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Correlation between muscle masses measured by chest computed tomography and bioelectrical impedance analysis in older adults

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Background and aims. There is a scarcity of research investigating the relationship between thoracic muscles and bioelectrical impedance analysis (BIA)-measured muscle mass specifically in older adults. Thus, the objective of this study is to assess the association between muscle measurements obtained from chest computed tomography (CT) scans and BIA in older adults.

Methods. The retrospective study included outpatients who previously applied to the geriatrics outpatient clinic of a university hospital, who were evaluated with BIA and who had a chest CT for any reason within 3 months before or after the BIA. Cross-sectional muscle area at Th10 and Th12 was obtained from chest CT images.

Results. The median age of the 83 patients was 73.0 (25p-75p: 69-79), and 51.8% (n = 43) were female. By CT, from Th10 median for cross-sectional area (CSA) was 81.7 cm^2 (25p-75p: 61.5-95.3); from Th12, median for CSA was 93.1 cm^2 (25p-75p: 70-107.6). At both thoracic vertebrae levels, muscle masses were correlated with muscle mass obtained by BIA in all participants, those with normal handgrip strength, those who were obese and non-obese, and those with normal SMI.

Conclusions. Muscle masses measured with BIA and CT correlated in older adults. It should be noticed that the thoracic muscles will also diminish if muscle mass measured by BIA decreases in older adults. Since BIA offers significant advantages in terms of non-invasiveness, portability, cost, time efficiency, ease of use and safety profile it can be a valid alternative to CT scans for thoracic muscle mass measurement.

Key words: aged, body composition, sarcopenia, thoracic vertebrae, thorax

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INTRODUCTION

Sarcopenia refers to a syndrome characterized by progressive and widespread loss of muscle mass and strength, leading to various negative health outcomes such as physical impairment, reduced quality of life, and increased mortality [1]. The diagnosis of sarcopenia takes into account three key factors: muscle strength, muscle mass and quality, and physical performance. Two techniques commonly used for assessing muscle mass are bioelectrical impedance analysis (BIA) and computed tomography (CT) [2]. BIA estimates muscle mass indirectly by measuring the electrical conductivity of the entire body, while also providing information on fat-free mass, total body fluid, and other variables, particularly in individuals without significant fluid and electrolyte disorders [3]. CT, considered as the most reliable among non-invasive methods along with magnetic resonance imaging (MRI), directly measures muscle mass and is a reliable assessment tool [4].

CT measurements of muscle mass mostly focus on the third lumbar vertebra level [5]. However, during the pandemic period, there has been an expanded use of thoracic muscle measurements [6]. These measurements encompass all the muscles at the level of the thoracic vertebrae [7]. Decreased thoracic muscle mass has been associated with negative health outcomes in individuals with malignancies and those undergoing surgical procedures [8,9]. Previous studies have shown a correlation between thoracic muscle mass, as measured by CT, and whole-body muscle mass determined through BIA [10,11]. However, there is a scarcity of research investigating the relationship between thoracic muscles and BIA-measured muscle mass specifically in older adults. Thus, the objective of this study is to assess the correlation between muscle measurements obtained from chest CT scans and BIA in older adults.

MATERIALS AND METHODS

Study population

The study was conducted retrospectively with outpatients who met the inclusion criteria in a university hospital geriatrics outpatient clinic. Inclusion criteria were: aged 65 or older, prior CT and BIA performed within three months before CT or within three months after CT. Patients with acute illness and/or history of hospitalization between BIA and CT were excluded. The inclusion-exclusion process was represented in Figure 1. Computed tomographies were acquired based on clinical indication, not for the purpose of the present study. All patients in the hospital's geriatrics outpatient clinic underwent thorough comprehensive geriatric assessments. Age, sex, education, marital status, chronic diseases, medications, neurocognitive and mood disorders, falls, incontinence, activities of daily living, nutritional status, frailty status, handgrip strength, 4-meter gait speed, anthropometric measurements, BIA and computed tomography measurements, and laboratory examinations of the patients were noted. Comprehensive geriatric assessment and anthropometric measurements were performed on the same day as BIA. The coexistence of two or more chronic diseases is known as multimorbidity [12].

