with the online-validated calculation tools.

Sarcopenia/Sarcopenic Obesity Assessment and Subcutaneous Fat Thickness Measurement

EWGSOP-2 criteria were used to establish the diagnosis of sarcopenia (1). Muscle strength was evaluated via the 5-times Sit and Stand test (5xSST) and HGS using the Takei grip strength dynamometer from the dominant hand, employing previously defined methods (1,23). To determine low HGS, we used two different cut-off points. In the first version, low HGS was defined using the cut-offs determined by EWGSOP-2 for the elderly in Europe: <16 kg for females and <27 kg for males (1). In the second version, we used the specific cut-offs for the Turkish population: <22 kg for females and <32 kg for males (24). Physical performance was evaluated via a four-metre gait-speed test and timed-up and go (TUG) test (1,25).

Total body composition analyses were performed via [BIA-Body Stat Quadscan 4000 bioimpedance analyzer (BodyStat Ltd, Douglas, Isle of Man, British Isles)]. While participants were lying in a supine position, a multifrequency, and tetrapolar technique for BIA was used. Total FM, phase angle (PA) and fat-free mass (FFM) were evaluated. Using the BIA-measured FFM, skeletal muscle mass (SMM) was calculated using the following equation: SMM (kg) = 0.566 ∗ FFM. Low SSM index [SMI = SMM (kg)/height squared (m^2)] was defined as <7.4 kg/m^2 and <9.2 kg/m^2 for females and males, respectively (26). Confirmed sarcopenia was defined as probable sarcopenia (two versions of

low HGS with different cut-offs provided as alternative cut-offs) plus low muscle mass (low SMI).

Obesity was defined as high BMI (≥30 kg/m^2) or high WC (≥102 and ≥88 for males and females, respectively), and a total of 99 patients were found to be living with obesity. Among these 99 patients, SO was defined in line with the ESPEN and EASO Sarcopenic Obesity Consensus Statement (2). Two versions of low HGS with two different cut-offs (<16 kg for females and <27 kg for males, or <22 kg for females and <32 kg for males) were given as different alternatives. Other cut-offs used for the definition of SO were ≥17 s for 5xSST, >43% and >31% (for females and males, respectively) for FM percentage and < 27.6% and <37.0% (for females and males, respectively) for SMM/weight. As suggested in the ESPEN and EASO Sarcopenic Obesity Consensus Statement, obese patients were defined as having a high BMI (≥30 kg/m^2) or high WC (≥102 for males and ≥88 for females), with a total of 99 patients included. In the obese population (n=99), patients with low muscle strength (via HGS or 5xSST) plus high- fat-percentage (FP) plus low SMM/weight were defined as having confirmed SO.

Abdominal muscle and subcutaneous fat thicknesses were assessed using B-mode USG (LOGIQ 200 PRO, General Electric Medical Systems) equipped with a 10-MHz linear-array transducer (5 cm footprint). All examinations were performed by a single radiologist with over 10 years of experience in musculoskeletal ultrasound (US), who was blinded to clinical and laboratory data to avoid measurement bias. Participants were evaluated in the supine position with knees flexed to ensure abdominal muscle relaxation. All measurements were performed at the end of a normal expiration, without breath holding, to minimize variability due to diaphragm movement or muscle contraction. ASFT was measured as the vertical distance from the skin surface to the superficial fascia of the rectus-abdomini (RA) muscle. This measurement was taken 1 cm superior to the umbilicus along the midline (xiphoid-pubic line) with the transducer placed transversely and perpendicular to the skin. Care was taken to apply minimal pressure. RA thickness was measured at the same site-1 cm above the umbilicus-by identifying the anterior and posterior fascia of the muscle in the axial plane. Thickness was defined as the anteroposterior distance between these two echogenic fascial borders, measured on the right side at the mid-belly of the RA. Lateral abdominal muscle thicknesses-including the external oblique (EO), internal oblique (IO), and transversus abdominis (TA)-were measured on the right side of the abdomen at a standardized location: the midpoint between the inferior margin of the 12th rib and the anterior superior iliac spine, aligned along the anterior axillary line. With minimal pressure, the transducer was positioned transversely (axial orientation), perpendicular to the skin surface. Each muscle layer was visualized as a distinct hypoechoic band bounded by hyperechoic fasciae. Muscle thickness was defined as the perpendicular distance between each muscle's superficial and deep fascial borders. Specifically:

