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ULTRASOUND-ASSESSED FAT DISTRIBUTION AND ITS RELATION TO SARCOPENIA PARAMETERS IN COMMUNITY-DWELLING OLDER ADULTS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Ageing is associated with significant alterations in body composition, characterized by increased fat accumulation and a gradual reduction in skeletal muscle mass. However, the association between specific abdominal fat distribution and sarcopenia parameters remains poorly understood.

Objective: To investigate the association between abdominal fat distribution, assessed by ultrasound (US), and sarcopenia parameters in community-dwelling young older adults aged 60-74 years.

Methods: A cross-sectional study was conducted in 58 community-dwelling older adults. Abdominal fat distribution was assessed by US, including visceral adipose tissue (VAT), subcutaneous adipose tissue (SAT), and the VAT/SAT ratio. Muscle strength was evaluated using a hand grip dynamometer, muscle mass indices [skeletal muscle mass Index (SMI) and appendicular skeletal muscle mass index (ASMI)] by bioelectrical impedance (BIA) and physical performance by gait speed (GS). Linear regression analyses were adjusted by age, sex, and physical activity.

Results: Participants were 66.50 ± 7.00 years old [67.24% (39/58) women], 89.7% (52/58) were non-sarcopenic, and 72.5% (42/58) were non-obese. After regression analysis, in all population, VAT was positively associated with muscle mass indices. SAT was negatively associated with GS and relative handgrip strength (HGS/BW). In women, VAT was positively associated with SMI and ASMI and inversely associated with HGS/BW, whereas SAT inversely associated with HGS/BW and GS.

Conclusions: These results suggest that abdominal fat distribution may influence physical performance and relative muscle strength in ageing populations, highlighting the importance of evaluating abdominal fat distribution when assessing sarcopenia parameters.

Keywords: Ultrasound, body composition, subcutaneous fat, visceral fat, sarcopenia.

RESUM

Introducció: L'envelliment s'associa amb alteracions significatives en la composició corporal, caracteritzades per un augment d'acumulació de greix i una reducció progressiva de massa muscular esquelètica. Tanmateix, l'associació entre la distribució específica del greix abdominal i els paràmetres de sarcopènia continua sent poc coneguda.

Objectiu: Investigar l'associació entre la distribució del greix abdominal, mesurada per ecografia (US), i els paràmetres de sarcopènia en adults grans joves comunitaris de 60-74 anys.

Mètodes: Es va realitzar un estudi transversal en 58 adults grans comunitaris. La distribució del greix abdominal es va avaluar mitjançant ecografia, incloent teixit adipós visceral (VAT), teixit adipós subcutani (SAT) i la relació VAT/SAT. La força muscular s'avaluà amb dinamòmetre de prensió manual, els índexs de massa muscular [índex de massa muscular esquelètica (SMI) i índex de massa muscular esquelètica apendicular (ASMI)] es van determinar mitjançant bioimpedància elèctrica (BIA), i el rendiment físic es va valorar mitjançant la velocitat de la marxa (GS). Els anàlisis de regressió lineal es van ajustar per edat, sexe i activitat física.

Resultats: Els participants tenien una edat de 66,50 ± 7,00 anys [67,24% (39/58) dones], el 89,7% (52/58) no presentaven sarcopènia i el 72,5% (42/58) no presentaven obesitat. Després de l'anàlisi de regressió, a la població total, el VAT es va associar positivament amb els índexs de massa muscular. El SAT s'associà negativament amb la GS i la força de prensió relativa (HGS/BW). En les dones, el VAT es va associar positivament amb l'SMI i l'ASMI i inversament amb la HGS/BW, mentre que el SAT es va associar inversament amb la HGS/BW i GS.

Conclusions: Aquests resultats suggereixen que la distribució del greix abdominal pot influir en el rendiment físic i en la força muscular relativa en poblacions envellides, destacant la importància d'avaluar la distribució del greix abdominal en l'estudi dels paràmetres de sarcopènia.

Paraules clau: Ecografia, composició corporal, greix subcutani, greix visceral, sarcopènia.

RESUMEN

Introducción: El envejecimiento se asocia con alteraciones significativas en la composición corporal, caracterizadas por un aumento de acumulación de grasa y una reducción progresiva de masa muscular esquelética. Sin embargo, la asociación entre distribución específica de grasa abdominal y parámetros de sarcopenia continúa siendo poco conocida.

Objetivo: Investigar la asociación entre la distribución de la grasa abdominal, evaluada mediante ecografía (US), y los parámetros de sarcopenia en adultos mayores jóvenes comunitarios de 60-74 años.

Métodos: Se realizó un estudio transversal en 58 adultos mayores comunitarios. La distribución de grasa abdominal se evaluó mediante ecografía, incluyendo tejido adiposo visceral (VAT), tejido adiposo subcutáneo (SAT) y la relación VAT/SAT. La fuerza muscular se evaluó mediante dinamómetro de prensión manual, los índices de masa muscular [índice de masa muscular esquelética (SMI) e índice de masa muscular esquelética apendicular (ASMI)] se determinaron mediante bioimpedancia eléctrica (BIA), y el rendimiento físico se valoró mediante la velocidad de la marcha (GS). Los análisis de regresión lineal se ajustaron por edad, sexo y actividad física.

Resultados: Los participantes presentaban una edad de 66,50 ± 7,00 años [67,24% (39/58) mujeres], el 89,7% (52/58) no presentaban sarcopenia y el 72,5% (42/58) no presentaban obesidad. Tras el análisis de regresión, en la población total, el VAT se asoció positivamente con los índices de masa muscular. El SAT se asoció negativamente con la GS y con la fuerza de prensión relativa (HGS/BW). En las mujeres, el VAT se asoció positivamente con el SMI y el ASMI e inversamente con la HGS/BW, mientras que el SAT se asoció inversamente con la HGS/BW y GS.

Conclusiones: Estos resultados sugieren que la distribución de la grasa abdominal puede influir en el rendimiento físico y en la fuerza muscular relativa en poblaciones envejecidas, destacando la importancia de evaluar la distribución de la grasa abdominal en el estudio de los parámetros de sarcopenia.

