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Original Article

Sarcopenia tendency through body measurements and physical fitness in older women

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Abstract:
Background: Sarcopenia is characterized by a gradual decline in muscle mass, strength, and function, primarily attributed to natural aging. The identification of sarcopenia relies on assessing muscle mass and strength levels, and using the skeletal muscle index (SMI) for this purpose remains uncertain. **Aim:** This study aimed to evaluate the effectiveness of the relative skeletal muscle method in estimating low muscle mass or sarcopenia and to explore potential correlations between sarcopenia, body measurements, and physical fitness. **Methods:** A total of 276 older adult women (71.95 ± 7.28 years of age) from Monterrey, Nuevo Leon, Mexico, participated in the study. Appendicular skeletal muscle mass (ASM) measurements were utilized to obtain the SMI, categorizing participants into either the low skeletal muscle index group (LSMIG), indicating a risk of sarcopenia, or the high skeletal muscle index group (HSMIG), denoting non-sarcopenia. Anthropometric measurements, body composition, and physical aptitudes were also assessed. **Results:** The HSMIG exhibited significantly higher values in body weight, perimeters (arm, waist, hip, and calf), triceps skinfold, body mass index (BMI), fat percentage, fat-free mass ($p \leq .001$), and muscle strength ($p = .014$) than the LSMIG. Notably, the LSMIG demonstrated high positive associations with body weight, waist circumference, hip circumference, and BMI ($p \leq .001$). **Conclusions:** Low values in body weight, perimeters, BMI, and muscle strength may indicate the presence of sarcopenia. However, high values in perimeters (waist and hip) and BMI may frequently be associated with sarcopenic obesity.

Keywords: **anthropometry, physical performance, body mass index, skeletal muscle, public health, nutrition**

Introduction

In the context of an aging population, sarcopenia has become a considerable health challenge, directly influencing the quality of life and functional abilities of older adults. Furthermore, its impact on quality of life is profound and multifaceted (Yuan & Larsson, 2023).

Sarcopenia is not merely an aesthetic consequence of aging; it is widely acknowledged as the gradual and pervasive reduction in muscle mass accompanied by a decline in muscle strength and function (Cruz-Jentoft et al., 2019; McPhee et al., 2016). For instance, in 75-year-old women, muscle mass diminishes at a rate of 0.64–0.70% per year; in men, the rate is 0.80–0.98% per year. Additionally, strength declines at a rate of 3–4% per year in men and 2.5–3% per year in women. Notably, the rate of strength loss is 2–5 times faster than that of mass loss (Mitchell et al., 2012). Furthermore, the strength in ankle and knee joints, crucial contributors to locomotion and balance, significantly diminishes with age (Sarvestan et al., 2020), thereby posing a higher risk of disability and death compared to muscle mass decline.

The complexity of sarcopenia arises from various factors, encompassing genetic, environmental, and lifestyle aspects. Among the extensively studied factors associated with sarcopenia are the loss of strength, body movement, metabolism, body temperature regulation, joint stability, and endocrine functions (Pedersen and Febbraio, 2012). Additionally, factors contributing to the decline in muscle mass and strength have been investigated (Steves et al., 2012), including the impact of physical activity and dietary interventions (Cruz-Jentoft et al., 2010; Vauzour et al., 2017; Yamada et al., 2012). The decline in muscle function and mass affects mobility and increases the risk of falls and fractures, pivotal events in geriatric health (Yeung et al., 2019). Furthermore, sarcopenia is implicated in an increased risk of various health conditions, including cancer, cardiovascular disease, diabetes, mitochondrial dysfunction, neurodegenerative diseases, oxidative stress, and underweight, such as malnutrition (Bianchi & Volpato 2016; Cruz-Jentoft et al., 2017; Deutz et al., 2014). This, in turn, leads to increased susceptibility to morbidity, mortality, and dependence (Cawthon et al., 2017; Manrique-Espinoza et al., 2017). Consequently, the age-related decline in muscle mass is intricately linked with impaired function (Goodpaster et al., 2006; McLeod et al., 2016).

