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Assessment of Skeletal Muscle Mass in Older People: Comparison Between 2 Anthropometry-Based Methods and Dual-Energy X-ray Absorptiometry

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A B S T R A C T

Objectives: Sarcopenia is a common geriatric syndrome, whose diagnosis implies the assessment of muscle mass. Dual-energy x-ray absorptiometry (DXA) is the reference method for clinical practice, but it is not universally available. We compared DXA with 2 anthropometry-based methods to assess muscle mass in older adults.
Design: Cross-sectional.
Setting: Ambulatory patients.
Participants: 148 (87 female and 61 male) white older adults.
Measurements: Mid-arm muscle circumference (MAMC), whole skeletal muscle mass estimated by the Lee's formula (eTSMM), and relative skeletal muscle index (RSMI).
Results: Men and women did not differ for MAMC and RSMI, whereas eTSMM was higher ($P < .001$) in men. MAMC and eTSMM correlated with RSMI, in the whole sample as in men and women separately ($P < .001$). According to the McNemar test, the frequencies of older men and women with low muscle mass identified by eTSMM did not differ from those detected by RSMI ($P = .066$) at variance with MAMC. Using EWGSOP (European Working Group on Sarcopenia in Older People) criteria for RSMI as standard reference, the receiver operating characteristic (ROC) curves provided redefined cut-offs of reduced muscle mass: 18.6 cm in women and 22.3 cm in men for MAMC, and 17.7 kg in women and 28.3 kg in men for eTSMM. The areas under the ROC curves (AUCs) for MAMC were 0.882 in women (sensitivity 89%, specificity 84%) and 0.826 in men (sensitivity 94%, specificity 67%). The AUCs for eTSMM were 0.8913 in women (sensitivity 95%, specificity 81%) and 0.878 in men (sensitivity 97%, specificity 67%). No significant difference was found between the ROC curves of MAMC and eTSMM in both sexes.
Conclusion: Two simple anthropometric methods, possibly used in every clinical setting, could be valuable screening tools for low muscle mass in older subjects.

Sarcopenia is defined as a low skeletal muscle mass, associated with poor muscle strength and/or physical performance.[1] It is associated with limited mobility,[2] increased risk of fall,[3] decreased quality of life,[4] and higher risk of hospitalization[5] and mortality.[6]

The current diagnostic criteria for sarcopenia[1] consist of low muscle mass, associated with low muscle strength and/or low physical performance. Low muscle mass alone is defined as pre-sarcopenia by EWGSOP (European Working Group on Sarcopenia in Older People) criteria,[1] and it is not sufficient for the diagnosis of sarcopenia because muscle mass and strength do not decrease proportionally with age and muscle mass measurement does not fully capture functionality.

The authors declare no conflicts of interest.

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However, according to current criteria, the estimate of muscle mass is an essential part of the diagnostic workup.

Because of the high prevalence of sarcopenia among older adults, growing attention is paid to simple and cheap methods to estimate muscle mass. Among the imaging technologies, both computed tomography and magnetic resonance imaging (MRI) are currently considered the gold standard in research settings, being capable to distinguish different tissue, and fat infiltration into the muscle. However, both techniques are expensive and not universally available, determine high radiation exposure (eg, computed tomography), and require a long time for total body scan (eg, MRI). These characteristics limit their widespread use in clinical practice, particularly in older people. Dual-energy x-ray absorptiometry (DXA), although unable to assess intramuscular fat infiltration, is a low-radiation, accurate, and reproducible technique,[7] and has become the imaging procedure of choice to assess appendicular muscle mass in clinical research and practice.[1]

However, many clinicians have no access to DXA devices, and as a result, anthropometric measurements are still widely used to assess skeletal muscle.[8] Among such measurements, mid-arm muscle circumference (MAMC) has been widely used to assess muscle mass in large samples of older people.[9] An alternative approach comes from the accurate measurement of total skeletal muscle mass by MRI and the setting up of a predictive equation to estimate muscle mass from anthropometric parameters.[10] Our study was aimed to investigate whether such anthropometric measurements may identify low skeletal muscle mass, and their possible use as diagnostic or screening tools, in older men and women. For this purpose, we compared MAMC and an equation-based estimate of muscle mass with the results of DXA assessment in a sample of older adults.