Muscle assessment

Weight and height were recorded without shoes and in light clothing. With the use of a tape, the circumferences of the waist and hips were measured at the level of the umbilicus and the broadest region of the buttocks, respectively. When the arm was 90 degrees bent from the elbow, the mid-arm circumference was measured from the midpoint of the acromial and olecranon protrusions. Calf circumference was measured with the foot pushing against a hard surface, from the broadest section of the calf.

Handgrip strength was measured with a calibrated hand-held dynamometer (T.K.K.5401; Takei Scientific Instruments, Tokyo, Japan). The patients' arms were parallel to the floor as handgrip strength was measured three times with a dynamometer. The highest of these three values was accepted as handgrip strength. Cut-off levels for handgrip strength were defined as 16 kg for females and 27 kg for males [13].

To measure walking speed using a digital watch, we asked the patients to walk four meters at their normal pace. Gait speed less than 0.8 m/sec indicates poor physical performance [13].

The patient's body composition was evaluated using the Bodystat Quadscan 4000 device. The measures were performed with the patients lying in the supine position; all metal (necklaces, rings, watches, etc.) was removed prior to measurements. Patients were fasting and had an empty bladder. Electrodes were positioned in two proximal and distal parts of the patients' right hand and foot for whole-body BIA measurements. It was not performed in those with a pacemaker or any implant, those with severe edema (≥ 3+), and those with severe electrolyte disturbances, as it may cause inaccurate measurements. Phase angle (PA) refers to a parameter that provides information about the quality and health of the body's cellular membranes. It is derived from the relationship between resistance (R) and reactance (Xc) in an electrical circuit that passes a small, safe electric current through the body. The formula for calculating PA (ϕ) in BIA is $\varphi=\arctan(Xc/R)$. Arctan represents the arctangent function [3]. The skeletal muscle mass (SMM) was calculated by the Janssen formula: (height^2/resistance × 0.401) + (gender [males= 1, females= 0] × 3.825) + (age × -0.071) + 5.102 (14). The skeletal muscle index (SMI) was calculated by dividing SMM by the height [2]. The cut-off points for low SMI were taken at 11.1 kg/m^2 for males and 8.9 kg/m^2 for females as determined by Bahat et al. [2].

Computed tomography scans were acquired on a third-generation dual-source CT scanner (Somatom Force, Siemens Healthineers). Online dose modulation (Care DOSE 4D, Siemens Medical Solutions) was used. Scanning parameters were as follows: tube current 50–120 mAs, tube voltage 70–120 kV, pitch 3, matrix 512×512, field of view 350×350 mm and slice thickness 3 mm. Reconstruction was performed with a slice thickness of 1 mm. A soft tissue kernel of reconstruction was used on all CT datasets. Forty-two (50.6%) of the CTs were enhanced with intravenous contrast.

All CT images were imported into Syngo. via (Siemens Healthineers, Erlangen, Germany) for image analysis. The muscle boundaries were manually drawn at the 10th (Th10) and 12th thoracic vertebrae from chest CT images for each patient. Semianutomatic segmentation was performed under the Hounsfield Unit (HU) thresholds of -50 to 150. Hounsfield Unit was used to represent muscle radiation attenuation (MRA). The volume for the segmented area was measured automatically. For calculating cross-sectional area (CSA), the following formula was used: cm^3 x (10/slice thickness in mm). The mean HU values of muscle CSA were also noted for showing muscle quality.

The latissimus dorsi, erector spinae, rectus abdominis, internal abdominal oblique, external abdominal oblique, and intercostal muscles at Th12 and also serratus anterior muscle at Th10 were included in the CSA measurements. Examples of measurement of CSA of the muscles are shown in Figure 2.

