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Skeletal Muscle and Physical Activity in Portuguese Community-Dwelling Older Adults

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The aims of this study were to describe age- and sex-related differences in total body skeletal muscle (TB-SM) mass and to determine the variance explained by physical activity (PA). This cross-sectional study included 401 males and 402 females, aged 60–79 years. TB-SM was determined by dual-energy x-ray absorptiometry (DXA) and PA by Baecke questionnaire. Statistical analysis included *t* test, ANOVAs, Pearson correlations, and multiple regression analysis. TB-SM mass was higher in the youngest age group when compared with the oldest in males and females. Males had greater TB-SM values than females. PA made a significant and positive contribution to the variation in TB-SM, $\beta = 0.071$; $p = .016$. Sex, height, fat mass, and PA explained 77% of the variance in TB-SM. The oldest cohorts and females had lower TB-SM than the younger cohorts and males. This study suggests that PA exerts a significant role in the explanation of TB-SM.

Keywords: lean soft tissue, lifestyle, sarcopenia

Sarcopenia, or the gradual loss of skeletal muscle mass and strength that occurs with advancing age, is associated with increased mortality, even after adjusting for major clinical variables (Visser & Schaap, 2011). In addition, it is accompanied by functional decline and disability (Aagaard, Suetta, Caserotti, Magnusson, & Kjaer, 2010; Janssen, Heymsfield, & Ross, 2002; Roubenoff & Castaneda, 2001; Roubenoff, 2003). With increasing age and starting from about 40–45 years old and onward, lean soft tissue mass (LSTM), as well as skeletal muscle mass, progressively decline, but longitudinal data over extended periods of time are lacking (Baumgartner, 2005; Janssen, Heymsfield, Wang, & Ross, 2000). The gradual decline in LSTM or skeletal muscle mass leads ultimately to sarcopenia, often defined as LSTM lower than 2 SD below the average of young (25–30 years), healthy adults (Baumgartner et al., 1998; Fielding et al., 2011; Janssen et al., 2002; Mazess, Hanson, & Barden, 2000).

The prevalence of sarcopenia below the age of 70 is about 10–20% in White and Hispanic men and women of New Mexico, USA, but, in persons above 80 years, the prevalence is > 50% (Baumgartner et al., 1998). The loss of skeletal muscle mass is associated with a loss in muscular strength, power, and functional ability (Akima et al., 2001; Frändin & Grimby, 1994; Häkkinen et al., 1998; Izquierdo et al., 1999; Visser et al., 2002). Parallel to the age-related decline in skeletal muscle mass and function, physical activity (PA) volume and intensity also decline with age (American College of Sports Medicine [ACSM] et al., 2009; Kruger, Yore, & Kohl, 2007; Speakman & Westerterp, 2010). Whether this increased prevalence of sarcopenia is a cause or a consequence of this reduction in physical activity with aging remains to be determined.

Since the 1980s, several randomized controlled trials have provided ample evidence that high-intensity resistance training improves strength, power, functional performance, and muscle cross-sectional area and muscle mass, even in older adults (Häkkinen et al., 2002; Porter, 2001; Roth, Ferrell, & Hurley, 2000; Steib, Schoene, & Pfeifer, 2010; Toth, Beckett, & Poehlman, 1999; Whiteford et al., 2010). Resistance training (2–3 days/week for the major muscle groups) is considered an important intervention in combating the decline in muscle strength, power, performance function, and sarcopenia, and is recommended as part of a healthy and physically active lifestyle for older adults (ACSM et al., 2009; Lynch, 2004; Nelson et al., 2007; Roubenoff, 2003). However, only 10–15% of older adults perform muscle-strengthening exercises at least twice a week (Nelson et al., 2007; Winett, Williams, & Davy, 2009). The most popular physical activities in older nonagrarian adults are walking, gardening, golf, and low-impact aerobic activities (ACSM et al., 2009), which provide uncertain preservation of skeletal muscle and functional strength.

There is a paucity of data concerning the impact of PA on the age-related decline in skeletal muscle or LSTM in older adults. Recently, it was demonstrated that older adults who were habitual walkers and those who walked at higher speeds had muscle mass above the sarcopenia threshold or had higher lean body mass (Fiser et al., 2010; Park, Park, Shephard, & Aoyagi, 2010). Step counts were also associated with increased leg strength and muscle quality in older women, but, in men and women no associations were found with lean leg mass (Scott, Blizzard, Fell, & Jones, 2009). Nevertheless, it is still uncertain whether and which types of PA provide benefit to muscle preservation in older populations. In this theoretical framework, the current study aims (1) to describe age- and sex-associated differences in total body skeletal muscle (TB-SM) mass and appendicular lean soft tissue (ALST) mass, and (2) to determine the variance in TB-SM and ALST explained by potential predictors, namely PA, in Portuguese community-dwelling older adults.