Methods

We investigated 148 (87 female and 61 male) white older adults (aged ≥65 years) consecutively enrolled in an ongoing study from our group. Subjects reporting rapid weight gain or loss in the last 6 months or with acute illnesses and endocrine, water and electrolyte, or neoplastic disorders were excluded. In particular, we excluded patients with severe heart failure, liver cirrhosis, or renal failure, whose body weight and composition could be affected by fluid retention. A total of 103 (52 female and 51 male) healthy subjects, aged 18 to 54 years (mean ± standard deviation 35.8 ± ±9.5 years), were used as a reference sample only to derive normative data for anthropometric parameters. The study was approved by the local ethics committee, and subjects gave written informed consent. Height was measured by a standard stadiometer and weight by a calibrated bathroom scale. Body mass index was calculated as weight (in kilograms) divided by squared height (in meters).

Anthropometry-Based Parameters

To calculate MAMC, the mid-arm circumference of the dominant arm was measured by a nonstretch plastic tape. Triceps skinfold thickness was measured using a conventional skinfold calliper. MAMC was then calculated by the formula[9]:

$$\text{MAMC (cm)} = \text{mid} - \text{arm circumference(cm)} - (3.14 \times \text{triceps skinfold thickness})$$

The estimated total body skeletal muscle mass (eTSMM) was calculated through the Lee formula, derived from whole-body MRI scans of subjects aged 20 to 81 years[10]:

$$\text{eTSMM(kg)} = 0.244 \times \text{body weight (kg)} + 7.80 \times \text{height (m)} + 6.6 \times \text{sex (female} = 0, \text{male} = 1) - 0.098 \times \text{age (years)} + \text{race (Asian} = -2.0, \text{African Americans} = 1.1, \text{white or Hispanics} = 0) - 3.3$$

DXA Measurements

In older adults only, a whole-body scan was performed using a new-generation DXA device (Lunar iDXA, GE Healthcare, Madison, WI; enCORE 2011 software, v.13.6), as reported,[11] to measure the relative skeletal muscle index (RSMI) (obtained by dividing the nonbone and nonfat mass of the limbs for squared height). Low appendicular muscle mass was defined on the basis of RSMI values lower than 7.26 in men and 5.5 in women, according to the EWGSOP criteria.

Statistical Analysis

Descriptive statistics of quantitative variables are expressed as mean ± standard deviation and qualitative variables (low muscle mass yes/no) as absolute and relative (%) frequencies. After normality testing by the test of Kolmogorov-Smirnov, mean comparisons were made using unpaired *t* test or Mann-Whitney test, as appropriate. Associations between variables were tested by Spearman correlation, and Fisher transform was used to compare correlation coefficients. For MAMC and eTSMM, cut-offs for low muscle mass were calculated using young adults data and were equal to 2 standard deviations below the reference mean for the young. For DXA-obtained RSMI values, the cut-off points fixed by EWGSOP for men and women were used (see above).[1] The frequencies of low muscle mass cases identified through MAMC, eTSMM, and RSMI were compared using the McNemar test. Thereafter, the cut-off thresholds for low skeletal muscle mass estimated by MAMC and eTSMM in older men and women were redefined using the EWGSOP criteria for RSMI as reference standard. The redefined cut-offs for MAMC and eTSMM were obtained from the highest sensitivity + specificity values in the receiver operating characteristic (ROC) curve. The areas under the ROC curve, indicating the probability of discriminating low muscle mass, were compared using the DeLong test. The level of significance was set at $P < .05$.

Results

The descriptive statistics of the main parameters of older people are presented in Table 1. Men and women did not significantly differ for age and weight, whereas body mass index was significantly higher in older women, men being significantly taller. Women also had higher fat mass and lower lean mass than men (data not shown). No

Table 1
Main Parameters of the Investigated Subjects

	Old Subjects (n = 148)	Old Men (n = 61)	Old Women (n = 87)
Age, y	76.0 ± 6.7	76.2 ± 6.6	75.9 ± 6.8
Weight, kg	72.5 ± 18.8	73.4 ± 20.2	71.9 ± 17.9
Height, m	1.60 ± 8.5	1.67 ± 6.5	1.56 ± 6.6*
BMI	28.6 ± 6.5	27.3 ± 6.7	29.6 ± 6.3†
MAMC, cm	20.7 ± 4.3	20.3 ± 4.5	21.1 ± 4.1
eTSMM, kg	22.2 ± 6.3	26.7 ± 5.3	19.0 ± 4.7*
RSMI	6.9 ± 1.5	7.2 ± 1.7	6.8 ± 1.3

BMI, body mass index.
RSMI was measured by DXA only in older subjects.
*$P < .001$ vs age-matched male subjects.
†$P < .05$ vs age-matched male subjects.

significant difference was found between men and women for MAMC and RSMI, whereas eTSMM was significantly higher ($P < .001$) in men.