Palabras clave: Ecografía, composición corporal, grasa subcutánea, grasa visceral, sarcopenia.

2. Introduction

Ageing is associated with significant alterations in body composition, characterized by increased fat accumulation and a gradual reduction in skeletal muscle mass [1]. This age-related loss of muscle mass is a key contributor to frailty, decreased functional capacity, and poorer health outcomes among older adults [2]. According to the European Working Group on Sarcopenia in Older People (EWGSOP, 2019), sarcopenia is a progressive and generalized skeletal muscle disorder characterized by reduced muscle strength, low muscle quantity or quality, and impaired physical performance [2].

In this context, obesity has been identified as a contributing factor to the development of sarcopenia [3], as excess adipose tissue promotes chronic inflammation, anabolic resistance, and fat infiltration into muscle, ultimately leading to a decline in muscle mass and function. Abdominal obesity is a major factor associated with alterations in body composition [4] and it is linked to the development of sarcopenic obesity [5], especially in the ageing population [6]. Commonly used anthropometric indicators of abdominal obesity include waist circumference (WC), waist-to-height ratio (WHtR) and conicity index (CI) [7]; however, these measures, together with BMI, do not allow differentiation of abdominal adipose tissue distribution [8].

Abdominal adipose tissue is formed by subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT), also named as intraabdominal fat, including preperitoneal, omental, mesenteric and perirenal fat [9]. SAT represents about 80% of total body adipose tissue and VAT accounts for about 10-20% in men and 5-10% in women [10, 11]. VAT comprises distinct compartments with unique anatomical locations and physiological functions. The accumulation of VAT depots is linked to sarcopenia risk [12]. In contrast, SAT is formed as a homogeneous compartment. Aging has been associated with an increase of SAT, being a greater rise in women than in men [13]. Visceral adiposity contributes to skeletal muscle dysfunction through multiple mechanisms, including chronic low-grade inflammation, insulin resistance, oxidative stress, mitochondrial dysfunction, and ectopic lipid infiltration into muscle tissue, ultimately impairing muscle quality and physical performance [14, 15]. While visceral adiposity has been consistently associated with metabolic dysfunction and sarcopenia, the

potential role of SAT in muscle strength, muscle mass and physical performance remains poorly understood.

Given the distinct physiological effects of the different abdominal fat depots, accurate quantification of abdominal adiposity is essential to better understand the relationship between adipose tissue compartments and sarcopenia-related outcomes. SAT and VAT have been evaluated using magnetic resonance imaging or computed tomography, which are regarded as gold-standard techniques [16]. However, their use in clinical practice is constrained by high costs, radiation exposure in the case of computed tomography, and technical complexity [17]. Ultrasound (US) provides a cost-effective and non-invasive alternative for the real-time assessment of SAT and VAT thickness [17,18,19]. Although abdominal US enables the evaluation of both adipose compartments, it is not yet considered a gold-standard method [17,18].

Although different abdominal fat depots may exert distinct metabolic and mechanical effects on musculoskeletal parameters, the associations between VAT and SAT and specific sarcopenia-related parameters, such as muscle strength, muscle mass, muscle quality, and physical performance, remain poorly understood. Moreover, to our knowledge, no previous studies have simultaneously compared ultrasound-derived VAT and SAT measurements with conventional anthropometric indices in relation to musculoskeletal parameters in community-dwelling older adults. Considering the age-related redistribution of abdominal adipose tissue, we hypothesized that visceral and subcutaneous adipose tissue compartments may differentially relate to sarcopenia-related parameters, including muscle mass, muscle strength, and physical performance.

2.1 Objectives

Primary objective

To investigate the association between abdominal fat distribution, assessed by ultrasound, and sarcopenia-related parameters in community-dwelling older adults, with a particular focus on the potential differential influence of visceral and subcutaneous adipose tissue on muscle health.

Secondary objectives

To compare the associations of ultrasound-derived abdominal adipose tissue measurements (VAT, SAT and VAT/SAT ratio) and commonly used anthropometric indicators of abdominal obesity (BMI, WC, WHtR and CI) with sarcopenia-related parameters.

To explore sex-specific differences in the associations between abdominal fat distribution and sarcopenia-related parameters.

3. Materials and Methods

3.1 Study design

The present study is a cross-sectional study based on the baseline data of the WinAging Randomized Controlled Trial. Baseline assessments were performed between May 2025 and January 2026 in Reus (Spain), and visits were conducted at Centre Mèdic Quirúrgic (CMQ). The WinAging Study was designed to assess the long-term effects of red wine polyphenols provided through non-alcoholic red wine within the framework of a Mediterranean diet, on locomotor and cognitive function, in community-dwelling young-old and older adults. At the time this analysis was conducted, participant recruitment for the WinAging study was still ongoing; therefore, the sample included in the present study does not represent the final sample size of the overall WinAging project.

The WinAging study was conducted in accordance with the principles of the Declaration of Helsinki and the International Conference on Harmonization Good Clinical Practice (ICH-GCP). Ethical approval was granted on 28/11/2024 by the Ethics Committee of the Pere Virgili Health Research Institute (IISPV) (256/2024). The study protocol was registered at ClinicalTrials.gov (NCT06871384). Written informed consent was obtained from all participants prior to their inclusion in the study.

3.2 Subjects and eligibility criteria

The inclusion criteria were men or women between ≥60 years and ≤74 years of age, with written informed consent before the initial visit.

The exclusion criteria were the following: a) men or women >75 years old; b) hypoglycaemia treatment or type 1 and type 2 diabetes mellitus diagnosed; c) anaemia (haemoglobin ≤13 g/dL in men and ≤12 g/dL in women); d) subjects diagnosed of intestinal disorders such as Chron's disease, colitis ulcerous, and irritable bowel syndrome, e) to present a clinical active chronic disease; f) to present severe sarcopenia; g) to present cognitive impairment (MMSE ≤24 or clinical diagnosis of mild cognitive impairment or dementia); h) dietary allergies to: Mediterranean foods (e.g., nuts), sulphites or nitrates; i) use of antioxidants supplements; j) regular consumers of red wine who do not agree to change the consumption of red wine with alcohol to non-alcoholised wine during the intervention; k) chronic alcoholism; l) current or past participation in a clinical trial or consumption of a research product in the 30 days prior to inclusion in the study; and m) failure to follow the study guidelines.