Statistical analysis

Statistical Package for the Social Sciences (SPSS) 24.0 was used to analyze the data. Categorical variables were expressed as numbers and percentages. Since there were no normally distributed continuous variables in the data, continuous variables are expressed as median and quartiles (25th and 75th percentiles). Comparisons of continuous variables were made with Mann Whitney U-test since continuous variables are not normally distributed, and chi-square test for categorical values. As the continuous variables were not normally

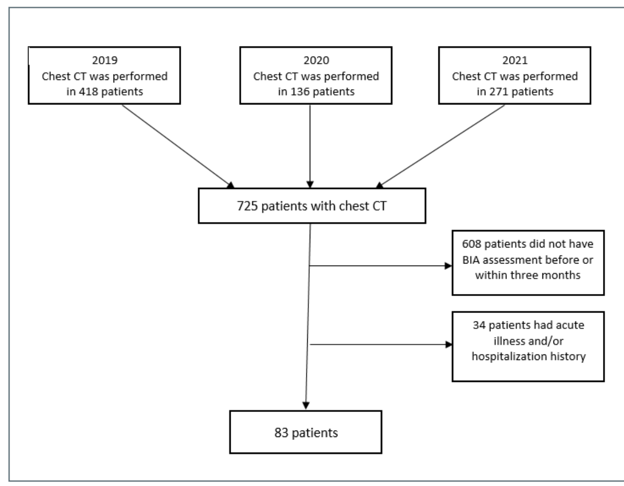

Figure 1. The inclusion-exclusion process.

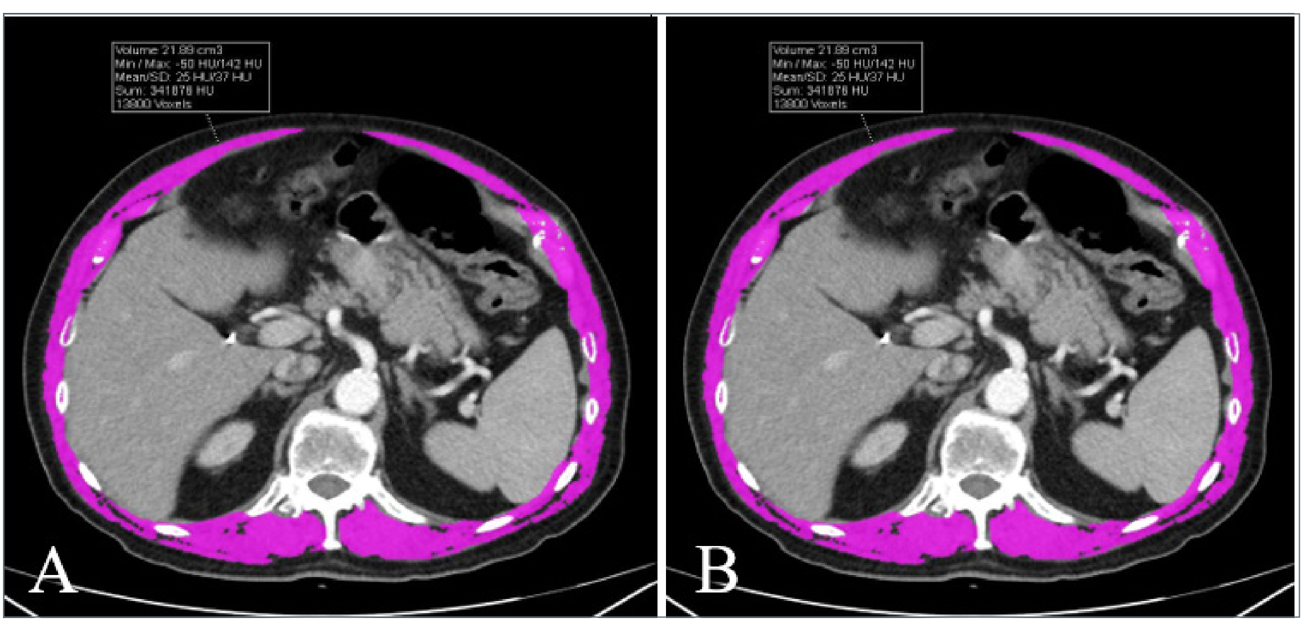

Figure 2. Semiautomatic segmentation of muscles on axial CT imaging at Th12 (A) and Th 10 (B) levels (pink). The volume of the segmented area was calculated automatically. The cross-sectional area measurement was performed via the following formula cm^3 X (10/slice thickness in mm). Mean muscle density (Hounsfield Unit) was calculated automatically after segmentation.