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Design and Methods

Study Design and Participants

This cross-sectional study included 803 subjects (401 males and 402 females) distributed similarly over four age cohorts (60–64, 65–69, 70–74, and 75–79 years old). In total, the sample comprises 2.1% of the older adults from the Autonomous Region of Madeira (ARM), Portugal. A proportional geographical representation was determined by stratified sampling, based on Census 2001 data from Statistics Portugal (Statistics Portugal, 2002), with the number of subjects per age cohort and sex serving as stratification factors. The sample includes older men and women from the 11 districts (municipalities) of Madeira and Porto Santo Islands. Participants were volunteers recruited via advertisements, who visited the laboratory of Human Physical Growth and Motor Development of the University of Madeira.

The inclusion criteria were: (1) to reside in the community in ARM; (2) age between 60 and 79 years old; and (3) to be able to walk independently. As exclusion criteria, we considered the following situations: (1) any medical contraindications to submaximum exercise according to the guidelines of the ACSM (2006); (2) having metal prostheses in the femur or lumbar spine; and (3) inability to understand and follow the assessment protocol of the study.

A priori power analysis was done using GPower 3.1 (Erdfelder, Faul, & Buchner, 1996). Sample size estimates for correlations and regression analysis, setting Cohen's effect size at 0.25, $\alpha = .05$, and 80% power comprised 100 and 269 older adults.

The study was approved by the University of Madeira, the Regional Secretary of Education and Culture, and the Regional Secretary of Social Affairs. Informed consent was provided by all participants before any assessment. Written and verbal information about the study was given to all volunteers. All data collection and management procedures took into account the participants' rights to privacy and confidentiality.

Anthropometry, Lean Soft Tissue Mass, and Gait Speed

Body mass (BM) was measured with a balance scale accurate to 0.1 kg (Seca alpha digital scales model 770, Germany) and standing height (cm) with a Holtain stadiometer (Holtain Ltd., Crymych, United Kingdom) accurate to 0.1 cm. Participants wore light, indoor clothing without shoes during the measurements. TB-LSTM and ALST (considered equivalent to the sum of lean soft tissue in both the right and left arms and legs) (Kim, Heymsfield, Baumgartner, & Gallagher, 2002; Baumgartner, 2005) were measured by dual energy x-ray absorptiometry (DXA; Lunar Prodigy Primo, with technologic fan beam—GE Healthcare, Encore 2007 software version 11.40.004). In addition, the scans yielded information on bone mineral density (BMD, g/cm^2) of the total body, total body fat mass (TBFM), and fat mass of the arms (AFM) and legs (LFM). After removing all objects suspected or known to contain metal, participants were positioned by the technician according to the manufacturer's recommended protocol. Subjects were in a supine position. Scans were standardized daily against a calibration phantom; the precision error expressed as the coefficient of variation was 0.31%. Scans were taken alternately by four different technicians over the course of the data collection. A detailed description of the procedures and reliability of DXA measurements can be found elsewhere (Gouveia et al., 2014).

As previously described by Kim et al. (2002), TB-SM mass was calculated as $(1.13 \times \text{ALST}) - (0.02 \times \text{age}) + (0.61 \times \text{sex}) + 0.97$; where sex (0 = female; 1 = male). The definition of the International Working Group on Sarcopenia was applied for this research (Fielding et al., 2011). This definition of sarcopenia is consistent with a gait speed of less than 1 m/s and an objectively measured low muscle mass (ALST relative to ht^2 that is ≤ 7.23 kg/m^2 in men ≤ 5.67 kg/m^2 in women).

In our study, the 50-foot walk test was used to assess gait speed (Rose, 2003). Participants were required to walk a total distance of 70 feet, at a preferred speed, and the distance between 10 and 60 feet was timed for the purpose of calculating gait speed (m/s).

Physical Activity Measures and Nutritional Habits

Total PA was assessed during face-to-face interviews using the Baecke questionnaire, developed in the Netherlands (Baecke, Burema, & Frijters, 1982). This questionnaire includes a total of 16 questions classified into three specific domains: PA at work/household activities (HS), sport, and leisure time, with the latter excluding sports. Numerical coding for most response categories varied from 1 to 5 (Likert scale), ranging from never to always or very often. Questions 1 and 9 pertain to main occupation and types of sport played, respectively, and required a written response. PA indices were calculated according to specific formulae for work (questions 1–8), sport (questions 9–12), and leisure time (questions 13–16).

If the subjects were not employed or if they were retired, their occupation was coded as homemaker. The work/HS index includes information about sitting, standing, walking, and lifting, and if sweating was elicited during these activities, as well as information about fatigue after work or HS. In addition, each subject was asked how they perceived their activity at work or during HS in relationship to that of others their own age. A sport score (one or two main sports) was also calculated from a combination of the intensity, amount of time per week, and proportion of the year the sport was practiced. The leisure-time activity index was based on the frequency of walking and cycling either for leisure and/or to work or shopping. PA categories were calculated based on the questionnaire's total score. Intraclass correlation coefficients were calculated to determine the test-retest reliability of the questionnaire in a pilot study involving 32 males and 59 females (68.3 ± 7.6 years old). Over an interval of 1 week, correlations were 0.83, 0.85, and 0.85 for the work, sport, and leisure time indices, respectively.