3.3 Assessment of abdominal fat distribution by ultrasound

SAT and VAT were evaluated by ultrasonography with subjects lying supine. The probe was placed about 2 cm superior to the umbilicus, at the L3–L4 level, where the aortic bifurcation into the iliac arteries occurs. Axial images were acquired while minimal transducer pressure was applied, identified by the onset of slight blurring in the lateral image [20, 21, 22, 23]. All scans were performed during expiration using a VINNO 5 ultrasound system (Vinno [Suzhou] Co., Ltd., Suzhou, China). The HAR-mode and Abdominal Resolution preset were selected, operating at a frequency of 5 MHz with a convex probe (F2-5CE). Each ultrasound parameter was measured three times by the same examiner, and the average of these measurements was considered for analysis. SAT (cm), including superficial and profound SAT, was measured as the distance between the skin and the linea alba, and VAT (cm), comprising preperitoneal, omental, and mesenteric fat but excluding perirenal fat, was measured as the distance between

the posterior aspect of the linea alba and the anterior wall of the aorta [20, 21, 22, 23]. The VAT/SAT ratio was subsequently calculated.

3.4 Assessment of anthropometric parameters

All anthropometric parameters were obtained while subjects were dressed in lightweight clothing and no footwear. Trained dietitians determined body weight (kg) and body composition using a Tanita MC 780-MA body composition analyser (Tanita Corp., Barcelona, Spain), and height (cm) was recorded with a wall-mounted stadiometer (Tanita Leicester Portable; Tanita Corp., Barcelona, Spain).

BMI was classified according to the classification for adults over 65 years old [24]. BMI was classified as follows: 18.5-22 kg/m² underweight; 22-26.9 kg/m² healthy weight; 27-29.9 kg/m² overweight; 30-34.9 kg/m² obese class 1; 35-39.9 kg/m² obese class2; 40-40.9 kg/m² obese class 3; and ≥50 kg/m² obese class 4 [24].

WC was recorded 2 cm above the umbilicus using a 150 cm steel anthropometric tape [25]. The WHtR and the CI, defined as WC (cm)/[0.109 × square root of weight (kg)/height (m)], were calculated.

3.5 Assessment of sarcopenia-related parameters

3.5.1 Muscle mass

Muscle mass was assessed by bioimpedance analysis (BIA), a segmental multifrequency body composition analyser (TANITA MC-780MA; Tanita Corp., Tokyo, Japan). The muscle mass quantity parameters assessed were the skeletal muscle mass (SM, kg), skeletal muscle mass index (SMI, kg), appendicular skeletal muscle mass (ASM, kg), appendicular skeletal muscle mass index (ASMI, kg/m²). Also, the muscle quality was determined by the phase angle (°) assessed by BIA [24].

3.5.2 Muscle strength

Muscle strength was evaluated through handgrip strength (HGS) of the dominant hand using a hydraulic hand dynamometer (JAMAR® Plus+ Dynamometer; Performance Health Supply, Inc., Cedarburg, WI, USA). Two maximal voluntary contractions were obtained, and the mean value was used for analysis. HGS adjusted by body weight (BW) (HGS/BW) was calculated. HGS/BW assessed the relative strength, making it particularly useful for identifying sarcopenia in individuals where absolute strength alone may be misleading, especially those with higher BW [26].

3.5.3 Physical performance

Physical performance was assessed by usual gait speed (GS) over a 4-m course [16]. The test was conducted twice, and the average of both trials was calculated for subsequent analyses.

3.5.4 Cut-off points for sarcopenia parameters based on EWGSOP1 and EWGSOP2

The cut-off points to determine low skeletal muscle strength were: <30 kg in men and <20 kg in women, based on EWGSOP1 consensus [27]; and <27 kg in men and <16 kg in women based on EWGSOP2 consensus [16]. The cut-off points to determine low muscle mass parameters were: <8.87 kg/m² of SMI in men and <6.42 kg/m² on SMI in women based on EWGSOP1 consensus [27]; and <20 kg ASM in men and <15 kg of ASM in women, or <7 kg/m² of ASMI in men and 5.5 kg/m² of ASMI in women based on EWGSOP2 consensus [16]. A GS of $\leq$0.8 meters/second (m/s) was considered low physical performance base on both EWGSPO consensus [27, 16]. Both consensuses were taken into account in order to compare the precision of each consensus to identify sarcopenic participants.

3.5.5 Physical activity

Physical activity was assessed using the validated Spanish short version of the International Physical Activity Questionnaire (IPAQ) [28], and results were expressed as metabolic equivalent task minutes per week (METs/week).

3.6 Statistical analysis

Categorical variables were presented as percentages (%). Normality was tested by Kolmogorov–Smirnov test. Continuous variables were presented as mean ± standard deviation (SD) (normal distribution) or median and interquartile range (IQR) (non-normal distribution), stratified by sex, and compared using Student's t-test or Mann–Whitney U test, depending on the nature of the variable.

Spearman's rank correlation coefficients (r) were computed to examine the associations between VAT, SAT, and the VAT/SAT ratio measured by US or by routinely applicable anthropometric parameters (BMI, WC, WHtR and CI) and sarcopenia parameters (SMI, ASMI, HGS, HGS/BW and GS). Linear regression analyses adjusted for age, sex, and physical activity were performed to evaluate the associations between abdominal adiposity measurements (VAT, SAT, and VAT/SAT ratio) measured by US or by routinely applicable anthropometric parameters (BMI, WC, WHtR and CI) and sarcopenia-related parameters.

All statistical analyses were performed using SPSS IBM (Corp. Released 2025. IBM SPSS Statistics for Windows, Version 31.0.0.0, IBM Corp., Armonk, NY). A p-value of <0.05 was considered significant.