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The accurate detection and measurement of sarcopenia are imperative for implementing effective interventions. Various methods are employed for this purpose, from advanced technologies to direct functional assessments. Bone densitometry, computed tomography, and magnetic resonance imaging provide detailed muscle mass and composition information. Electrical bioimpedance (BIA) assesses the body's electrical resistance, providing estimates of body composition. Direct muscle strength tests and blood markers, such as creatinine and albumin, contribute to a more comprehensive assessment. Additionally, physical fitness tests complement muscle mass measurements for sarcopenia detection (Cruz-Jentoft et al., 2010; Mijnarends et al., 2012). Some studies associate the values of these tests with body composition and muscle parameters (Delmonico et al., 2007; Visser et al., 2002). The commonly used tests are gait speed, standing and balance (Guralnik et al., 1995), and the 6-minute test (Ettinger et al., 1997). Combining these methods and tests provides a comprehensive perspective on sarcopenia, facilitating personalized and precise interventions.

Estimating appendicular muscle mass values with BIA makes the determination of the skeletal muscle index (SMI) possible. This index is increasingly recognized as a reference marker for global health, including the prediction of sarcopenia (Cruz-Jentoft et al., 2010). This index transcends the traditional isolated assessments of muscle mass or bone density, acknowledging the interdependence between these two critical systems.

Sarcopenia and the musculoskeletal index underscore the importance of evaluating the quantity and quality of muscle and bone tissues. Consequently, in this study, we outlined the following objectives: 1) ascertain and employ the relative SMI as a predictor of sarcopenia and non-sarcopenia, and 2) explore the correlation between the SMI and anthropometric, body composition, and fitness measurements. This approach aims to enable a more accurate assessment of musculoskeletal health and facilitate the implementation of more effective interventions.

Materials & methods

Research design and participants

We conducted a descriptive, cross-sectional study involving 276 healthy elderly women (mean age 71.9 ± 7.3 years). The participants were affiliated with a social assistance institution in Monterrey, Nuevo León (Mexico), and its metropolitan area. The sample size was determined based on the total number of older adults (9174) registered in the list of 19 clubhouses belonging to two centers in Monterrey and seven centers in the Metropolitan area. Using the nQuery Advisor package version 4.0 (nQuery by Dotmatics, Boston, MA, United States), the calculated sample size was determined to be 376 older adults, of which 276 women voluntarily chose to participate in this study.

Procedures

The first step involved explaining the study protocol and its criteria and obtaining informed consent through signed consent letters from participants agreeing to undergo evaluations. Subsequently, a comprehensive medical survey (anamnesis) was administered, encompassing personal data, pathological history, medication consumption, musculoskeletal history, and lifestyle. A multidisciplinary team comprising nurses, doctors, nutritionists, anthropometrists, and physical trainers was responsible for evaluations, including body measurements and physical fitness tests. These assessments took place in the Human Performance Laboratory, maintaining an average temperature of 21°C and an average relative humidity of 54%. To ensure thoroughness, each participant required a single day to complete all the tests. The study adhered to ethical guidelines outlined in the Declaration of Helsinki and obtained approval from the Research Bioethics Committee of the Center for Research and Development in Health Sciences at the Autonomous University of Nuevo Leon.

Anthropometric measurements

Nutritionists and personnel certified by the International Society for Advances in Kineanthropometry (ISAK) conducted anthropometric measurements following established procedures (Esparza-Ros et al., 2019). Participants were scheduled for assessments in the morning, after a fasting period not exceeding 4 hours, and were appropriately attired. Basic weight measurements were obtained using the Tanita BC-418 scale (0–200 kg ± 0.01 kg), while height was measured with the Seca 213 stadiometer (20–205 cm ± 5 mm). Perimeters, including those of the relaxed arm, waist, hip, and calf, were measured using a metallic tape measure (0–200 cm, Lufkin). The triceps fold was measured with the Harpenden plicometer (0–80 ± 0.2 mm; Harpenden Skinfold Caliper, John Bull British Indicators®, England).

Body composition

After recording weight and height, the body mass index (BMI) was calculated using the formula established by the World Health Organization (body weight in kg/height in m^2) (World Health Organization, 2022). Body composition assessments were conducted using the Tanita scale (BC-418), employing the tetrapolar method to derive fat, fat-free, and muscle mass for the entire body and specific regions (arms, legs, and trunk). Participants were instructed to wear minimal clothing, be barefoot, maintain a consistent level of hydration without recent dehydration or fluid retention, and have emptied their bladder before the assessments.