In this study, as an internal validation of the Baecke questionnaire approach, PA was also assessed using the RT3 triaxial accelerometer in a subsample of 173 older adults, consisting of 89 males and 84 females ages 60–79 (Gouveia et al., 2014). The correlation of total score for PA from the Baecke questionnaire with the total "counts" from the RT3 in the total sample was positive, but nonsignificant ($r = .131$; $p > .87$). These results are similar to those reported by Pols, Peeters, Kemper, and Collette (1996) in a sample of 33 women aged 51–71 years, in which the correlation between the Baecke total PA score and the Caltrac was 0.22. However, this study concluded that the Baecke questionnaire seemed to be a useful tool to rank older adults, according to physical activity, in epidemiological studies.

Dietary intake was estimated using a semiquantitative food frequency questionnaire developed by the Epidemiology and Hygiene Service of Porto University (Lopes, 2000). This questionnaire assessed caffeine and alcohol intake (combination of consumption of wine, beer, and liquor drinks). In this manuscript, only alcohol consumption was included as a confounding variable.

Statistical Analysis

Descriptive characteristics of subjects were reported as means and SDs. All data were tested for normality by the Kolmogorov-Smirnov statistic. If required, nonnormal distributed characteristics were appropriately transformed using log10, square root, or inverse transform functions. ANOVAs were calculated to test for mean differences between age groups in absolute lean soft tissue mass (TB-LSTM and ALST mass), TB-SM, and other descriptive variables. Mean differences in lean soft tissue mass measurements between men and women were tested with a *t* test for independent groups.

Sex-specific univariate associations between the lean soft tissue mass measurements, TB-SM, and putative predictors (age, age^2, height, BM, BMI, FM, alcohol consumption, total PA, and sport-related PA) were calculated for all age cohorts combined using Pearson correlations. Standard multiple linear regression (MLR) analysis was then used to identify the contribution of the predictors for TB-SM mass and ALST mass. Betas, namely standardized regression coefficients, were used to assess the independent contributions of each predictor, and the R^2s indicated the percentage of explained variance by the predictors for TB-SM mass and ALST mass. The standard MLR was used, with all predictors entered into the equation simultaneously. The selection of the putative predictors (sex, age, height, FM, and PA) was based on known key important predictors previously identified in the literature, and the strength and significance of the zero-order correlations in the preliminary analysis. Since body dimensions were introduced as putative predictors, the MLR was done only with TB-SM mass and ALST mass as dependent variables. The level of significance was set at $p < .05$. Analysis were performed using SPSS, version 17.0 (SPSS, 2008) and SYSTAT13 (SYSTAT, 2010).

Results

Age- and sex-related differences in lean soft tissue mass and descriptive variables are reported in Table 1. On average, TB-LSTM and TB-SM mass were higher in the youngest age group (60–64 years) when compared with the oldest age group (75–79 years) in males and females. Particularly, TB-SM values decreased significantly across age groups by 9.2% and 9.1% for men and women, respectively. Similar results were seen for height and gait speed in both sexes for BMI, ALST mass, sport PA, and alcohol consumption in men, and body mass and total PA in women. There were no statistically significant differences in fat mass (TBFM, AFM, LFM) among groups across sex-specific age cohorts. In men, total PA was similar in all age groups, whereas sport-related PA (PA sport) was higher and similar in the two youngest age groups (60–64 and 65–69 years), but lower in the two oldest age cohorts compared with the younger cohorts. The opposite was observed in women, where total PA was higher and similar in the two youngest age groups but lower in the two older cohorts, and there were no age-related differences for sport-related PA.

Sex differences for all compartments of absolute lean soft tissue mass for the total age group are summarized in Table 2. For all characteristics, men had higher absolute lean soft tissue mass compared with women of equivalent ages. Sex-specific correlations, calculated over the entire age span, between the absolute lean soft tissue mass measurements, TB-SM, and age or age^2 were statistically significant and negative, confirming an age-associated reduction in lean soft tissue mass and skeletal muscle mass (Table 3). Height, BM, BMI, and FM were significant and positively correlated to absolute lean soft tissue mass and TB-SM mass in both sexes. In women, a statistically significant positive correlation was seen between total PA (including PA sport) and all measurements of lean soft tissue mass and TB-SM mass (r between 0.123 and 0.184), with one exception, TB-LSTM. In men, these correlations were not statistically significant, with exceptions for total PA and arm LSTM. No statistically significant correlations were found for alcohol consumption. Finally, gait speed was significantly correlated to all absolute lean soft tissue mass measurements, except for TB-LSTM, in both men and women, and ALST in women.