- EO: from the subcutaneous fascia to the EO-IO interface,
- IO: from the EO-IO interface to the IO-TA interface,
- TA: from the IO-TA interface to the inner fascial margin (transversalis fascia or peritoneal lining). All measurements were performed three times, and the mean value was recorded. This protocol was established based on widely accepted sarcopenia assessment methodologies and validated protocols from recent literature.

Statistics

Statistical analysis was executed using SPSS version 27.0 (IBM). We conducted a power analysis to determine the required sample size, based on results from earlier studies (G*Power 3.1.9.7) (27,28). The sample size with a margin of error of 0.05 (alpha), a power of 90%, and a medium effect size was calculated as 118 participants. Variables were assessed via visual and analytic tools for the normal distribution. Descriptive statistics were given as mean ± standard deviation for normally distributed variables, median [interquartile range (IQR)] for variables without normal distribution, and the number of cases and percentage (%) for nominal variables. Depending on whether the data followed a normal distribution, Pearson or Spearman correlations were performed to analyze the relationship between ASFT and the other factors. Due to the non-normal distribution, the logarithmic version of ASFT was computed to attain normal distribution and used in the linear regression analysis to identify independent factors related to ASFT. Using a logarithmic transformation alters values according to the properties of the logarithm. Given its characteristics, the discrepancies between the transformed values diminish relative to those observed in the original values. This transformation compresses the variations between the upper and lower portions. A logarithmic transformation normalizes positively skewed distributions and is called a "log-normal distribution". Linear regression analysis requires a normal distribution for the dependent variable. After applying a logarithmic transformation to the data, the outcome can be considered an estimate. Using a logarithmic transformation in linear regression complicates the interpretation of the results. When the dependent variable necessitates a logarithmic transformation, the interpretation of the regression coefficient changes from signifying a unit change to representing a proportional change. Essentially, the regression coefficient means "a one-unit change in the independent variable produces an increase (or decrease) in the dependent variable by the amount of the regression coefficient". The transformed dependent variable's arithmetic change will be converted into a ratio through the back-transformation of an exponential function (29). Multicollinearity analysis for linear regression showed that a variance inflation factor higher than 5 indicated

high collinearity. All models are created considering collinearity. A p-value less than 0.05 was regarded as statistically significant.

Disclosure Statement

Each participant in the study gave their informed consent, and the study received ethics approval from the clinical research ethics committee at Hacettepe University's Faculty of Medicine and Hacettepe University Health Sciences Research Ethics Committee (research number: 24/313, decision number: 2024/05-12, date: 05.03.2024). Every procedure carried out in studies involving human participants met the ethical standards set by the institution's or country's research committee, as well as those outlined in the 1964 Declaration of Helsinki and its later updates, or equivalent standards.

Results

A total of 139 geriatric outpatients enrolled in the study. The median (IQR) of the participants was 71 (67-76) years, and 65.5% (n=91) of them were female. Table 1 provides a summary of the study population's demographic and clinical characteristics. The frequencies of sarcopenia were 8.6% (n=12) in the whole sample; confirmed SO among the patients with obesity (n=99) was 11.3% (n=11).

In the correlation analysis, ASFT was significantly correlated with CC (r=0.315, p<0.001), MC (r=0.432, p<0.001), hip circumference (HC) (r=0.354, p<0.001), WC (r=0.199, p=0.019), BMI (r=0.391, p<0.001), BRI (r=0.387, p<0.001), FM (r=0.466, p<0.001), FP (r=0.443, p<0.001), FFM (r=-0.183, p=0.031). PA (r=0.336, p<0.001), RA (r=0.175, p=0.039), IO (r=0.137, p=0.021), and TA (r=0.209, p=0.014). No correlation was observed between ASFT and age (r=-0.132, p=0.120) and HGS (r=-0.117, p=0.171). All correlations of ASFT with other indicators are shown in Table 2.