4. Results

4.1 Characteristics of the study participants

Baseline characteristics of all participants are presented in **Table 1**. A total of 58 participants were included, 67,2% were women (n=39/58), and 32,8% were men (n=19/58). The mean ± SD age of participants was 66.50 ± 7.00, and the median (IQR) BMI was 27.10 (5.65) kg/m^2. There were significant differences between sexes for anthropometric measures, sarcopenia parameters and abdominal fat US measures ($p<0.05$).

Frequencies of obesity and sarcopenia classification of the participants are presented in **Table 2**.

Obesity classification

Regarding the BMI classification, a total of 53.5% of participants were classified as having excess body weight, including 25.9% with overweight and 27.6% with obesity, with higher prevalence observed in men for both categories (p<0.001). In contrast, 65.5% (n=38/58) of the study population presented elevated WC [66.7% women (n=26/39), and 63.2% men (n=12/19); p=0.012].

Sarcopenia parameters

Regarding sarcopenia parameters and according to EWGSOP1 consensus, reduced HGS was more prevalent in women (41.0%; 16/39) than in men (10.5%; 2/19), p<0.004. There are no cases found for low SMI. When classified by EWGSOP1 consensus, 65.5% (n=38/58) were non-sarcopenic [53.8% women (n=21/39) and 89.5% men (n=17/19)], 34.5% (n=20/58) presented presarcopenia [46.2% women (n=18/39) and 10.5% men (n=2/19)], and nobody met the criteria for sarcopenia or severe sarcopenia. The differences in sarcopenia classification according to EWGSOP1 were significant when compared between sexes (p=0.018).

In contrast, based on EWGSOP2 consensus, low HGS was identified in 10.3% (n=6/58) of all population [12.8% women (n=5/39) and 5.3% men (n=1/19); p<0.001] and 1.75 (n=1/58) presented low ASMI [0% women (n=0/39) and 5.3% men (n=1/19); p<0.001]. When classified by EWGSOP2 consensus, 89.7% (n=52/58) were non-sarcopenic [87.2% women (n=34/39) and 94.7% men (n=18/19)], 8.6% (n=5/58) presented probable sarcopenia [10.3% women (n=4/39) and 5.3% men (n=1/19)], and 1.7% (1/58) presented sarcopenia [2.6% women (n=1/39) and 0% men (n=0/19)]. There were no cases for severe sarcopenia.

The difference in sarcopenia classification according to EWGSOP2 consensus were significant when compared between sexes (p<0.001).

Presence of low GS was of 12.1% (n=7/58) for all population, 15.4% (n=6/39) for women and 5.3% (n=1/19) for men (p<0.001).

4.2 Association between abdominal fat distribution assessed by ultrasound and sarcopenia parameters

Spearman correlation analysis in all population is presented in **Supplementary Table 1**. Linear regressions analysis between abdominal fat distribution assessed by ultrasound and sarcopenia parameters in all population of the study participants are presented in **Table 3**. Among abdominal ultrasound parameters, total abdominal fat was positively associated with ASMI (β=0.217, p=0.029) and visceral adipose tissue positively associated with SMI and ASMI (β=0.305, p=0.009; β=0.397, p<0.001). Moreover, VAT/SAT ratio was positively associated with ASMI (β=0.256, p=0.011). Whereas SAT was inversely associated with HGS/BW (β=−0.246, p=0.024) and GS (β=−0.299, p=0.033).

In men (**Table 4**), no significant association were observed between abdominal fat distribution, assessed by ultrasound, and sarcopenia parameters. In women (**Table 5**), VAT was positively associated with SMI (β=0.443, p=0.008) and ASMI (β=0.646, p<0.001) and inversely associated with HGS/BW (β=-0.527, p<0.001). In women, SAT was inversely associated with HGS/BW (β=-0.415, p=0.008) and GS (β=-0.362, p=0.029). Spearman correlation analysis in men and women are presented in **Supplementary Table 2 and 3**.

4.3 Association between abdominal fat distribution assessed by routinely applicable anthropometric parameters and sarcopenia parameters

Spearman correlation analysis in all population is presented in **Supplementary Table 1**. Linear regressions analysis between abdominal fat distribution assessed by routinely applicable anthropometric parameters and sarcopenia parameters in all population of the study participants are presented in **Table 3**.

Regarding routinely anthropometric parameters, BMI, WC and WHtR showed positive association with SMI and ASMI (β= above 0.4 and p-values <0.001). Moreover, BMI and WHtR also showed inverse association with HGS/BW (β= above -0.4 and p-values <0.001).

In men (**Table 4**), BMI, WC and WHtR showed positive association with SMI and ASMI (β= above 0.8 and p-values <0.001). Moreover, in men, WC was inversely

associates with HGS/BW (β=-0.623, p=0.013). In women, (**Table 5**), BMI, WC and CI showed positive association with SMI and ASMI (β= above 0.3 and p-values <0.001). Moreover, in women, BMI, WC and CI showed inverse associations with HGS/BW and GS (β= above 0.4 and p-values <0.05). Spearman correlation analysis in men and women are presented in **Supplementary Table 2 and 3**.

5. Discussion

The results of the present cross-sectional study demonstrate novel vision into the relationship between abdominal fat distribution, assessed by US and routinely applicable anthropometric parameters, and sarcopenia-related parameters in older adults. The present study results provides that some abdominal fat depots are distinctively associated with sarcopenic parameters such as muscle mass, muscle strength, and physical performance, with notable sex-specific patterns.

In all population, increased abdominal fat, total abdominal fat, SAT and VAT were positively associated with muscle mass indices (SMI and ASMI) while total abdominal fat and SAT being inversely associated with physical performances (GS) and relative muscle strength (HGS/BW).

Even though 12.1% of the participants (7/58) present low GS they are not classified as sarcopenic coinciding with any consensus. Moreover, there are no participants presenting low SMI by EWGSOP1 consensus and only 1.7% (n=1/58) presented low ASMI by EWGSOP2 consensus. These findings support the emerging concept that muscle quality and physical performance may deteriorate despite preserved muscle quantity, potentially reflecting early adiposity-related muscle dysfunction [29]. According to the evidence of describing age-related adipose redistribution, individuals aged 65–75 years are the target group in which these changes seem especially relevant, as many older adults at this transitional stage do not yet complete the diagnostic criteria for sarcopenia despite already showing reductions in certain functional and physiological parameters. Nevertheless, measurable alterations in body composition and physical function are already present, making this period a critical stage in the

progression toward frailty, where early signs of functional decline begin to emerge [30,31].