Skeletal muscle index (SMI)

The Tanita scale (BC-418) was utilized to measure muscle mass, focusing on the appendicular skeletal muscle mass (ASM) of the four limbs (right and left arm, and right and left leg). Subsequently, the ASM values were normalized using the SMI formula, expressed as SMI = ASM in kg / height in m^2. Once the SMI was determined, the study population was categorized into two groups based on percentiles of the SMI. Values falling below the 15th percentile were designated as the low skeletal muscle index group (LSMIG), indicating a risk of sarcopenia. In contrast, values above the 15th percentile were classified as the high skeletal muscle index group (HSMIG), denoting non-sarcopenia.

Manual grip strength test

Grip strength was assessed using the GRIP-D (Grip Strength Dynamometer T.K.K.5401, Texas Scientific Instruments, Niigata, Japan), a digital hand-held adaptive grip dynamometer with an accuracy of 0.5 kg, designed to measure the isometric strength of the upper limb. The test adhered to the recommended protocol (Cruz-Jentoft et al., 2010) and was conducted for both extremities. Three attempts were made for each arm (right and left), and the best result from these attempts was chosen to interpret muscle strength. According to the criteria established by Cruz-Jentoft et al. (2010), values below 20 kg in women indicated low muscle strength, while values above 20 kg were classified as high muscle strength.

Chair stand test

Participants were seated in a chair with feet flat on the floor and arms crossed on the chest to assess lower limb strength. The test involved standing up and sitting down on the chair five times, performed as rapidly as possible, with the total time taken recorded for analysis.

Gait speed test

Agility and dynamic balance were assessed using the gait speed test, administered by a nurse following the established protocol (Guralnik et al., 1994). Participants, wearing snug-fitting shoes without heels, were instructed to walk to the other side at a comfortable pace. During the test, the participant covered a distance of 4 m at their usual walking speed. The stopwatch was initiated as the subject crossed the starting line and stopped when they crossed the finish line, with the nurse providing continuous support. The test was repeated twice, and the shortest time was recorded.

Statistical analysis

The data were analyzed using the SPSS statistical package (Version 25), with the Shapiro–Wilk test employed to assess the normality of data distribution. Descriptive statistics, including mean and standard deviation, were calculated for body measurement (anthropometric measurements and body composition) and physical fitness (physical tests) variables. A Student's t-test was utilized as an independent samples test to compare body measurement and physical aptitude test variables between the LSMIG and HSMIG of elderly women. Additionally, the Pearson correlation test was applied to examine the association between SMI variables and physical aptitude test variables in relation to body measurements. Throughout all analyses, the significance level was set at $p < .05$.

Results

The results detailing physical characteristics, body composition, and physical fitness for individuals classified with sarcopenia and non-sarcopenia are presented in Table 1. The LSMIG or sarcopenia group (n = 41) was defined for participants with values below the 15th percentile (<6.55 kg/m^2) of the SMI, while the HSMIG or non-sarcopenia group (n = 235) comprised participants with values above the 15th percentile (>6.55 kg/m^2) of SMI. Participants with sarcopenia exhibited significantly lower ($p \leq .001$) anthropometric and body composition values compared to non-sarcopenic participants. No significant differences in height were observed between the two groups. In terms of physical fitness, LSMIG participants demonstrated lower values in the strength test ($p = .014$) than HSMIG participants ($p = .014$).

Table 1

Comparison of anthropometric measurements, body composition, and physical aptitude tests between the LSMIG and HSMIG

	Sarcopenia (LSMIG) (n = 41)	Non-sarcopenia (HSMIG) (n = 235)	*p*
Anthropometric measurements			
Age (years)	74.85 ± 7.47	71.44 ± 7.15	.005
Body weight (kg)	53.98 ± 7.14	69.80 ±11.96	≤.001
Height (cm)	151.14 ± 6.39	150.15 ± 5.79	.323
Arm circumference (cm)	25.51 ± 3.18	30.42 ± 4.73	≤.001
Waist circumference (cm)	84.84 ± 7.97	97.09 ± 10.12	≤.001
Hip circumference (cm)	95.69 ± 6.24	107.43 ± 10.12	≤.001
Calf circumference (cm)	31.08 ± 4.21	34.40 ± 3.80	≤.001
Triceps fold (mm)	19.93 ± 4.78	27.61 ± 9.01	≤.001
Body composition			
BMI (kg/m^2)	23.57 ± 2.27	30.88 ± 4.51	≤.001
Percent fat	33.57 ± 5.99	39.69 ± 5.72	≤.001
Fat mass (kg)	18.40 ± 5.16	28.25 ± 8.54	≤.001