Various models were generated in the linear regression analysis to evaluate the independent association between ASFT and sarcopenia parameters, and AMs (Table 3). All models are adjusted for age, sex, and frailty status based on prior evidence of the relationship between ASFT and the related confounders. Our results revealed that ASFT is significantly related to CC, MC, HC, WC, BMI, BRI, FM, FFM, PA, HGS, the thickness of RA, and IO muscles, and SO regardless of age, sex, and frailty. In the logistic regression modeling evaluating the relationship between confirmed sarcopenia and ASFT in the whole sample (n=136), when adjusted for age, sex, and frailty, ASFT was not associated with confirmed sarcopenia for both HGS cut-offs used [for the model low HGS defined as <16 kg for females and <27 kg for males, Odds ratio (OR): 0.94, 95% confidence interval (CI): 0.84-1.06, p=0.334 and for the model low HGS defined as <22 kg for females and <32 kg for males, OR: 0.95, 95% CI: 0.87-1.04, p=0.335]. In addition, in the logistic regression model where only obese patients (n=99) were included, factors associated with SO were evaluated, and ASFT was found to be related to SO, regardless of age, sex, and frailty (for the model low HGS defined as <16 kg for females and <27 kg for males OR: 1.04, 95% CI: 1.01-1.18, p=0.025, and for the model low HGS defined as <22 kg for females and <32 kg for males OR: 1.11, 95% CI: 1.03-1.20, p=0.005).

Table 1. Summary of demographical and clinical characteristics of the study population

Age, median (IQR)	71.0 (67.0-76.0)
Female gender, n (%)	55 (64.7%)
Clinical Frailty Score, median (IQR)	3 (3.0-4.0)
Diabetes mellitus, n (%)	43 (30.9%)
Hypertension, n (%)	64 (46.0%)
Coronary arterial disease, n (%)	16 (11.5%)
Atrial fibrillation, n (%)	6 (4.3%)
Chronic pulmonary disease, n (%)	8 (5.8%)
Chronic renal diseases, n (%)	2 (1.4%)
Dementia, n (%)	7 (5.0%)
Hypothyroidism, n (%)	21 (15.1%)
Malignancies, n (%)	14 (10.1%)
Cerebrovascular diseases, n (%)	7 (5.0%)
Number of drugs, median (IQR)	5 (3.0-6.0)
Polypharmacy, n (%)	52 (37.4%)
Katz activities of daily living, median (IQR)	6 (6.0-6.0)
Lawton-Brody Instrumental ADLs, median (IQR)	8 (8.0-8.0)
SARC-f, median (IQR)	1 (0.0-2.5)
Mini-nutritional assessment short form	14 (12.0-14.0)
Gait speed (sec), median (IQR)	4.1 (3.4-5.3)
Timed-up-and-go test (sec), median (IQR)	10 (8.0-14.0)
Chair stand test (sec), median (IQR)	15 (12.0-18.1)
Mini-mental state examination, median (IQR)	28 (25.0-29.0)
Calf circumstance, mean ± SD	35.0±3.8
Mid-arm circumstance, mean ± SD	29.0±3.7
Hip circumstance, mean ± SD	106.2±9.5
Waist circumstance, mean ± SD	97.2±14.7
Body mass index, mean ± SD	29.5±4.6
High BMI (≥30 kg/m^2)	68 (48.9%)
High fat-percentage <27.6% and <37.0% for female (F) and male (M)	61 (43.9%)
Body roundness index, mean ± SD	5.99±1.72