The contributions of sex, age, height, FM, and total PA in explaining the variation in TB-SM mass and ALST mass was investigated by standard MLR analyses (Table 4) with both sexes combined. For TB-SM, sex, height, and TB-FM were the most important predictors, followed by total PA and age. Betas were negative for sex and age, indicating that women and older females, in particular, had lower TB-SM mass. Height, FM, and total PA were positively associated with TB-SM. Similar results were seen for ALST; however, height was not a significant predictor. Interestingly, if a person increases 5 units in the PA score, it is expected there will be an increase of 1.5 kg on the TB-SM and 2.0 kg on the ALST. The total explained variance was very high for TB-SM mass ($R^2 = .77$) and ALST mass ($R^2 = .47$).

For comparative reasons, the prevalence of sarcopenia in each of the age categories for men and women were calculated using the procedure suggested by the International Working Group on Sarcopenia (Fielding et al., 2011). The prevalence of sarcopenia was higher in the oldest (6.6%) compared with the youngest age (2.0%) cohort in men, with a similar but less evident difference (2.2% versus 1.9%) in women. For the total sample, prevalence was 2.8% in men and 1.5% in women.

Discussion

The relationships between changes with age in muscle strength and size continues to be a controversial issue. Part of the controversy lies in the methods used to estimate skeletal muscle mass or lean soft tissue mass (Baumgartner, 2005). Magnetic resonance imaging (MRI) estimates of muscle mass indicated relative stability up to 45 years after which accelerated loss of muscle mass was found in both sexes (Janssen et al., 2000). The TB-LSTM and ALST obtained or derived from DXA scans comprises not only skeletal muscle mass (the largest fraction), but also skin, organ, and connective tissue (the smaller fraction). However, Kim et al. (2002) demonstrated that ALST, as measured in the current study, was highly associated with skeletal muscle mass ($r^2 = .96$, SEE = 1.63 kg). The relationship between TB-LSTM and TB-SM was also investigated in Portuguese community-dwelling older adults. We confirm a strong positive correlation between the two variables in males ($r = .86$, $n = 401$, $p < .001$) and females ($r = .85$, $n = 402$, $p < .001$). However, the prediction improved somewhat when age and sex were added as covariates. For comparative reasons, TB-SM mass in our study was estimated according to the prediction equation validated by Kim et al. (2002). If these predictions are valid for our population and applied to our age- and sex-specific ALST values, the average TB-SM in our oldest cohort of men 75–79 years is lower by 2.48 kg than that of those 60–64 years (24.72 kg vs. 27.20 kg, respectively). This difference is less pronounced (0.52 kg) between the two youngest age cohorts (60–64 vs. 65–69 years) compared with the other age categories (about 1.0 kg between successive age groups). In women, the TB-SM is 1.3 kg lower in the oldest, when

Table 1 Age- and Sex-Specific Descriptive Characteristics (Means ± SD)