Fat-free mass (kg)	35.45 ± 3.00	41.43 ± 5.73	≤.001
SMI (kg/m^2)	6.17 ± 0.30	7.62 ± 0.74	≤.001
Physical aptitudes			
Grip strength (kg)	16.26 ± 4.24	18.58 ± 5.60	.014
Lower limb strength (s)	14.29 ± 4.51	15.12 ± 5.03	.354
Agility and balance (s)	4.71 ± 2.04	4.52 ± 1.96	.572

Note: LSMIG: low skeletal muscle index group; HSMIG: high skeletal muscle index group; n: number; kg: kilogram; cm: centimeter; BMI: body mass index; kg/m²: kilogram divided by meter squared; mm: millimeter; SMI: skeletal muscle index; s: seconds; *p:* significance level

The correlation of SMI with calf circumference, triceps crease, and fat percentage revealed low associations (p ≤ .001), whereas moderate associations were observed with arm circumference (p ≤ .001) (Table 2). Additionally, SMI exhibited strong positive associations with body weight, waist circumference, hip circumference, and BMI (Figure 1) (p ≤ .001). In the physical fitness tests, weak correlations were identified between manual grip strength and body weight (p ≤ .001), arm (p ≤ .05), waist (p ≤ 0.01), hip (p ≤ 0.01), calf (p ≤ .001), BMI (p ≤ .01), and SMI (p ≤ .01). Meanwhile, the lower limb strength test and gait speed test demonstrated weak associations with age (p ≤ .001) (Table 2).

Table 2

Pearson correlation analysis of the SMI and physical skills in relation to anthropometric measurements and body composition

	SMI	Grip strength	Strength limb lower	Agility and balance
Anthropometric measurements				
Age (years)	−0.235***	−0.318***	0.235***	0.397***
Body weight (kg)	0.745***	0.336***	0.047	−0.064
Arm circumference (cm)	0.568***	0.126*	0.012	−0.015
Waist circumference (cm)	0.632***	0.188**	0.109	−0.015
Hip circumference (cm)	0.666***	0.199**	0.099	0.037
Calf circumference (cm)	0.459***	0.278***	−0.026	0.001
Triceps skinfold (mm)	0.434***	0.064	−0.061	−0.147*
Body composition				
BMI (kg/m^2)	0.836***	0.191**	0.069	0.015
SMI (kg/m^2)	1	0.202**	0.099	0.073
Percent fat	0.438***	0.074	0.083	−0.042

Note: BMI: body mass index; SMI: skeletal muscle index; *p*: significance level; * *p* ≤ .05; ** *p* ≤ .01. *** *p* ≤ .001