Table 1. Continued

Age,median (IQR)	71.0 (67.0-76.0)
Fat-mass, mean ± SD	27.1±10.4
Fat percentage, mean ± SD	35.7±10.9
Fat-free mass, mean ± SD	47.4±10.9
Phage angle, median (IQR)	5.0 (2.7-18.1)
Hand grip strength (HGS), mean ± SD	21.5 (16.8-27.0)
Low HGS (<16 and <27 for female and male), n (%)	45 (32.4%)
Low HGS (<22 and <32 for F and M), n (%)	91 (65.9%)
Low SMMI (<7.4 and <9.2 for F and M), n (%)	15 (10.8%)
Confirmed sarcopenia [low HGS (<16 and <27 for F and M) + low SMMI], n (%)	12 (8.6%)
Confirmed sarcopenia [low HGS (<22 and <32 for F and M) + low SMMI], n (%)	15 (10.9%)
Confirmed sarcopenic obesity [using (low HGS (<16 and <27 for F and M)], n (%)*	11 (9.0%)
Confirmed sarcopenic obesity [using (low HGS (<22 and <32 for F and M)], n (%)*	15 (15.2%)
Subcutaneous fat thickness, mean ± SD	18.7±9.8
Rectus-abdominis muscle thickness, mean ± SD	8.1±9.4
External oblique muscle thickness, mean ± SD	3.6±1.2
Internal oblique muscle thickness, mean ± SD	5.8±2.1
Transversus abdominis muscle thickness, mean ± SD	3.9±1.4

*Among the 99 patients with obesity
IQR: Interquartile range, ADL: Activities of daily living, SD: Standard deviation, BMI: Body mass index, HGS: Handgrip strength, SMMI: Skeletal muscle mass index, F: Female, M: Male

Table 2. Correlations of abdominal subcutaneous fat thickness and different indicators

	Abdominal subcutaneous fat thickness	
	r	p
Age	-0.132	0.120
Clinical frailty scale	-0.146	0.086
Weight	0.247	**0.004**
Body mass index	0.391	**<0.001**
Body roundness index	0.387	**<0.001**
Calf circumstance	0.315	**<0.001**
Mid-arm circumstance	0.432	**<0.001**
Hip circumstance	0.354	**<0.001**
Waist circumstance	0.199	**0.019**

Table 2. Continued

	Abdominal subcutaneous fat thickness	
	r	p
Handgrip strength	-0.117	0.171
SARC-f	-0.074	0.472
Mini-nutritional assessment short form score	-0.089	0.331
Gait speed (sec)	0.128	0.143
Timed-up-and-go test (sec)	0.079	0.365
Chair stand test (sec)	0.033	0.721
Fat-mass	0.466	**<0.001**
Fat percentage	0.443	**<0.001**
Fat-free mass	-0.183	**0.031**
Phage angle	0.336	**<0.001**
Rectus abdominis muscle thickness	0.175	**0.039**
External oblique muscle thickness	0.080	0.351
Internal oblique muscle thickness	0.137	**0.021**
Transversus abdominis muscle thickness	0.209	**0.014**

Discussion

ASFT is an important body composition parameter that can be measured easily and accurately, without any radiation exposure. Although the relationship between ASFT and many different AM has been evaluated in different populations, comprehensive studies that evaluate the relationship between sarcopenia and/or SO (defined via current guideline recommendations), body composition analyses determined by BIA, and other AM in older adults are limited in the literature. Our results demonstrated that, even if adjusted for common confounders known to be related to ASFT (age, sex, and frailty) (30,31), ASFT was significantly related to CC, MC, HC, WC, BMI, BRI, FM, FFM, PA, HGS, the thickness of RA and IO muscles, and the confirmed SO. This supports the notion that ASFT may be seen as a potential radiological marker in older adults.

The aging process is characterized by an increase in total FM and a decrease in lean mass (muscle and bone), which occurs even if body weight and BMI remain constant (32). Moreover, there is a change in the distribution of fat tissue. While peripheral subcutaneous tissue decreases, abdominal subcutaneous and visceral fat tissue increases (33). SFT plays an essential role in energy storage and the release of free fatty acids. Upper body/abdominal ASFT is more lipolytic and releases more free fatty acids compared to lower body fat accumulation (34). This may explain the relationship of ASFT and total body FM, as well as AM, to the individual's energy metabolism.