Contrary to eTSMM (which included age in the generating formula), MAMC did not correlate with age, whereas RSMI correlated with age only in older men ($r = -0.288$, $P = .025$). MAMC correlated with RSMI, both in the whole sample ($r = 0.528$) and in men and women separately ($r = 0.582$, and $r = 0.520$) ($P < .001$ for all). A significant correlation was also found between eTSMM and RSMI, in the whole sample ($r = 0.659$, $P < .001$) as in older men and women separately ($r = 0.790$, and $r = 0.820$, respectively) ($P < .001$ for all). All the investigated estimates of skeletal muscle significantly correlated with both body weight and lean body mass.

The threshold values for low muscle mass identified by MAMC according to the distribution in the sample of healthy young adults were below 10.3 cm in women and 11.0 cm in men. The corresponding thresholds for eTSMM were below 16.3 kg in women and 27.5 kg in men. The frequencies of older subjects with low skeletal muscle mass detected according to these cut-offs are reported in Table 2. No subject could be defined as pre-sarcopenic by MAMC, whereas EWGSOP-defined low appendicular muscle mass was identified by eTSMM with a sensitivity of 84% in women and 88% in men, the respective specificities being 88% and 67%. The McNemar test showed that the frequencies of older male and female subjects with low skeletal muscle mass according to eTSMM did not significantly differ from those detected by RSMI, but the P value ($P = =.066$) was close to the significance level, at variance with those identified by MAMC.

By using the EWGSOP criteria for RSMI as standard reference in the ROC curve analyses, we obtained different cut-offs to define low muscle mass in older subjects. The threshold values for MAMC redefined through the ROC curves were below 18.6 cm in women and 22.3 cm in men, whereas those for eTSMM were below 17.7 kg in women and 28.3 kg in men. Table 3 reports the characteristics of subjects grouped for low muscle mass, according to these redefined cut-off values of MAMC and eTSMM. The areas under the ROC curve for MAMC were 0.882 in women (with a sensitivity of 89% and a specificity of 84%) and 0.826 in men (with a sensitivity of 94% and a specificity of 67%). The ROC curves of male and female subjects did not significantly differ from each other. The areas under the ROC curve for eTSMM were 0.891 in women (with a sensitivity of 95% and a specificity of 81%), and 0.878 in men (with a sensitivity of 97% and a specificity of 67%). Also, for eTSMM, the ROC curves of the 2 sexes did not differ from each other. No significant difference was found between the ROC curves of MAMC and eTSMM in both sexes.

Table 3
Main Parameters of the Investigated Subjects Grouped According to the Redefined Cut-offs of MAMC and eTSMM for Low Muscle Mass, Obtained From DXA-Derived EWGSOP Criteria

Parameters	MAMC		*P*
	<18.6 cm in Women, <22.3 cm in Men	≥18.6 cm in Women, ≥22.3 cm in Men	
Age, y	76.2 ± 6.8	75.9 ± 6.6	.786
Male/female, n	28/41	59/20	<.001
Weight, kg	61.2 ± 14.0	82.4 ± 16.8	<.001
Height, m	161.4 ± 9.3	159.2 ± 7.6	.124
BMI	23.4 ± 4.8	32.4 ± 5.7	<.001
MAMC, cm	17.3 ± 1.7	23.8 ± 3.5	<.001
eTSMM, kg	20.7 ± 5.9	23.5 ± 6.3	.006
RSMI	6.2 ± 1.4	7.6 ± 1.3	<.001
	eTSMM		*P*
	<17.7 kg in Women, <28.3 kg in Men	≥17.7 kg in Women, ≥28.3 kg in Men	
Age, y	76.8 ± 6.6	75.2 ± 6.7	.140
Male/female, n	31/42	56/19	<.001
Weight, kg	58.2 ± 10.4	86.4 ± 14.2	<.001
Height, m	159.8 ± 9.6	160.6 ± 7.2	.579
BMI	22.8 ± 3.9	33.5 ± 4.8	<.001
MAMC, cm	18.7 ± 3.8	22.7 ± 3.8	<.001
eTSMM, kg	19.6 ± 5.5	24.6 ± 6.0	<.001
RSMI	6.0 ± 1.1	7.9 ± 1.3	<.001

BMI, body mass index; EWGSOP, European Working Group on Sarcopenia in Older People.

Discussion

Sarcopenia is a common geriatric syndrome[12] severely affecting health,[2–6] whose diagnosis implies the assessment of muscle mass. Our results demonstrate that anthropometry-based methods may be precious screening tools for low muscle mass in older men and women (without diseases/conditions potentially affecting the DXA or anthropometric estimates), provided adequate cut-off limits are used.