Variables	Age Groups (Years) 60–64 (1)	65–69 (2)	70–74 (3)	75–79 (4)	p	Contrast
Men	*n* = 103	*n* = 99	*n* = 107	*n* = 92		
Age (years)	62.7 ± 1.5	67.6 ± 1.5	72.6 ± 1.6	77.2 ± 1.4		
Height (cm)	166.9 ± 5.2	165.9 ± 6.2	164.5 ± 6.1	164.6 ± 6.2	.011	1 > 3 e 4
BM (kg)	80.3 ± 12.1	79.7 ± 13.1	79.9 ± 13.3	75.8 ± 13.0	.058	–
BMI (kg/m²)	28.8 ± 3.7	28.9 ± 4.0	29.4 ± 3.9	27.9 ± 4.1	.066	3 > 4
TB-LSTM (kg)	54.3 ± 5.9	53.3 ± 5.8	52.8 ± 5.5	51.2 ± 6.3	.003	1 > 4
TB-FM (kg)	22.5 ± 8.1	23.3 ± 7.9	23.6 ± 8.6	21.5 ± 8.2	.285	–
TB-SM (kg)	27.2 ± 3.9	26.7 ± 3.5	25.7 ± 3.4	24.7 ± 3.5	< .001	1 > 3 e 4; 2 > 4
Legs-LSTM (kg)	17.2 ± 2.5	17.0 ± 2.3	16.5 ± 2.2	16.1 ± 2.3	.003	1 > 4
LFM (kg)	5.5 ± 2.4	5.7 ± 2.3	5.8 ± 2.3	5.5 ± 2.3	.766	–
Arms-LSTM (kg)	6.6 ± 1.1	6.5 ± 0.9	6.1 ± 1.0	5.8 ± 1.0	< .001	1 > 3 e 4; 2 > 4
AFM (kg)	1.9 ± 0.9	2.1 ± 1.0	2.0 ± 0.9	1.8 ± 0.8	.069	–
ALST (kg)	23.8 ± 3.4	23.4 ± 3.1	22.6 ± 3.0	21.8 ± 3.1	.002	1 > 4; 2 > 4
Total PA (3–15)	7.6 ± 1.3	7.3 ± 1.2	7.1 ± 1.4	7.2 ± 1.2	.065	–
PA sport (1–5)	2.2 ± 0.6	2.2 ± 0.6	2.0 ± 0.6	1.9 ± 0.5	.015	1 > 4; 2 > 4
Alcohol (dl/day)	16.7 ± 20.5	13.1 ± 17.3	11.6 ± 18.2	9.2 ± 15.3	.028	1 > 4
Gait speed (m/s)	1.4 ± 0.2	1.3 ± 0.2	1.3 ± 0.3	1.2 ± 0.3	< .001	4 < 1 e 2 e 3
Women	*n* = 102	*n* = 109	*n* = 98	*n* = 93		
Age (years)	62.5 ± 1.3	67.7 ± 1.5	72.4 ± 1.4	77.3 ± 1.5		
Height (cm)	154.2 ± 5.4	153.8 ± 5.5	152.0 ± 5.8	150.1 ± 5.4	< .001	1 > 3 e 4;2 > 4
BM (kg)	72.2 ± 11.7	71.2 ± 12.7	70.6 ± 10.6	67.8 ± 11.5	.063	1 > 4
BMI (kg/m²)	30.3 ± 4.6	30.1 ± 5.1	30.6 ± 4.2	30.0 ± 4.4	.812	–
TB-LSTM (kg)	39.9 ± 4.9	40.0 ± 5.5	39.3 ± 3.9	38.2 ± 4.3	.033	2 > 4
TB-FM (kg)	29.7 ± 7.8	28.7 ± 8.0	28.2 ± 7.3	27.1 ± 7.8	.131	–
TB-SM(kg)	18.7 ± 2.6	18.3 ± 2.8	17.6 ± 2.3	17.0 ± 2.6	< .001	1 > 3 e 4; 2 > 4
Legs- LSTM (kg)	12.6 ± 1.7	12.5 ± 1.9	12.2 ± 1.6	11.8 ± 1.8	.008	1 > 4; 2 > 4
LFM (kg)	9.1 ± 3.0	8.8 ± 2.7	8.5 ± 2.6	8.4 ± 2.8	.243	–
Arms-LSTM (kg)	4.2 ± 0.7	4.1 ± 0.7	3.8 ± 0.6	3.8 ± 0.7	< .001	1 > 3 e 4; 2 > 3 e 4
AFM (kg)	3.2 ± 1.1	3.1 ± 1.1	2.9 ± 0.9	2.9 ± 1.0	.080	–
ALST (kg)	16.8 ± 2.3	16.6 ± 2.5	16.0 ± 2.0	15.6 ± 2.3	.593	–
Total PA (3–15)	7.5 ± 1.3	7.5 ± 1.1	7.3 ± 1.1	6.9 ± 1.2	.002	1 > 4; 2 > 4
PA sport (1–5)	2.2 ± 0.6	2.3 ± 0.6	2.3 ± 0.6	2.1 ± 0.6	.072	–
Alcohol (dl/day)	2.1 ± 3.9	1.5 ± 4.1	1.2 ± 2.7	1.3 ± 2.9	.178	–
Gait speed (m/s)	1.3 ± 0.2	1.3 ± 0.2	1.2 ± 0.3	1.1 ± 0.3	< .001	1 > 3 e 4; 2 > 4; 3 > 4

Abbreviations: BM = body mass; BMI = body mass index; TB-LSTM = total body lean soft tissue mass; TB-FM = total body fat mass; TB-SM = total body skeletal muscle; Legs-LSTM = legs lean soft tissue mass; LFM = legs fat mass; Arms-LSTM = arms lean soft tissue mass; AFM = arms fat mass; ALST = appendicular lean soft tissue; PA = physical activity; 1 > 3 e 4 = 60–64 age group is higher than 70–74 and 75–79 age groups; 3 > 4 = 70–74 age group is higher than 75–79 age group; 1 > 4 = 60–64 age group is higher than 75–79 age group; 2 > 4 = 65–69 age group is higher than 75–79 age group; 2 > 3 e 4 = 65–69 age group is higher than 70–74 and 75–79 age groups; 4 < 1 e 2 e 3 = 75–79 age group is lower than 60–64 and 65–69 and 70–74 age groups.

compared with the youngest age cohort. As for men, the decline is less pronounced (0.38 kg) between the two youngest age cohorts compared with the older age groups (0.56–0.72 kg).