Table I. Demographic and clinical characteristics of participants (n = 83).

	N (%)
Age* (years)	73 (69-79)
Illiterate (never attending school)	18 (21.7)
Married	57 (68.7)
Living alone	13 (15.7)
Smoking	29 (34.9)
Multimorbidity (≥ 2 chronic diseases)	62 (74.7)
Comprehensive geriatric assessment	
Urinary incontinence	25 (30.1)
Polypharmacy (≥ 5 drugs)	59 (71.1)
Drug number*	6 (4-8)
Katz activities of daily living*	6 (5-6)
Lawton-Brody instrumental activities of daily living*	8 (7-8)
Mini nutritional assessment-short form*	11 (9-13)
Mini nutritional assessment-short form (≤ 11)	46 (55.4)
SARC-F*	2 (0-4)
Clinical Frailty scale*	4 (3-5)
Clinical Frailty scale (≥ 4)	56 (67.5)

* median, 25p-75p, SARC-F: strength, assistance with walking, rising from a chair, climbing stairs, falls.

distributed, Spearman rho was used in the correlation analysis. A two-tailed p-value of 0.05 or lower was regarded as significant.

In method comparison studies, a higher correlation coefficient (above 0.7 or 0.8) is desired to demonstrate agreement between two methods. In the present study, the correlation coefficients are around 0.4. While it is generally considered modest in terms of strength of association, this level of correlation may be meaningful in certain contexts. It is essential to interpret such correlations cautiously, considering factors like sample size, measurement precision, and potential confounding variables. In medical research, correlations of 0.4 may be observed between body composition measures like muscle mass and functional outcomes in older adults [15,16].

RESULTS

The median age of the 83 patients was 73.0 (25p-75p: 69-79), and 51.8% (n = 43) were female. Multimorbidity was present in 74.7% of patients (n = 62). Demographic and clinical characteristics of patients and comprehensive geriatric assessment results are listed in Table I.

The ratio of obese patients was 38.6% (n = 32), while the median BMI was 28.3 kg/m^2 (25p-75p: 25.4-31.2). The median number of days between CT and BIA measurements was 19 (25p-75p: 8-37). The number of patients with low SMI was 51 (61.4%). By CT, from Th10 median for muscle volume was 11.1 cm^3 (25p-75p: 9-14.9), for HU was 22 (25p-75p: 15-26), and for CSA was 81.7 cm^2 (25p-75p: 61.5-95.3); from Th12, median for muscle volume was 12.6 cm^3 (25p-75p: 9.8-16.4), HU 21 (25p-75p: 15-27), and for CSA 93.1 cm^2 (25p-75p: 70-107.6). Values of muscle parameters were summarized in Table II.

At both thoracic vertebrae levels, Muscle mass from both measurement methods was correlated in entire cohort, in the subgroup of non-obese patients, patients with low and normal handgrip strength, and low and normal SMI groups (Tab. III).

DISCUSSION

The relationship between muscle parameters measured with thorax CT and BIA was investigated by the present study. Muscle mass from both measurement methods was correlated in entire cohort, non-obese patients, and those with low and normal handgrip strength, low and normal SMI groups. These findings suggest that BIA values can be used to assess thoracic muscle mass.

This significant relationship between the thoracic muscles and the total muscle mass is important for a number of reasons. To understand respiratory function, assess sarcopenia, improve physical performance, guide clinical management, and promote research and treatment development in related areas, the relationship between the thoracic muscles and total muscle mass is crucial. It can facilitate insights into respiratory function and quality of life in individuals with respiratory conditions [7]. The assessment of the association between thoracic muscle mass and total muscle mass is of value in the diagnosis and monitoring of sarcopenia, which is of importance in the prevention of functional decline and frailty in older adults [11,17]. A strong association between thoracic muscles and total muscle mass can help predict and improve functional capacity, mobility, and independence in various populations [9,18]. Research on the association between thoracic muscles and total muscle mass contributes to advancing knowledge in fields such as respiratory medicine, geriatrics, and rehabilitation sciences. It can also inform the development of novel treatments or interventions targeting thoracic muscles to improve respiratory function and overall well-being.