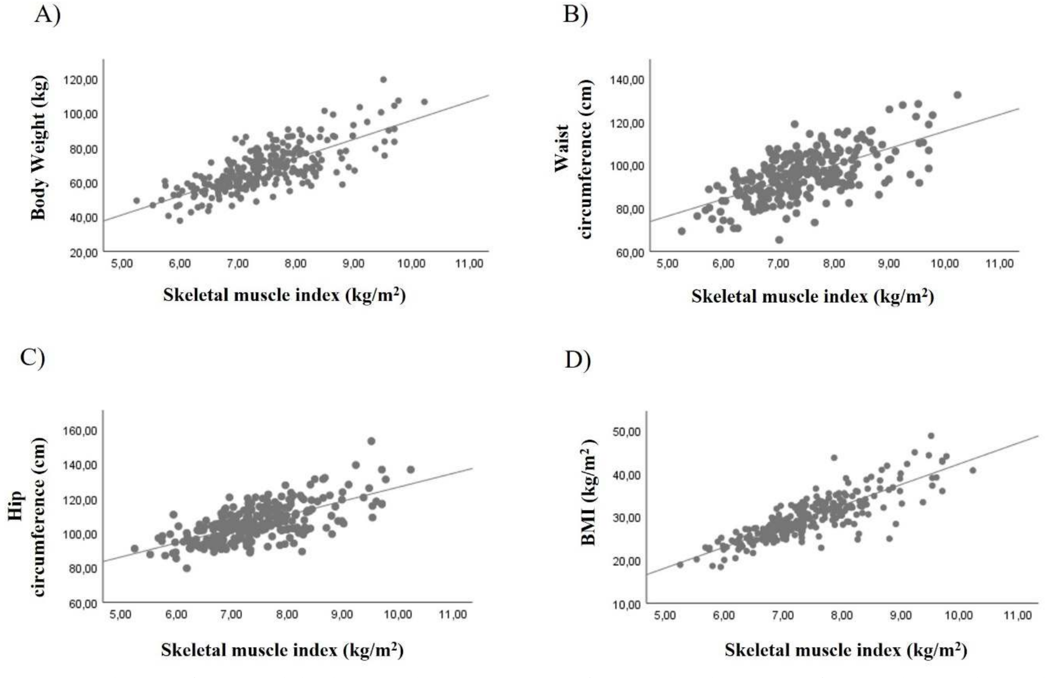

Figure 1 *Correlation of SMI with body mass (A), waist circumference (B), hip circumference (C), and BMI (D)*

Discussion

This study determined the SMI, yielding a mean value of 7.40 kg/m^2. These findings align closely with other studies reporting SMI values ranging from 7.04 to 7.35 kg/m^2 (Chien et al., 2008; Tanimoto et al., 2013). However, studies utilizing dual-energy x-ray absorptiometry as a measurement method obtained values ranging from 5.5 to 6 kg/m^2 (Delmonico et al., 2007; Rolland et al., 2003). Our study employed electrical bioimpedance as a reference method to determine SMI.

The SMI values were utilized in our study to distribute participants into percentiles, categorizing them as either having sarcopenia or not. A percentile <15 (<6.55 kg/m^2) was established as an LSMIG, indicating a risk of sarcopenia, while a percentile >15 (>6.55 kg/m2) was designated as an HSMIG, denoting non-sarcopenia. Other studies employing similar procedures identified sarcopenia risk values for SMI of <5.23 to 5.46 kg/m^2 and non-sarcopenia risk for SMI of >6.02 to 6.90 kg/m^2 (Ishii et al., 2014; Tanimoto et al., 2013; Yamada et al., 2012).

Studies utilizing different methods to categorize samples into sarcopenia and non-sarcopenia risk, based on the percentage of SMI, lean mass index, or appendicular lean mass index, have demonstrated results consistent with our study (Janssen et al., 2002; McIntosh et al., 2013).

The anthropometric measurement results revealed that the HSMIG obtained significantly higher perimeter values than the LSMIG ($p \leq .001$). This finding mirrors observations in the study by Ishii et al. (2014), where the non-sarcopenia group exhibited higher values than the sarcopenia group, albeit below the perimeter values reported in our study. Ishii et al. (2014) describe differences in centimeters, such as calf circumference >23 cm, chest circumference >23 cm, etc. In contrast, the studies by McIntosh et al. (2013) and Rolland et al. (2003), conducted with a population over 70 years of age, reported perimeter values very similar to our data. While calf circumference is linked to age and physical fitness, indicating lower strength with increasing age and consequently lower calf circumference, as demonstrated in the study by Lauretani et al. (2003), both groups in our study surpassed the recommended calf cut-off (>31 cm) set by the European Working Group on Sarcopenia in Older People (EWGSOP) (Cruz-Jentoft et al., 2019). Falling below this threshold may indicate decreased muscle mass. This suggests that lower muscle mass in adults may lead to reduced calf circumference, potentially indicating malnutrition in this age group (Vellas et al., 2006).

In terms of BMI, the LSMIG fell within the normal weight range (23.57 kg/m^2), while the HSMIG was classified as class I obese (30.88 kg/m^2). Similar BMI values within the normal weight range (21–24.4 kg/m^2) are observed in other studies involving older adults (Ishii et al., 2014; Tanimoto et al., 2012; Tanimoto et al., 2013; Yamada et al., 2012). Conversely, some studies indicate overweight and obese BMI values (25.3–33.6 kg/m^2) (Janssen et al., 2002; McIntosh et al., 2013). Furthermore, the studies by Yamada et al. (2012) and Tanimoto et al. (2012) present an older age with a lower BMI than other studies. In conclusion, these findings suggest that during adulthood, body weight is typically lost, often attributed to muscle mass loss, as observed in our study and the study by Ishii et al. (2014), where the sarcopenia risk group, with a younger age than the non-sarcopenia group, exhibited a lower BMI ($p \leq .001$).