The average ALST in men 70–74 years (22.6 ± 3.0 kg) in our study was closer to the ALST value reported in the New Mexico Elder Health Survey (22.5 ± 2.6 kg) (Baumgartner et al., 1998) in similar-aged males and also to the more recent values reported by Hairi et al. (2010) in men aged 70–74 years (22.8 ± 3.0 kg). Similarly, ALST (21.8 ± 3.1 kg) for the oldest age category of males in our study was not substantially different (22.1 ± 3.0 kg) from that of males 75–79 years in the study developed by Hairi et al. (2010). The ALST values for women 70–74 years were higher (16.0 ± 2.0 kg) for Madeira women when compared with the New Mexico Elder Health Survey (ALST = 14.5 ± 2.2 kg) (Baumgartner et al., 1998). Compared with males, Madeira's older adult women have less TB-LSTM and ALST and TB-SM (Table 2). This sexual

Table 2 Sex Differences in Lean Soft Tissue Mass (Means ± SD)

Variables	Men (1) n = 401	Women (2) n = 402	p	Contrast
TB-LSTM (kg)	52.9 ± 6.0	39.4 ± 4.8	< .001	1 > 2
TB-SM (kg)	26.1 ± 3.7	18.0 ± 2.6	< .001	1 > 2
Arms-LSTM (kg)	6.2 ± 1.0	4.0 ± 0.7	< .001	1 > 2
Legs-LSTM (kg)	16.7 ± 2.4	12.3 ± 1.8	< .001	1 > 2
ALST (kg)	22.9 ± 3.2	16.3 ± 2.3	< .001	1 > 2

Abbreviations: TB-LSTM = total body lean soft tissue mass; TB-SM = total body skeletal muscle; Arms-LSTM = arms lean soft tissue mass; Legs-LSTM = legs lean soft tissue mass; ALST = appendicular lean soft tissue; 1 > 2 men presented higher values than women.

Table 3 Sex-Specific Pearson Correlations Between Absolute Lean Soft Tissue Mass Measurements and Selected Descriptive Characteristics

Variables	TB-LSTM (kg)	Legs-LSTM (kg)	Arms-LSTM (kg)	ALST (kg)	TB-SM (kg)
			Men		
Age (years)	–0.181†	–0.187†	–0.288†	–0.230†	–0.258†
Age^2	–0.183†	–0.188†	–0.289†	–0.231†	–0.260†
Height (cm)	0.635†	0.613†	0.448†	0.592†	0.593†
BM (kg)	0.774†	0.628†	0.517†	0.626†	0.625†
BMI (kg/m^2)	0.587†	0.425†	0.383†	0.434†	0.432†
TB-FM (kg)	0.469†	0.365†	0.232†	0.342†	0.340†
AFM (kg)	0.357†	0.301†	0.249†	0.300†	0.299†
LFM (kg)	0.397†	0.406†	0.211†	0.364†	0.362†
PA sport (1–5 units)	–	–	–	–	–
Total PA (3–15 units)	–	–	0.112‡	–	–
Alcohol (dl/day)	–	–	–	–	–
Gait speed (m/s)	–	0.141†	0.152†	0.152†	0.160†
			Women		
Age (years)	–0.149†	–0.193†	–0.245†	–0.221†	–0.261†
Age^2	–0.151†	–0.194†	–0.245†	–0.222†	–0.262†
Height (cm)	0.511†	0.561†	0.453†	0.565†	0.572†
BM (kg)	0.799†	0.644†	0.600†	0.672†	0.671†
BMI (kg/m^2)	0.623†	0.428†	0.434†	0.457†	0.453†
TB-FM (kg)	0.574†	0.461†	0.461†	0.491†	0.491†
AFM (kg)	0.487†	0.423†	0.607†	0.505†	0.505†
LFM (kg)	0.396†	0.461†	0.389†	0.469†	0.469†
PA sport (1–5 units)	0.114‡	0.180†	0.100‡	0.168†	0.168†
Total PA (3–15 units)	–	0.184†	0.123‡	0.178†	0.183†
Alcohol (dl/day)	–	–	–	–	–
Gait speed (m/s)	–	0.169†	0.125‡	–	0.169†

Abbreviations: TB-LSTM = total body lean soft tissue mass; Legs-LSTM = legs lean soft tissue mass; Arms-LSTM = arms lean soft tissue mass; ALST = appendicular lean soft tissue; TB-SM = total body skeletal muscle; BM = body mass; BMI = body mass index; TB-FM = total body fat mass; AFM = arms fat mass; LFM = legs fat mass; PA = physical activity.

Note. Only correlations that were statistically significant were included. ‡ Correlation is significant at the 0.05 level (two-tailed); † correlation is significant at the 0.01 level (2-tailed).

dimorphism, which is accentuated during the adolescent growth spurt (Malina, 2005), appears to remain over the lifespan.