Muscle masses were measured using the two different methods correlated in the present study. Data supporting these findings have also been reported in previous studies examining different populations. Muscle mass at the Th12 level and FFMI measured with BIA were found to be correlated in patients with advanced lung cancer [19,20]. BIA values were compared with measurements from pectoralis muscles and Th12 level in healthy Chinese adults. Muscle mass obtained by BIA was seen to be correlated with muscle mass calculated by thorax CT [10,21].

The present study was carried out in older adults. Older adults are special population and measuring thoracic muscles can provide valuable information. Including thoracic muscles in the evaluation allows for a more comprehensive assessment of muscle mass throughout the body. This is important because low muscle mass can affect various muscle groups differently, and focusing solely on limbs or specific areas may miss important indicators of overall muscle health [22]. Changes in thoracic muscle mass and function can occur early in the progression of sarcopenia or other muscle-related conditions [23]. By measuring these muscles, healthcare providers can detect muscle decline sooner. Another point, thoracic muscles are crucial for trunk stability [24]. Assessing these muscles gives insights into core muscle strength, which is essential for posture, balance, and daily activities like walking and standing. Including thoracic muscle measurements in the diagnostic process enables more personalized treatment planning. For example, if a patient shows significant weakness in thoracic muscles, targeted interventions such as respiratory exercises or specific strength training can be incorporated into their rehabilitation or management plan. Older adults are the population most susceptible to loss of thoracic muscles, as with other muscle groups. There is, however, not much research in the literature that focuses on the thoracic muscles in older people. Decreased muscle mass measured at Th12 levels in hospitalized older adults increased the risk of in-hospital death [25]. Patients aged 65 years and older who underwent surgical aortic valve replacement were at higher risk for early-term adverse events and long-term mortality compared to non-sarcopenic patients [26]. Lower pectoral muscle volume was related to longer mechanical ventilation duration, greater SOFA scores, and increased in-hospital mortality in ICU patients [17]. The decrease in paraspinal muscle mass at Th12 level in geriatric trauma patients increased the risk of death within one year [27]. Reduced thoracic paravertebral muscle size and attenuation on a CT scan were associated with lower odds of surviving in older people with hip fractures [28]. In addition, the worsening of muscle quality indicators in older adults was associated with disability in patients' activities of daily living [18]. It is important to evaluate the thoracic muscles in older adults, who are the most vulnerable to adverse health outcomes, and to take the necessary precautions for patients with reduced muscle mass. It will be vital to enrich the literature on the assessment of thoracic muscle mass in older adults, specifically.

Table II. Anthropometric, bioelectrical impedance analysis and computed tomography measurements (N = 83).

	N (%)
Anthropometric measurements	
Body Mass Index* (kg/m^2)	28.3
	(25.4-31.2)
≥ 30 kg/m^2	32 (38.6)
Mid-arm Circumference* (cm)	28
	(26-31)
Calf circumference* (cm)	34
	(31-37)
Waist/hip Ratio*	0.94
	(0.89-1)
Muscle performance	
Handgrip Strength** (kg)	20.9 ± 7.9
Low	39 (47)
4-meter Gait speed* (m/sn)	1.05
	(0.85-1.30)
Bioelectrical impedance analysis	
Fat (%) (mean ± SD)	36.3 ± 10.5
Skeletal muscle mass** (kg)	24.5 ± 7.8
Skeletal muscle index** (kg/m^2)	9.4 ± 2.4
Low	51 (61.4)
Phase angle*	4.9
	(3.8-8.5)
Computed tomography	
Th10	
Volume* (cm^3)	11.1
	(9-14.9)
HU*	22
	(15-26)
Cross-sectional area* (cm^2)	81.7
	(61.5-95.3)
Th12	
Volume* (cm^3)	12.6
	(9.8-16.4)
HU*	21.0
	(15-27)
Cross-sectional area* (cm^2)	93.1
	(70-107.6)

* median, 25p-75p, ** mean ± standart deviation, kg: kilogram, m: meter, cm: centimeter, sn: second, Th: Thoracic vertebrae, HU: Hounsfield unit, anthropometric measurements were measured concurrently with BIA.