Table 3. Results of the linear regression analyses of independent factors associated with subcutaneous fat thickness

		Abdominal subcutaneous fat thickness	
MODELS*		**β (95% CI)**	**p**
Model 1	Calf circumstance	0.023 (0.012-0.034)	**<0.001**
Model 2	Mid-arm circumstance	0.033 (0.023-0.045)	**<0.001**
Model 3	Hip circumstance	0.010 (0.006-0.014)	**<0.001**
Model 4	Waist circumstance	0.005 (0.002-0.007)	**0.002**
Model 5	Fat-mass	0.011 (0.008-0.015)	**<0.001**
Model 6	Fat-free mass	-0.004 [-0.008-(-0.001)]	**0.024**
Model 7	Phase angle	0.005 (0.002-0.008)	**0.002**
Model 8	Handgrip strength	-0.007 [-0.013-(-0.001)]	**0.024**
Model 9	Rectus abdominis thickness	0.005 (0.001-0.010)	**0.046**
Model 10	External oblique muscle thickness	0.036 (0.004-0.067)	**0.026**
Model 11	Transversus abdominis muscle thickness	0.027 (-0.013-0.056)	0.079
Model 12	Body mass index	0.015 (0.06-0.024)	**0.002**
Model 13	Body roundness index	0.050 (0.28-0.078)	**<0.001**
Model 14	Confirmed sarcopenia [using low HGS (<16 and <27 for F and M) + low SMMI] n (%)	-0.051 (-0.213-0.111)	0.533
Model 15	Confirmed sarcopenia [using low HGS (<22 and <32 for F and M) + low SMMI] n (%)	-0.039 (-0.181-0.102)	0.583
Model 16	Confirmed sarcopenic obesity (using low HGS [<16 and <27 for F and M) (*among 99 obese patients]	0.187 (0.123-0.350)	**0.026**
Model 17	Confirmed sarcopenic obesity (using low HGS [<22 and <32 for F and M) (*among 99 obese patients]	0.231 (0.087-0.372)	**0.002**

*All models are individually adjusted for age, sex and frailty.
CI: Confidence interval, HGS: Handgrip strength, SMMI: Skeletal muscle mass index, F: Female, M: Male

US is a commonly used method for assessing various tissues and the beginning of its usage in fat tissue evaluation dates back to the 1960s (35). Although cross-sectional imaging methods [computed tomography (CT) and magnetic resonance imaging (MRI)] are regarded as the gold standard for assessing many body compositions, including ASFT, there are well-established limitations for these tools, such as radiation exposure and cost-effectiveness (36). US is a cost-effective, radiation-free, and reliable alternative to MRI/CT since it showed promising results for ASFT measurements that significantly correlated with cross-sectional methods (37,38,39). ASFT also successfully predicted the total body FM measured on DXA, another gold standard method for body composition assessment (10,11). Similar to DXA, BIA is a commonly utilized tool to assess body composition by measuring the electrical properties of body tissue and estimating the related parameters (40). Our results showed that ASFT was correlated with the BIA measurements. FM and PA were positively correlated; FFM was negatively correlated with SFT, and these relationships remained significant after adjustment for age, sex, and frailty. The positive correlation of ASFT with total body FM aligns with evidence in the literature revealing the association between ASFT and body fat composition (10,11). The evidence in the literature is contradictory regarding the relationship between PA and total FM. Additionally, no study compares the PA with ASFT. Our results show that ASFT positively correlates with PA, this may be parallel to the evidence on PA's relationship with the general nutritional status and total body weight (41). Our results are also noteworthy, as this is the first study in the literature to show the relationship between body composition parameters measured with BIA and US-measured ASFT.

Defining obesity based solely on BMI has become less preferred since markers such as WC, BRI, and body composition have outperformed BMI in important outcomes, including cardiovascular outcomes (2,42,43). Our results showed that ASFT was positively associated with all obesity-related markers (BMI, BRI, and WC), MC and CC-which are measures related to muscle mass-as well as total body mass. Furthermore, our findings indicate a positive, modest correlation between ASFT and the thickness of the abdominal muscles. Although ASFT appears to be related to local muscle-related measurements, it was negatively associated with specific measures of muscle strength and total muscle mass (HGS and FFM) when adjusted for age, sex, and frailty. While it is generally recommended to evaluating the decrease in extremity muscle mass when defining muscle wasting conditions such as sarcopenia or malnutrition, there are limited data on the usability of abdominal muscle thickness for determining total muscle mass. Our study's results indicate that ASFT showed a modest positive correlation with abdominal muscle thickness (1,44), similar to other markers indicating total