In the present research, men showed a higher prevalence of sarcopenia (2.8%) than women (1.5%). These prevalence estimates are lower than, yet similar in regard to sex differences, to the ones found by Iannuzzi-Sucich, Prestwood, and Kenny (2002) in older adults aged 64–93 years (26.8% in men and 22.6% in women), when using a different method of estimate of sarcopenia. Also, Castillo et al. (2003), when using bioelectrical impedance for the estimate of SM in older adults aged 55–98 years, found a prevalence of 6.2%

Table 4 Standard MLR Between Total Body Skeletal Muscle (TB-SM) Mass and Appendicular Lean Soft Tissue (ALST) Mass and Putative Predictors

Predictors	Adjusted B ± *SE*	Beta	*p*†	95% CI*	Increase/Decrease[a]
Total Body Skeletal Muscle Mass (R^2_{adj} = .773)					
Sex (0 male; 1 female)	–5.415 ± 0.295	–0.523	< .001	–5.994; –4.836	–[b]
Height (cm)	0.257 ± 0.016	0.431	< .001	0.225; 0.289	2.569[c]
TB-FM (kg)	0.099 ± 0.012	0.162	< .001	0.076; 0.122	0.495[d]
Total PA (3–15 units)	0.297 ± 0.072	0.071	< .001	0.155; 0.439	1.486[e]
Age (years)	–0.063 ± 0.016	–0.068	< .001	–0.095; –0.032	–0.633[f]
Appendicular Lean Soft Tissue Mass (R^2_{adj} = .465)					
Sex (0 male: 1 female)	–1.893 ± 0.106	–0.841	< .001	–2.102; –1.684	–[g]
Height (cm)	–0.009 ± 0.005	–0.067	.107	–0.019; 0.002	–0.336[h]
Appendicular FM (kg)	0.095 ± 0.009	0.329	< .001	0.076; 0.113	3.648[i]
Total PA (3–15 units)	0.114 ± 0.024	0.125	< .001	0.067; 0.161	1.982[j]
Age (years)	–0.015 ± 0.005	–0.074	.006	–0.025; –0.004	–0.162[k]

Abbreviations: MLR = multiple linear regression; TB-FM = total body fat mass; PA = physical activity.

[a] Per additional increase/decrease in predictors for TB-SM and ALST, respectively. [b] 5.4 kg decrease in TB-SM for women in comparison to men. [c] 2.6 kg increase in TB-SM per additional 10 cm in height. [d] 0.5 kg increase in TB-SM per additional 5 kg in total body fat mass. [e] 1.5 kg increase in TB-SM per additional five units total physical activity score. [f] 0.63 kg increase in TB-SM per additional 10 years in age. [g] 1.9 kg decrease in ALST for women in comparison to men. [h] 0.34 kg increase in ALST per additional 10 cm in height. [i] 3.7 kg increase in ALST per additional 5 kg in appendicular fat mass. [j] 2.0 kg increase in ALST per additional five units total physical activity score. [k] 0.16 kg increase in ALST per additional 10 years in age.

† Significant contribution by an independent variable to the total explained variation in the model ($p < .05$).

* 95.0% confidence interval for B-values.

in men and 5.9% in women. On the other hand, Baumgartner et al. (1998), also using different cut-points for sarcopenia, found distinct and higher results in non-Hispanic White older adults aged 61–80 years (20.0% in men and 30.8% in women). Janssen et al. (2000), using bioelectrical impedance estimates of SM and NHANES III reference data to define sarcopenia cut-points, found a prevalence of 7% in men and 10% in women aged 60 and over. In regard to this trend in sarcopenia throughout the lifespan, our results confirm a greater decrease in skeletal muscle in men than in women, which appears to accelerate in older ages (60–79 years). This supports the idea presented by Baumgartner (2005), who described a more rapid decline in the soft tissue components of fat free mass in older men when compared with older women.

Our sample was a very unique community-dwelling older adult population, described by low rates of retirement, high prevalence of gainful employment in farming, and low dependency on social assistance. In Madeira, there are almost as many female farmers (47%) as male farmers (53%), and their average age is 64 years (Statistics Portugal, 2009), while retirement age in the country is 66 years old. In addition, it should be noted that 47.4% of the men and 38.9% of the women reported walking at least 30 min/day. Furthermore, there was a low association between farming and walking ($r_t = 0.157$). The Madeira females may represent a highly selective group whose daily activities mitigated muscle loss, thus accounting for their substantially lower prevalence of sarcopenia compared with previous studies. The smaller disparity in sarcopenia prevalence for males in our study, when compared with previously published rates, likewise may be partially explained by differing physical activity levels or perhaps even by a survival bias in our sample, favoring the healthy, most fit, and best muscled of the older adult Madeira male population. It can be argued that our sample of community-dwelling volunteers was very active for their age. However, the total PA (PA = 7.5 ± 1.3), and sport PA (sport PA = 2.2 ± 0.6) of women 60–64 years old from our study was somewhat lower than the physical activity levels of slightly younger, healthy 57-year-old postmenopausal women reported in the study by Walsh, Hunter, and Livingstone (2006) (total PA = 7.7 ± 2.1 *SD*; sport PA = 2.7± 1.1 *SD*), both obtained with the Baecke questionnaire. For Madeira's men, total PA (total PA ranged between 7.1 and 7.6 ± 1.2–1.4 *SD*) was not surprisingly lower than that of younger, healthy adult Belgians 30–40 years of age (PA = 7.9–8.8 ± 1.4–1.8 *SD*) reported by Philippaerts and Lefevre (1998). In addition, the sport PA (sport PA ranged between 1.9 and 2.2) of Madeira's older adult men was lower than that of adult Belgians (sport PA ranges between 2.8 and 3.0) (Philippaerts & Lefevre, 1998). Apart from the PA levels, the older adults in our sample are small and heavy, and their average BMI is high (Table 1).