Thoracic sarcopenia has entered the literature in the last decade and is related to adverse health outcomes. It was mostly evaluated in patients before or after chest surgery, patients before or after cardiac surgery, patients with chronic lung diseases and malignancy. Patients undergoing coronary artery bypass grafting who have thoracic sarcopenia have longer lengths of postoperative hospital stays, intensive care unit (ICU) stays, greater costs, higher readmission rates within 30

Table III. Correlations of muscle measurements by computed tomography and bioelectrical impedance analysis.

Cross-sectional area level		Number of participants	Correlation coefficent*	P
Th10	Entire cohort	83	0.417	< 0.001
	Low handgrip strength	39	0.519	0.001
	Normal handgrip strength	44	0.323	0.03
	Obese	32	0.275	0.13
	Non-obese	51	0.526	< 0.001
	Low skeletal muscle index	51	0.479	< 0.001
	Normal skeletal muscle index	32	0.517	0.002
Th12	Entire cohort	83	0.390	< 0.001
	Low handgrip strength	39	0.387	0.02
	Normal handgrip strength	44	0.421	0.004
	Obese	32	0.325	0.07
	Non-obese	51	0.432	0.002
	Low skeletal muscle index	51	0.555	< 0.001
	Normal skeletal muscle index	32	0.533	0.002

*Spearman rho, N: number, Th: thoracic.

days of discharge, and higher mortality rates [9]. Thoracic sarcopenia has been linked to a worsening clinical state and a lower quality of life for COPD patients [7]. The morbidity and mortality of cancer patients are adversely affected by thoracic sarcopenia [29-31]. As a result of studies in COVID-19 patients during the pandemic, it gained increased attention. Patients with low SMI measured from Th12 level had more infections and prolonged hospital stay [6]. Better muscle metrics were associated with lower mortality in COVID-19 patients, according to another study looking at the pectoralis muscles [32].

Several limitations should be noted in the present study. Firstly, the sample size is relatively small, which may affect the generalizability of the findings. Secondly, due to the retrospective design of the study, some participant information is missing, which may have introduced bias. Furthermore, it is important to note that CT and BIA were not consistently performed on the same day for many participants. Body weight or any other parameter was not measured during both measurements to evaluate body composition. However, efforts were made to exclude those with acute illnesses and hospitalization history and minimize factors that could affect muscle parameters. It is worth mentioning that BIA has been reported to potentially overestimate muscle mass, which could affect the accuracy of the measurements [33]. No additional adjustments were made to correct this situation in the present study. The strengths of the present study are it specifically examines the relationship between thorax CT and BIA measurements in older adults, and that measurements were performed at two different thoracic levels.

CONCLUSIONS

Muscle masses obtained with BIA and CT correlated in older adults. It should be borne in mind that thoracic muscles may also diminish if muscle mass measured by BIA decreases in older adults. Since BIA offers significant advantages in terms of non-invasiveness, portability, cost, time efficiency, ease of use and safety profile it can be a valid alternative to CT scans for thoracic muscle mass measurement.

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

SC: conceptualization, methodology, data curation, writing - original draft; MG, AOB, YO, MK, OD, ZK, CY: data curation - review & editing; BBD, MGH, MC: conceptualization, review & editing; GD, CB: conceptualization, methodology, data curation, visualization, review & editing.

Ethical consideration

Non-interventional Clinical Research Ethics Board of Hacettepe University Faculty of Medicine gave its approval to the present study (Project number: GO 22/673, Decision number: 22/12-40). It was designed in accordance with the principles of the Declaration of Helsinki.

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