In the present study, VAT demonstrated stronger positive associations with sarcopenia-related indicators of muscle mass, whereas SAT exhibited consistent negative associations with muscle strength and physical performance across the overall population. Although the relationships between SAT and muscle mass indices (SMI and ASMI) were weaker and less consistent than those observed for VAT, higher SAT levels were associated with lower relative muscle strength (HGS/BW) and reduced GS. In contrast, these associations with functional parameters were not identified for VAT in all population (**Table 3**).

Reduced GS is identified as an early marker of frailty and a strong predictor of functional decline, disability and adverse health outcomes in older adults [32,33]. Adipose tissue compartments do not age uniformly, as VAT and SAT exhibit distinct physiological and functional responses to ageing process [34,35]. Although SAT is generally considered a metabolically protective compartment, age-related structural and cellular alterations impair adipogenesis and promote chronic inflammatory signalling, ultimately contributing to increased tissue fibrosis [36,37]. Age-related dysfunction of SAT reduces its lipid-buttering capacity, promoting lipid redistribution toward VAT and skeletal muscle. This process may contribute to impaired muscle quality and reduces physical performance, ultimately increasing the development of sarcopenia and frailty risk in older adults [37,38].

Sex-specific analyses revealed important differences in the relationship between abdominal fat distribution and sarcopenia-related parameters (**Table 4 and 5**). In men, no significant association were observed between abdominal fat distribution, assessed by US, and sarcopenia parameters. In women, associations were more consistent, VAT was positively associated with SMI and ASMI and inversely associated with HGS/BW. Moreover, in women, SAT was inversely associated with HGS/BW and GS.

These findings suggest that sex-related differences in fat distribution, hormonal profile, and muscle physiology may influence the relationship between adiposity and sarcopenia in older adults [39,40].

Anthropometric measures such as BMI, WC, WHtR and CI also showed significant associations with sarcopenia-related parameters. These outcomes were positively associated with muscle mass (SMI and ASMI) and inversely associated with relative muscle strength (HGS/BW) and physical performance (GS) (**Table 3**).

Among the assessed measures, WC and WHtR showed the most consistent associations, supporting previous evidence and highlighting their value as simple and low-cost screening tools for identifying individuals at risk of sarcopenia [41]. The findings are consistent with Baş et al. (2025), who reported ultrasound-measured SAT correlates with anthropometric indices such as BMI and WC, and was inversely associated with HGS, although this relationship was observed only in individuals with obesity [42]. Specifically, in the present study, SAT is significantly inversely associated with muscle strength (HGS/BW) and physical performance (GS), in all population and in women. These findings suggest that SAT may have more relevant role in sarcopenia than previously thought, as loss of adipose plasticity and increased fibrosis reduce its lipid-buffering capacity, leading to lipid redistribution to VAT and skeletal muscle [36]. While younger muscle can compensate, ageing muscle is more vulnerable due to chronic low-grade inflammation, anabolic resistance and impaired repair capacity [43,44]. That fat dysfunction, not just fat location, is key to metabolic and musculoskeletal health [43,44].

Interestingly, while simple anthropometric indices such as WC and WHtR showed strong and consistent associations with sarcopenia-related parameters, they do not differentiate between SAT and VAT. In contrast, ultrasound-derived measures provide more detailed information about fat distribution and how each fat compartment affects to different sarcopenia-related parameters, supporting their use as practical screening tool in clinical practice in the assessment of sarcopenia. The associations were observed in the whole population and differed by sex. Women showed more consistent associations between fat compartments and both relative muscle strength and physical function.

Our findings are in line with previous evidence, indicating that greater adiposity, particularly central obesity, is associated with impaired muscle function and diminished physical performance [45]. Adiposity and low muscle strength are strongly associated with functional decline, whereas muscle mass alone shows weaker or inconsistent associations with physical performance and disability outcomes [46]. This indicates that reduced physical performance can occur even in the presence of relatively preserved muscle mass, particularly in the early stages of aging. Future longitudinal research is warranted to clarify the casual pathways and to explore potential interventions targeting both adiposity and muscle function in older adults.

This study has some notable strengths. First, it provides a direct comparison between ultrasound-based measurements and commonly used anthropometric indicators of abdominal obesity. Second, it provides a multidimensional assessment of sarcopenia in line with the current consensus definitions because of the simultaneous evaluation of muscle mass, strength and physical performance. Third, the sex-stratified analyses enable the identification of important differences between men and women.

However, several limitations should be acknowledged. The small sample size, 58 participants and a predominantly female population (39/58, 64.2%) may limit statistical power and the generalisability of our findings. That was because this study was conducted in a single-centre Spanish population form de Camp de Tarragona region. Also, the cross-sectional design of the study avoids any interference of causality. In addition, although ultrasound provides a non-invasive and practical method for assessing fat distribution, it is operator-dependent and may present measurement variability.

6. Conclusion

In conclusion, this cross-sectional study demonstrates that abdominal fat distribution is closely associated with sarcopenia-related parameters. Ultrasound-assessed abdominal fat distribution showed sex-specific associations with sarcopenia parameters. VAT showed positive association with muscle mass indices, while SAT was the only depot associated with lower relative muscle strength and physical performance in all population. Sex-specific results showed that in women, VAT was positively associated with muscle mass and negatively associated with relative muscle strength. Whereas in women, SAT was the only fat depot negatively associated with physical performance.

These results reinforce that abdominal fat distribution may influence physical performance and relative muscle strength in older adults. Highlighting the importance of evaluating abdominal fat distribution when evaluating sarcopenia parameters.

Table 1. Baseline characteristics of the study participants.