Evidence about the association between PA and lean soft tissue among older adults is still equivocal. In our study, we found a statistically significant positive correlation between total PA (including PA sport) and all measurements of lean soft tissue mass, with one exception, TB-LSTM, in older women. In men, total PA was only significantly correlated to the arm LSTM. These observations partly confirm previous findings. Scott et al. (2009) found that pedometer counts were associated with maintenance of leg strength and muscle quality in older women (50–79 years). Furthermore, energetics of walking (gait speed and number of steps/day) were associated with higher lean body mass in Japanese adults aged 65–84 years (Park et al., 2010) and Americans aged in 60–88 years (Fiser et al., 2010). In addition, above 52 years of age, fat free mass, daily energy expenditure, and activity energy expenditure measured by the doubly labeled water technique were negatively associated with age (Speakman & Westerterp, 2010). However, pedometer counts were not associated with leg lean mass in community-dwelling Australians aged 50–79 years (Scott et al. 2009). There is obviously a need to further clarify these associations, since only a minority of older adults participate in strength training programs (Nelson et al., 2007; Winett et al., 2009). Notwithstanding, this type of exercise has been shown to have a positive impact on muscle mass and muscle function in this population (Häkkinen et al., 2002; Porter, 2001; Roth et al., 2000; Steib et al., 2010; Toth et al., 1999; Whiteford et al., 2010).

Associations between measures of PA and lean soft tissue are more consistent when wider age ranges were considered. This could be explained by the simultaneous decline in lean soft tissue and PA over longer periods. In the current study, height declined with age, but AFM, LFM, and TB-FM remained fairly constant between the 60–64 and 75–79 year age groups. In both sexes, the lowest TB-SM and ALST were seen in the oldest age group (75–79 years).

The multivariate analyses indicated that, in males (60–79 years), sex, height, and FM, and, to a lesser extent, total PA and age, contributed to the explained variance in TB-SM and ALST (R^2 = .77–.47). These results suggests that PA exerts a significant role in explanation of TB-SM and ALST mass among Portuguese community-dwelling older adults and that FM is positively associated with higher lean soft tissue mass. These findings suggest that a higher FM might be protecting muscle mass, perhaps by increased loading during weight-supported activities. Overall, it has been recognized that age-related changes in TB-SM may interact in a constant proportional relationship with body fatness. An unbalanced relation between fat and fat-free body mass may lead to sarcopenic obesity, which is characterized by low muscle mass in the presence of high levels of body fatness. In our study, the prevalence of sarcopenic obesity was 0% (60–64 years), 3.4% (65–69 years), 3.9% (70–74 years), and 5.1% (75–79 years). This increase of sarcopenic-obesity with age was also reported by Baumgartner et al. (1998) in the New Mexico Elder Health Survey, however, with a higher prevalence (2% in those 60–69 years to about 10% in those over 80 years).

In conclusion, this study adds important information about the prevalence of sarcopenia in a large sample of community-dwelling older men and women, including a significant cohort of older adults aged 75 and older, in which information in the literature is still limited.

This research shows evidence of a decline in TB-SM and ALST throughout the age cohorts, especially after 75 years, and confirms the persistence of a sexual dimorphism in muscle mass in old age. A significant positive association between PA and TB-SM and ALST was found. An additional increase of five units in the total PA score can lead to an increase of 1.5 kg and 2 kg in TB-SM and ALST, respectively. In addition, PA makes a stronger contribution to the explanation of the variance of TB-SM and ALST masses than age. This is suggestive that the increasing prevalence of sarcopenia with advancing age could be due to the reduction in PA, rather than aging per se. Longitudinal and interventional studies, using further measurements of PA, are needed to confirm this association and provide stronger evidence about the role of PA in the preservation of SM and muscle function among older adults. In addition, while muscle mass and function in later life is determined by the rate of muscle loss in older adulthood, it also reflects the peak attained earlier in life. Further research is needed, integrating a life-course approach to muscle mass and function and influencing behavioral factors, such as diet, to contribute to a better understanding of this topic.

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