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Cross-validation of 20 anthropometric prediction equations for appendicular muscle mass in older Brazilian women: a cross-sectional study

Validação cruzada de 20 equações antropométricas de massa muscular apendicular para idosas brasileiras: um estudo transversal

Pedro Pugliesi Abdalla[a], Lucimere Bohn[b,c], André Pereira dos Santos[a], Leonardo Santos Lopes da Silva[a], Márcio Fernando Tasinafo Júnior[a], Ana Claudia Rossini Venturini[a], Nilo César Ramos[d], Pablo Jorge Marcos-Pardo[e], Jorge Mota[b], Dalmo Roberto Lopes Machado[a,b,f]

[a]Universidade de São Paulo – São Paulo (SP), Brazil.
[b]Universidade do Porto – Porto, Portugal.
[c]Lusófona Universidade do Porto – Porto, Portugal.
[d]Coastal Carolina University – South Carolina, United States.
[e]Universidad de Almeria – Almería, Espanha.
[f]Universidade do Algarve, Campus da Penha – Faro, Portugal.

Correspondence data
Pedro Pugliesi Abdalla – Avenida Bandeirantes, 3 900 – CEP: 14040-907 – Ribeirão Preto (SP), Brazil.
E-mail: pedroabdalla11@gmail.com

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Abstract

Objective: To test the cross-validation of anthropometric prediction equations for appendicular muscle mass (AMM) in older Brazilian women. **Methods:** Sixty-seven older women (69.84 ± 5.95 years old) underwent anthropometric measurements. AMM (kg) reference values obtained by dual-energy X-ray absorptiometry (AMMDXA) were compared to 20 anthropometric equations for estimating AMM in older adults. A paired t-test ($p > 0.05$), standard error of estimate (SEE < 3.50 kg), and $r^2 > 0.70$ confirmed the validity of the equations. The agreement between predictions and the reference was also verified (Bland-Altman analysis of agreement between methods). **Results:** Four American equations and one Mexican equation were not statistically different from AMMDXA ($p > 0.05$) but did not present suitable r^2 values for validation. The American equation from the National Health and Nutrition Examination Survey (NHANES), AMM (kg) = (-0.04 × age [years]) + (0.46 × calf circumference [cm]) + (0.32 × arm circumference [cm]) + (0.11 × thigh circumference [cm]) – (0.27 × body mass index [BMI, kg/m^2]) + (0.07 × waist circumference [cm]) – 13 119 showed the best performance ($r^2 = 0.64$; SEE = 3.24 kg), with minimal mean difference (0.26 kg), no heteroscedasticity for extreme values, and with high agreement with the Brazilian sample (-3.90 to 3.40 kg). **Conclusion:** When specific equations for a given population are not available, the use of generic equations of greater sample representativeness with scientifically and reliably analyzed data is allowed.

Keywords: anthropometry, body composition, sarcopenia, geriatric assessment.

Resumo

Objetivo: Testar a validação cruzada das equações antropométricas preditivas da massa muscular apendicular (MMA) em idosas brasileiras. **Metodologia:** Sessenta e sete idosas (69,84 ± 5,95 anos) foram submetidas a medidas antropométricas. Os valores de referência da MMA (kg) fornecida pela absorciometria de raios X de dupla energia (MMADXA) foi comparada com 20 equações antropométricas preditivas para estimar a MMA para idosos. Teste t pareado ($p > 0,05$), erro padrão de estimativa (EPE) < 3,50 kg e $r^2 > 0,70$ confirmaram a validade das equações. A concordância entre as previsões e a referência também foi verificada (análise de concordância entre métodos de Bland-Altman). **Resultados:** Quatro equações americanas e uma equação mexicana não foram estatisticamente diferentes da MMADXA ($p > 0,05$), mas nenhuma delas apresentou r^2 adequado para validação. A equação americana dos dados do National Health and Nutrition Examination Survey (NHANES), MMA (kg) = (-0,04 × idade [anos]) + (0,46 × circunferência da panturrilha [cm]) + (0,32 × circunferência do braço [cm]) + (0,11 × circunferência da coxa [cm]) – (0,27 × índice de massa corporal-IMC [kg/m^2]) + (0,07 × circunferência da cintura [cm]) – 13,12 apresentou o melhor desempenho ($r^2 = 0,64$; EPE = 3,24 kg): com diferença média mínima (0,26 kg), sem heterocedasticidade para valores extremos e alta concordância com a amostra brasileira (-3,90 a 3,40 kg). **Conclusão:** Quando não existem equações específicas para uma determinada população, é permitida a utilização de equações genéricas de maior representatividade amostral, cujos dados tenham sido analisados de forma científica e confiável.