	All population (n=58)	**Women (n=39)**	**Men (n=19)**	***p*-value***
Age, *years*	66.50 ± 7.00	67.00 ± 6.00	66.00 ± 9.00	0.630
Anthropometric measures				
Weight, *kg*	70.40 (19.60)	68.70 (13.65)	86.60 (19.30)	**<0.001**
Height, *m*	1.62 (0.09)	1.57 (0.06)	1.72 (0.06)	**<0.001**
BMI, *kg/m²*	27.10 (5.65)	25.90 (6.10)	28.00 (5.60)	0.177
Fat mass, *%*	32.55 (11.20)	33.80 (8.30)	26.70 (5.20)	**<0.001**
Waist circumference, *cm*	96.00 (17.13)	94.00 (16.25)	102.00 (11.50)	**<0.001**
Waist-to-height ratio	0.59 (0.09)	0.59 (0.11)	0.59 (0.06)	0.933
Conicity index	1.31 (0.09)	1.30 (0.09)	1.35 (0.08)	0.060
Sarcopenia parameters				
Handgrip strength, *kg*	23,68 (13.49)	21.40 (4.90)	36.65 (9.95)	**<0.001**
Skeletal muscle mass, *kg*	26.10 (8.13)	25.00 (3.45)	34.80 (5.70)	**<0.001**
Skeletal muscle mass index, *kg/m²*	10.64 (1.52)	9.92 (0.97)	12.05 (1.43)	**<0.001**
Appendicular muscle mass, *kg*	17.95 (6.70)	17.30 (2.10)	25.90 (5.00)	**<0.001**
Appendicular muscle mass index, *kg/m²*	7.13 (1.57)	6.78 (0.58)	8.50 (1.31)	**<0.001**
Phase angle, *º*	5.40 (0.78)	5.00 (0.75)	5.90 (0.80)	**<0.001**
Gait speed, *m/s*	1.05 (0.30)	0.99 (0.29)	1.18 (0.36)	0.193
Ultrasound parameters				
Total abdominal fat, *cm*	7.13 (3.46)	6.59 (2.46)	9.03 (4.09)	**0.007**
SAT thickness, *cm*	1.86 (1.24)	2.00 (1.11)	1.37 (0.79)	**0.011**
VAT thickness, *cm*	4.73 (3.47)	4.22 (2.15)	7.20 (3.39)	**0.001**
VAT/SAT ratio	2.59 (1.82)	2.37 (1.23)	3.98 (3.29)	**<0.001**

BMI, body mass index; SAT, subcutaneous adipose tissue; VAT, visceral adipose tissue. Values are expressed as mean ± standard deviation (SD) for variables with normal distribution or median and interquartile range (IQR) for variables with non-normal distribution. * Sex differences by t-test or Mann-Whitney U test, depending on the nature of the variable, a p-value <0.05 is statistically significant. Significant results are expressed in **bold**.

Table 2. Frequencies of cardiovascular disease risk factors and risk sarcopenia of the study participants.

	Total (n=58)	Women (n=39)	Men (n=19)	*p*-value*
Body mass index classification				**<0.001**
Underweight, *% (n)*	6.9 (4/58)	5.1 (2/39)	10.5 (2/19)	
Healthy weight, *% (n)*	39.7 (23/58)	51.3 (20/39)	15.8 (3/19)	
Overweight, *% (n)*	25.9 (15/58)	17.9 (7/39)	42.1 (8/19)	
Obese, *% (n)*				
Class 1, *% (n)*	22.4 (13/58)	20.5 (8/39)	26.3 (5/19)	
Class 2, *% (n)*	5.2 (3/58)	5.1 (2/39)	5.3 (1/19)	
Class 3, *% (n)*	0 (0/58)	0 (0/39)	0 (0/19)	
Waist circumference classification [a]				**0.012**
Low risk, *% (n)*	32.8 (19/58)	30.8 (12/39)	36.8 (7/19)	
High risk, *% (n)*	65.5 (38/58)	66.7 (26/39)	63.2 (12/19)	
Sarcopenia parameters, EWGSOP1 [b]				
Low Handgrip Strength, *% (n)*	31.0 (18/58)	41.0 (16/39)	10.5 (2/19)	**0.004**
Low SMI, *% (n)*	0 (0/58)	0 (0)	0 (0/19)	
Low Gait Speed, *% (n)*	12.1 (7/58)	15.4 (6/39)	5.3 (1/19)	**<0.001**
Sarcopenia parameters, EWGSOP1 [b]				**0.018**
Non-sarcopenic, *% (n)*	65.5 (38/58)	53.8 (21/39)	89.5 (17/19)	
Presarcopenia, *% (n)*	34.5 (20/58)	46.2 (18/39)	10.5 (2/19)	
Sarcopenia, *% (n)*	0 (0/58)	0 (0/39)	0 (0/19)	
Severe Sarcopenia, *% (n)*	0 (0/58)	0 (0/39)	0 (0/19)	
Sarcopenia parameters, EWGSOP2 [c]				
Low Handgrip Strength, *% (n)*	10.3 (6/58)	12.8 (5/39)	5.3 (1/19)	**<0.001**
Low AMM, *% (n)*	89.7 (52/58)	84.6 (33/39)	100 (19/19)	**<0.001**
Low ASMI, *% (n)*	1.7 (1/58)	0 (0/39)	5.3 (1/19)	**<0.001**
Low Gait Speed, *% (n)*	12.1 (7/58)	15.4 (6/39)	5.3 (1/19)	**<0.001**
Sarcopenia parameters, EWGSOP2 [c]				**<0.001**
Non-sarcopenic, *% (n)*	89.7 (52/58)	87.2 (34/39)	94.7 (18/19)	
Probable sarcopenia, *% (n)*	8.6 (5/58)	10.3 (4/39)	5.3 (1/19)	
Sarcopenia, *% (n)*	1.7 (1/58)	2.6 (1/39)	0 (0/19)	
Severe Sarcopenia, *% (n)*	0 (0/58)	0 (0/39)	0 (0/19)	

SMI, Skeletal Muscle Index; AMM, Appendicular Skeletal Muscle Mass; ASMI, Appendicular Skeletal Muscle Index; EWGSOP, European Working Group on Sarcopenia in Older People; BMI, Body Mass Index; WC, Waist Circumference. [a] World Health Organization, 2008; [b] EWGSOP, 2010; [c] EWGSOP2, 2019; [d] ESPEN and EASO Consensus Statement, 2022. * Gender differences by Chi-square test, a p-value <0.05 is statistically significant. Significant results are expressed in **bold** and borderline results are expressed in *italic*.