body mass (a combination of muscle and fat). Furthermore, more specific markers of total muscle mass and/or strength FFM [HGS]) exhibited a negative relationship with ASFT, suggesting that abdominal muscle thickness may be more closely related to total mass, particularly in the obese population. Considering the modest relationship in the correlation coefficients, the limited number of patients, and the cross-sectional design, larger studies are warranted to confirm these findings. In addition, even if the association between ASFT and confirmed sarcopenia or physical performance tests (TUG and gait speed) could not be demonstrated, in the subgroup analysis performed in obese patients defined using BMI and WC, high ASFT and SO were found to be related in the linear and logistic regression models. Although no study directly evaluated the relationship between SO and ASFT, one study investigating the use of the US in the definition of SO also identified an association between increased ASFT and SO (13). In the aforementioned study, SO was defined as solely using BMI to define obesity with a limited number of patients (13). Demonstrating the relationship between SO and ASFT, as defined by the current SO criteria, is consistent with the literature and more objectively supports the relationship between these two variables. Taken together, beyond its relationship with AM, total body mass, body FM, and local muscle masses, ASFT is potentially an important radiological marker of SO in obese older individuals.

Study Limitations

The primary limitation of the study was the relatively small sample size, the cross-sectional design, which limits assessing causality, and the fact that it was not designed specifically to assess the power of ASFT in predicting SO. Therefore, large-sample prospective studies to evaluate the causality of the relationship between ASFT and other variables, with sex-specific cut-offs of ASFT for SO prediction, are warranted to confirm our findings. Validating US-measured ASFT with gold-standard cross-sectional imaging techniques (MRI or CT) could improve the reliability of this measurement. Although we did not compare the ASFT measurement via the US to a cross-sectional method, our results, demonstrating the relationship between ASFT and adiposity markers from and body composition analyses via BIA, support the evidence in the literature that the US may be a suitable alternative for ASFT measurement. However, prospective studies are still needed to compare ASFT with other gold standard methods. Although factors that may affect BIA measurements and anthropometric assessments, such as edema, BIA measurements and anthropometric assessments were reduced through physical examination and detailed anamnesis, it is possible that factors like dehydration and newly developing anemia were overlooked, even in a small number of patients. This oversight might also be a limitation. The inability to demonstrate very strong correlation coefficients for each parameter with a significant relationship with ASFT was another significant limitation. This limitation might also result from the relatively small sample size of our study. Therefore, studies with much larger samples and including other cross-sectional methods such as BIA, CT, or MRI are required to generalize the results.

Conclusion

To the best of our knowledge, this is the first study comprehensively evaluating the relationship between ASFT and body composition analysis of BIA, abdominal muscle thicknesses, and SO. Prospective studies on the role of ASFT in predicting SO, in particular, are warranted.

Ethics

Ethics Committee Approval: The study received ethics approval from the clinical research ethics committee at Hacettepe University's Faculty of Medicine and Hacettepe University Health Sciences Research Ethics Committee (research number: 24/313, decision number: 2024/05-12, date: 05.03.2024).

Informed Consent: Each participant in the study gave their informed consent.

Footnotes

Authorship Contributions

Surgical and Medical Practices: H.B., A.O.B., Y.Ö., M.G., S.C., M.K., M.H., Z.Ş., C.B., B.B.D., M.C., M.G.H. Concept: H.B., A.O.B., Y.Ö., B.B.D., M.G.H. Design: H.B., A.O.B., Y.Ö., M.C., M.G.H. Data Collection or Processing: H.B., A.O.B., M.G., S.C., M.K., M.H., Z.Ş., C.B., M.G.H. Analysis or Interpretation: H.B., A.O.B., Y.Ö., M.G.H. Literature Search: H.B., A.O.B., Y.Ö., M.K., M.C., M.G.H. Writing: H.B., A.O.B., Y.Ö., M.G.H.

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