Regarding fat percentage, HSMIG demonstrated a higher body fat percentage (39.69%) than LSMIG (33.57%). Both results indicate elevated values associated with high health risk (Lee et al., 2018). Fat percentage often changes and varies at these ages (Chien et al., 2008; Delmonico et al., 2007; McIntosh et al., 2013). Some studies involving menopausal women aged 50–60 years report elevated fat percentages (33–38%), often attributed to a decline in sex hormones such as estrogens (Maddalozzo et al., 2007; von Stengel et al., 2007).

The physical fitness assessment results revealed values of 18.58 kg in the manual grip strength test for the HSMIG and 16.26 kg for the LSMIG ($p = .014$). These findings closely align with the study by Ishii et al. (2014), where the non-sarcopenia group exhibited greater strength than the sarcopenia group. Other studies (Chen et al., 2011; Tanimoto et al., 2013; Yamada et al., 2012) reported strength values (21 to 26 kg) very similar to those observed in the HSMIG in our study. However, both groups in our study (LSMIG and HSMIG) fall below the sarcopenia risk cutoff point (<20 kg), as defined by the EWGSOP (Cruz-Jentoft et al., 2019).

In the sit-to-stand test, assessing lower body strength, the LSMIG exhibited a shorter duration (14.29 s) compared to the HSMIG (15.12 s) in completing five repetitions of getting up and sitting down from the chair ($p = .354$). Similarly, Janssen et al. (2002) observed that their sarcopenia-prone group, with overweight and obesity BMI, took longer than the non-sarcopenia group with normal weight BMI. However, when comparing the test duration with other studies, it is evident that our subjects took longer in this test (Janssen et al., 2002; Yamada et al., 2012). This discrepancy may be attributed to factors such as body weight, BMI, fat percentage, muscle mass, or physical activity levels among adults. In our study, the HSMIG had more than 15 kg of body weight than the LSMIG, potentially influencing the results. In assessing agility and dynamic balance (gait speed test), the HSMIG demonstrated a shorter time over the 4-m test course than the LSMIG. When measuring speed per meter, HSMIG achieved a time of 1.13 m/s, while LSMIG achieved 1.17 m/s. Some studies report similar velocities of 1.18 (Ishii et al., 2014; McIntosh et al., 2013; Tanimoto et al., 2012). In studies where the test covered 15 m, velocities per meter ranged from 0.83 to 0.88 m/s (Yamada et al., 2012).

Regarding the correlations between physical test variables and SMI with body composition and anthropometric measurements, we observed high positive associations of SMI with body weight, waist circumference, hip circumference, and BMI ($p = .000$). This suggests that anthropometric measures could serve as indicators to predict sarcopenia. Supporting this hypothesis, a study noted correlations of SMI with BMI and leg circumference, indicating their potential as predictors of muscle mass in older adults (Nagasaki et al., 1996). Additionally, we found moderate positive correlations of SMI with arm and calf perimeter (p = .000), implying that larger limb perimeters are associated with higher muscle quantity. The study by Ishii et al. (2014) reported an association between SMI and thigh and calf perimeters, reinforcing the idea that larger perimeters can be positive predictors for avoiding sarcopenia in adults.

Strengths and limitations

One of the primary limitations of the study was the absence of an assessment of the nutritional status of the elderly women. This assessment would have offered insights into their caloric intake behavior, potentially influencing their body composition. Another limitation was the exclusion of additional physical tests that could have provided a more comprehensive profile of their physical fitness level, offering an additional indicator to gauge the impact of muscle mass decline. However, the study's strength lies in evaluating certain anthropometric measurements, such as body weight, BMI, and specific perimeters, which are relatively easy for even older adults to obtain. This contributes to establishing a straightforward and practical indicator for identifying sarcopenia. Additionally, it can empower individuals in this age group by promoting a certain level of independence in monitoring their health status.

Conclusions

Older women exhibiting a low SMI are predisposed to sarcopenia. Reduced anthropometric measurements, including body weight, arm circumference, calf, waist, hip, and body composition metrics such as BMI, fat percentage, and fat-free mass, may indicate the presence of sarcopenia. However, elevated values in parameters like waist and hip perimeters, BMI, and fat percentage are often associated with sarcopenic obesity. Conversely, women with a higher musculoskeletal index display increased strength, correlating with higher anthropometric values such as body weight and perimeters such as calf. These findings underscore the utility of anthropometry and fitness testing tools for evaluating and implementing strategies to mitigate or prevent sarcopenia.

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