Table 3. Linear regression between abdominal fat distribution and sarcopenia parameters in all population.

	Sarcopenia parameters									
	SMI, *kg/m²*		**ASMI**, *kg/m²*		**HGS**, *kg*		**HGS/BW**		**GS**, *m/s*	
	β	*p-value*	*β*	*p-value*	*β*	*p-value*	*β*	*p-value*	*β*	*p-value*
Abdominal fat distribution assessed by ultrasound										
Total abdominal fat, *cm*	0.176	0.119	0.217	**0.029**	0.016	0.831	-	-	-	-
Subcutaneous adipose tissue, *cm*	-	-	-	-	-	-	-0.246	**0.024**	-0.299	**0.033**
Visceral adipose tissue, *cm*	0.305	**0.009**	0.397	**<0.001**	-0.054	0.499	-	-	-	-
VAT/SAT ratio	0.131	0.272	0.256	**0.011**	-0.051	0.524	-	-	-	-
Abdominal fat distribution assessed by routinely applicable anthropometric parameters										
Body mass index, *kg/m²*	0.555	**<0.001**	0.59	**<0.001**	-	-	-0.468	**<0.001**	-0.398	**0.003**
Waist circumference, *cm*	0.490	**<0.001**	0.50	**<0.001**	0.008	0.922	-	-	-0.519	**<0.001**
Waist-to-height ratio	0.455	**<0.001**	0.461	**<0.001**	-	-	-0.422	**<0.001**	-0.495	**<0.001**
Conicity Index	0.262	0.019	0.243	0.012	-0.044	0.565	-	-		

SMI, Skeletal Muscle Mass Index; ASMI, Appendicular Skeletal Muscle Mass Index, HGS, Handgrip Strength; BW, Body Weight; GS, Gait Speed; VAT, Visceral Adipose Tissue; SAT, Subcutaneous Adipose Tissue. Linear regression was adjusted for age, sex and total physical activity (METs/week), a p-value <0.05 is statistically significant. Significant results are expressed in **bold**, borderline results are expressed in *italic*.

Table 4. Linear regression between abdominal fat distribution and sarcopenia parameters in men.

	Sarcopenia parameters									
	SMI, *kg/m²*		**ASMI**, *kg/m²*		**HGS**, *kg*		**HGS/BW**		**GS**, *m/s*	
	β	*p-value*	*β*	*p-value*	*β*	*p-value*	*β*	*p-value*	*β*	*p-value*
Abdominal fat distribution assessed by ultrasound										
Total abdominal fat, *cm*	0.335	0.232	0.408	0.112	-	-	-0.440	*0.063*	-0.361	0.191
Subcutaneous adipose tissue, *cm*	-	-	-	-	-	-	-0.105	0.653	-0.064	0.810
Visceral adipose tissue, *cm*	0.286	0.303	0.403	0.111	-	-	-0.397	0.092	-0.331	0.226
VAT/SAT ratio	-	-	-	-	-	-	-	-	-	-
Abdominal fat distribution assessed by routinely applicable anthropometric parameters										
Body mass index, *kg/m²*	0.897	**<0.001**	0.881	**<0.001**	-	-	-0.453	*0.062*	-0.433	0.121
Waist circumference, *cm*	0.859	**<0.001**	0.808	**0.001**	-	-	-0.623	**0.013**	-0.472	0.117
Waist-to-height ratio	0.944	**<0.001**	0.815	**0.003**	-	-	0.499	0.077	-0.652	0.037
Conicity Index	0.466	0.184	0.290	0.384	-0.137	0.677	-0.547	0.067	-	-

SMI, Skeletal Muscle Mass Index; ASMI, Appendicular Skeletal Muscle Mass Index, HGS, Handgrip Strength; BW, Body Weight; GS, Gait Speed; VAT, Visceral Adipose Tissue; SAT, Subcutaneous Adipose Tissue. Linear regression was adjusted for age, sex and total physical activity (METs/week), a p-value <0.05 is statistically significant. Significant results are expressed in **bold**, borderline results are expressed in *italic*.

Table 5. Linear regression between abdominal fat distribution and sarcopenia parameters in women.

	Sarcopenia parameters									
	SMI, *kg/m²*		**ASMI**, *kg/m²*		**HGS**, *kg*		**HGS/BW**		**GS**, *m/s*	
	β	*p-value*	*β*	*p-value*	*β*	*p-value*	*β*	*p-value*	*β*	*p-value*
Abdominal fat distribution assessed by ultrasound										
Total abdominal fat, *cm*	0.145	0.388	0.178	0.291	-	-	-0.228	0.142	-0.284	0.080
Subcutaneous adipose tissue, *cm*	-	-	-	-	-	-	-0.415	**0.008**	-0.362	**0.029**
Visceral adipose tissue, *cm*	0.443	**0.008**	0.646	**<0.001**	-	-	-0.527	**<0.001**	-0.311	*0.062*
VAT/SAT ratio	-	-	-	-	-	-	-	-	-	-
Abdominal fat distribution assessed by routinely applicable anthropometric parameters										
Body mass index, *kg/m²*	0.654	**<0.001**	0.856	**<0.001**	-	-	-0.648	**<0.001**	-0.412	**0.010**
Waist circumference, *cm*	0.531	**<0.001**	0.683	**<0.001**	-	-	-0.572	**<0.001**	-0.540	**<0.001**
Waist-to-height ratio	0.545	**<0.001**	0.731	**<0.001**	-	-	-0.539	**<0.001**	-0.512	**<0.001**
Conicity Index	0.352	**0.042**	0.423	**0.013**	-0.025	-0.170	-0.398	**0.010**	-0.506	**0.002**

SMI, Skeletal Muscle Mass Index; ASMI, Appendicular Skeletal Muscle Mass Index, HGS, Handgrip Strength; BW, Body Weight; GS, Gait Speed; VAT, Visceral Adipose Tissue; SAT, Subcutaneous Adipose Tissue. Linear regression was adjusted for age, sex and total physical activity (METs/week), a p-value <0.05 is statistically significant. Significant results are expressed in **bold**, borderline results are expressed in *italic*.