Palavras-chave: antropometria; composição corporal; sarcopenia; avaliação geriátrica.

INTRODUCTION

Appendicular muscle mass (AMM)[1] is a skeletal muscle mass (SMM) parameter recommended by consensus boards to identify sarcopenia, and dual-energy X-ray absorptiometry (DXA) is currently considered the reference technique for objectively assessing AMM.[2] A high correlation (r = 0.97) between AMM measured by DXA and that measured by magnetic resonance imaging (MRI) was reported for both men and women (18 – 92 years).[2] Characterized by reductions in strength, muscle mass, and function with age, sarcopenia is associated with disability and premature death in older adults, increasing hospitalization costs compared to older adults without this disease.[3] Sarcopenia is closely linked to the frailty phenotype described by Fried et al.[4] However, using DXA as the main tool for monitoring muscle loss is expensive and unfeasible for some health systems.[5] To overcome this constraint, strategies to estimate AMM can come from anthropometric equations,[6-14] but their desired cross-validation for a given population should be confirmed to avoid diagnostics bias. Anthropometry is simple, portable, noninvasive, and inexpensive,[11] but it requires training to ensure the reliability of measurements.

Thus, we aimed to test the cross-validation of anthropometric prediction equations for AMM in Brazilian community-dwelling older women. We hypothesized that specific anthropometric equations derived from ethnic similarities (Brazilian populations) would be better for predicting AMM with enough accuracy.

METHODS

Study population

This is a cross-sectional study involving a convenience sample of 67 Brazilian community-dwelling older women. Our study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the School of Physical Education and Sports of Ribeirão Preto (EEFERP-USP) with CAAE No. 54345016.6.0000.5659. The manuscript also followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist guidelines.

Participants were involved in health services at University Hospital of Ribeirao Preto School of Medicine, University of Sao Paulo (HC-FMRP/USP) — namely the Fragility Project (FMRP-USP), and the Physical Activity for Seniors program at the EEFERP-USP. Data collection took place from July 2016 to August 2017.

Inclusion criteria were:

a) individuals able to walk independently;
b) with no amputated limbs;
c) free of unstable cardiovascular diseases and other conditions such as acute infections, tumors, and back pain;
d) with no knee or hip prostheses;
e) with no loss of more than 3 kg of body mass in the previous 3 months; and
f) who were able to perform the proposed battery of tests.

Participants were excluded when:

a) they were unable to complete the testing protocol;
b) presented any uncontrolled chronic disease;
c) had post-stroke sequelae; or
d) had voluntarily decided to no longer participate in the study.

To ensure data quality, we calculated sample size ($n = [ZySD/\varepsilon]^2$).[15] To calculate "n", we established the desired maximum error ($\varepsilon \leq 1.0\%$) and degree of confidence ($Zy = 0.95$), with previous knowledge from a multiethnic study[16] of the variability among women's (over 18 years old) AMM (highest observed variance; SD = 1.75 kg). The minimum number of participants was reached (n = 12) even after applying the exclusion criteria.

Measurements

Reference AMM values were obtained with DXA (AMMDXA): a fan-beam densitometer, Hologic® scanner, model QDR4500W; software version 11.2 (Bedford, MA, USA). The equipment was calibrated every morning before measurements by the same specialized technician, according to the manufacturer's instructions. Variables required to predict AMM (age, anthropometrics, and muscle strength) were measured following conventional international standardization.[17] Anthropometrics involves body mass (kg); stature (cm); and measurements of circumferences (cm) of the arm, forearm, calf, waist, and hip with an inextensible measuring tape; of the biceps, triceps, subscapular, suprailiac, and thigh skinfolds with a Lange caliper; and of knee height (cm) with a segmometer. To predict AMM with foreign equations, we calculated the participants' body mass index (BMI, kg/m^2) and their corrected arm muscle area (CAMA) in cm^2.[18] To predict AMM with the American (Baumgartner), Chilean, and Mexican equations, we determined handgrip strength (Jamar, model 5030J1), according to the current recommendations.[19]

Anthropometric prediction equations for appendicular muscle mass

In order to select eligible equations, we conducted a literature search including the keywords "appendicular lean mass", "equation", and "model" in the PubMed, Web of Science, Embase, and Scopus databases. The following inclusion criteria were adopted: equations published between 1998 and 2022 and sample comprising exclusively older adults. Twenty predictive anthropometric equations developed for Brazilian,[9,10] American,[6,14] Indian,[11] Australian,[8] Chilean,[12] Danish,[7] and Mexican[13] individuals were found in the literature and were compared to AMMDXA.