We compared MAMC and eTSMM with DXA results, because the accuracy, precision, and quite low radiation exposure has made DXA the reference standard for daily practice,[13,14] although DXA cannot evaluate intramuscular fat. Even though much more accessible than MRI and computed tomography, DXA devices are still scarcely available in peripheral clinical settings. Besides, the estimate of muscle mass at the desk of every physician would be of value, because more than one-fourth of people aged >65 years do have muscle mass below the EWGSOP-suggested cut-off values.[14] Accordingly, the anthropometric methods retain utmost utility in daily practice. However, few studies specifically examined their reliability in samples exclusively including older people. Several studies developed anthropometric estimates from reference methods.[15–17] Actually, fewer works compared MAMC or eTSMM with DXA (ie, the clinical reference). In an article by Giusto et al, for instance, a significant correlation was found between MAMC and DXA in patients with liver cirrhosis.[18] Lee equation results were compared with DXA findings in a sample of men and women aged 60 to 81 years by Rech et al.[19] Their results were similar to ours but were obtained from a sample of subjects on average 8 to 9 years younger than those we studied.

When comparing the results obtained through different anthropometric approaches and those obtained by DXA, it should be kept in mind that although both anthropometric methods highly significantly correlated with DXA-measured RSMI, the different method of muscle mass assessment strongly influences the obtained results. Indeed, MAMC reflects the circumference of upper limb muscle, RSMI measures the lean mass of the 4 limbs adjusted for squared height, and eTSMM is generated by a formula obtained through total body MRI assessment. This may be relevant in older persons because the age-related decrease in muscle mass is not uniform in the upper and lower limbs and between sexes.[20,21]

We found that MAMC did not significantly correlate with age, at variance with eTSMM, which in turn includes age in the generating formula. Concerning MAMC, the lack of correlation with age could

Table 2
Frequencies of Older Adult Subjects With Low Skeletal Muscle Mass Estimated by MAMC and eTSMM, Who Had Values Below 2 SD of the Mean of Young Healthy Subjects

	Older Men (n = 61)	Older Women (n = 87)	Total Sample of Older Adults (n = 148)
MAMC	0/61 (0.0)	0/87 (0.0)	0/148 (0.0)
eTSMM	39/61 (63.9)	24/87 (27.6)	63/148 (42.5)
RSMI	35/61 (57.4)	16/87 (18.4)	51/148 (34.5)

BMI, body mass index; SD, standard deviation.
Values in parentheses are percentages. EGWSOP criteria were used to define the cut-off of low muscle mass as measured by RSMI.

depend on its inability to differentiate between muscle and intramuscular fat, the latter of which increases with age. Consequently, MAMC does not distinguish at all the relative decrease of muscle and increase of fat into the so called muscle circumference. As for eTSMM, because of the equation used, its estimate of muscle mass could be affected by the uneven inclusion of malnourished patients, which implies an overrepresentation of sarcopenia. On the other hand, sarcopenic obesity may not be highlighted by the equation used.

Besides, the anthropometric methods did not adequately discriminate low muscle mass in older subjects when using a sample of young subjects as reference: MAMC did not identify sarcopenic older adults, whereas eTSMM displayed only a moderate sensitivity. This partly could be related to secular trends: older subjects in their youth did probably have higher muscle mass than today's young subjects because of the recent mechanization of work (especially in rural areas). To overcome possible errors in sampling of the young reference group or due to secular trends, we then obtained different cut-offs through the ROC curve analysis, by using EWGSOP criteria for RSMI values as the reference standard.[1] Notably, RSMI was measured using a very accurate DXA device.[7] Through these redefined cut-offs, older subjects with pre-sarcopenia were identified with excellent sensitivity: 89% in women and 94% in men for MAMC, and 95% in women and 97% in men for eTSMM, whereas the respective specificity were moderate (84% and 67% for MAMC, and 81% and 67% for eTSMM). This in turn limits the validity of anthropometric estimates to confirm the diagnosis. Although higher than in previous works including subjects of all ages, these sensitivity values are similar to those of a previous study carried out in older subjects.[19] We cannot ignore that anthropometric results better identify low muscle mass when used in older subjects with a tighter age frame.

In any case, the high sensitivity we found in our sample of older subjects after redefinition of the thresholds for low muscle mass should be compared to the moderate specificity. Such results suggest the possible widespread use of anthropometric methods in areas where DXA devices are scarcely available, or at least as screening tools fit to identify subjects needing confirmation of low muscle mass by DXA.

Conclusion

Our results show that 2 simple anthropometric methods, possibly used in every clinical setting, could be valuable screening tools for sarcopenia in older subjects, at least to identify those deserving confirmatory diagnosis by other methods with higher specificity.

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