Supplementary Table 1. Spearman correlations between abdominal fat distribution and sarcopenia parameters in all population.

	Sarcopenia parameters									
	SMI, *kg/m²*		**ASMI**, *kg/m²*		**HGS**, *kg*		**HGS/BW**		**GS**, *m/s*	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*
Abdominal fat distribution assessed by ultrasound										
Total abdominal fat, cm	0.491	**<0.001**	0.516	**<0.001**	0.311	0.017	-0.106	0.428	-0.212	0.110
Subcutaneous adipose tissue, cm	-0.032	0.817	-0.093	0.494	-0.223	**0.099**	-0.435	**<0.001**	-0.310	**0.020**
Visceral adipose tissue, cm	0.584	**<0.001**	0.653	**<0.001**	0.332	**0.012**	-0.083	0.541	-0.183	0.177
VAT/SAT ratio	0.421	**0.001**	0.493	**<0.001**	0.314	**0.019**	0.221	0.101	0.041	0.766
Abdominal fat distribution assessed by routinely applicable anthropometric parameters										
Body mass index, kg/m2	0. 715	**<0.001**	0.722	**<0.001**	0.129	0.334	-0.420	**<0.001**	-0.330	**0.011**
Waist circumference, cm	0.706	**<0.001**	0.734	**<0.001**	0.316	**0.017**	-0.236	0.077	-0.293	**0.027**
Waist-to-height ratio	0.463	**<0.001**	0.478	**<0.001**	-0.097	0.474	-0.535	**<0.001**	-0.444	**<0.001**
Conicity Index	0.393	**<0.001**	0.430	**0.001**	0.095	0.481	-0.378	**0.004**	-0.378	**0.004**

SMI, Skeletal Muscle Mass Index; ASMI, Appendicular Skeletal Muscle Mass Index, HGS, Handgrip Strength; BW, Body Weight; GS, Gait Speed; VAT, Visceral Adipose Tissue; SAT, Subcutaneous Adipose Tissue. A p-value <0.05 is statistically significant. Significant results are expressed in **bold**, borderline results are expressed in *italic*.

Supplementary Table 2. Spearman correlations between abdominal fat distribution and sarcopenia parameters in men.

	Sarcopenia parameters									
	SMI, *kg/m²*		**ASMI**, *kg/m²*		**HGS**, *kg*		**HGS/BW**		**GS**, *m/s*	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*
Abdominal fat distribution assessed by ultrasound										
Total abdominal fat, cm	0.189	0.437	0.332	0.166	-0.176	0.472	-0.512	**0.025**	-0.299	0.213
Subcutaneous adipose tissue, cm	0.135	0.581	-0.005	0.983	-0.011	0.963	-0.116	0.637	0.062	0.800
Visceral adipose tissue, cm	0.237	0.329	0.370	0.119	-0.136	0.579	-0.493	**0.032**	-0.178	0.466
VAT/SAT ratio	0.163	0.505	0.298	0.215	0.030	0.903	-0.232	0.340	-0.155	0.525
Abdominal fat distribution assessed by routinely applicable anthropometric parameters										
Body mass index, kg/m2	0.799	**<0.001**	0.924	**<0.001**	0.004	0.986	-0.652	**0.002**	-0.322	0.179
Waist circumference, cm	0.645	**0.003**	0.810	**<0.001**	-0.227	0.351	-0.796	**<0.001**	-0.204	0.403
Waist-to-height ratio	0.579	**0.009**	0.795	**<0.001**	-0.177	0.468	-0.698	**0.001**	-0.243	0.316
Conicity Index	0.212	0.383	0.342	0.152	-0.462	**0.046**	-0.665	**0.002**	-0.350	0.302

SMI, Skeletal Muscle Mass Index; ASMI, Appendicular Skeletal Muscle Mass Index, HGS, Handgrip Strength; BW, Body Weight; GS, Gait Speed; VAT, Visceral Adipose Tissue; SAT, Subcutaneous Adipose Tissue. A p-value <0.05 is statistically significant. Significant results are expressed in **bold**, borderline results are expressed in *italic*.

Supplementary Table 3. Spearman correlations between abdominal fat distribution and sarcopenia parameters in women.

	Sarcopenia parameters									
	SMI, *kg/m²*		**ASMI**, *kg/m²*		**HGS**, *kg*		**HGS/BW**		**GS**, *m/s*	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*
Abdominal fat distribution assessed by ultrasound										
Total abdominal fat, cm	0.309	*0.055*	0.346	**0.031**	0.133	0.421	-0.240	0.141	-0.293	0.070
Subcutaneous adipose tissue, cm	0.247	0.140	0.243	0.148	0.096	0.572	-0.345	0.037	-0.343	**0.038**
Visceral adipose tissue, cm	0.427	0.008	0.509	**<0.001**	-0.003	0.986	-0.347	**0.035**	-0.305	0.066
VAT/SAT ratio	0.126	0.457	0.145	0.391	-0.235	-0.161	-0.021	0.902	0.024	0.888
Abdominal fat distribution assessed by routinely applicable anthropometric parameters										
Body mass index, kg/m2	0.704	**<0.001**	0.798	**<0.001**	-0.016	0.923	-0.630	**<0.001**	-0.415	**0.009**
Waist circumference, cm	0.538	**<0.001**	0.606	**<0.001**	0.000	0.998	-0.561	**<0.001**	-0.502	**0.001**
Waist-to-height ratio	0.511	**0.001**	0.617	**<0.001**	-0.171	0.304	-0.587	**<0.001**	-0.501	**0.001**
Conicity Index	0.329	**0.044**	0. 369	0.023	-0.149	0.371	-0.452	**0.004**	-0.523	**0.001**

SMI, Skeletal Muscle Mass Index; ASMI, Appendicular Skeletal Muscle Mass Index, HGS, Handgrip Strength; BW, Body Weight; GS, Gait Speed; VAT, Visceral Adipose Tissue; SAT, Subcutaneous Adipose Tissue. A p-value <0.05 is statistically significant. Significant results are expressed in **bold**, borderline results are expressed in *italic*

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