Statistical analyses

Descriptive analysis with a 95% confidence interval (CI) was used to describe the sample. The validity of the equations was tested using the following criteria[9]:

a) no statistically significant difference ($p > 0.05$) from AMMDXA using a paired t-test;
b) standard error of the estimate (SEE) < 3.50 kg between predicted (by equations) and measured (DXA) AMM; and
c) coefficient of determination (r^2) > 0.70 in the estimates.[20]

A Bland-Altman plot identified the degree of agreement between measured and predicted AMM values. Statistical analyses ($\alpha = 5\%$) were performed using SPSS software, version 20 (Chicago, IL, USA). Plots were created using MedCalc 2015 (version 15.2).

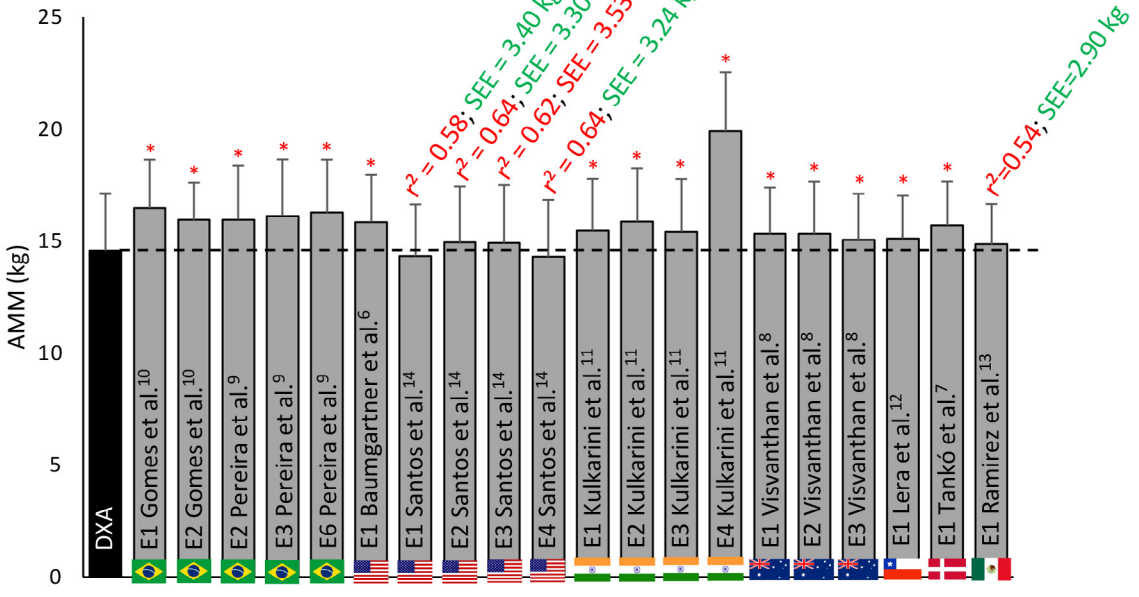
RESULTS

Twenty anthropometric prediction equations for AMM found in the literature are shown in Supplementary Table 1.

Descriptive statistics are presented in Supplementary Table 2. The mean age of older women was 69.84 ± 5.95 years and the mean BMI was in the overweight range (≥ 25 kg/m^2). The AMM predicted by the four equations of Santos et al. and Ramirez et al. (14.33 to 14.94 kg) was the closest to mean AMMDXA values (14.57 ± 2.56 kg).

Only four American National Health and Nutrition Examination Survey (NHANES) equations ($p = 0.12$ to 0.31) proposed by Santos et al. and one Mexican equation proposed by Ramirez et al. ($p = 0.17$) were not statistically different from AMMDXA (Figure 1). However, none of them presented suitable r^2 for validation ($r^2 > 0.70$). The fourth NHANES equation,[14] AMM [kg] = (-0.04 × age [years]) + (0.46 × calf circumference [cm]) + (0.32 × arm circumference [cm]) + (0.11 × thigh circumference [cm]) – (0.27 × BMI [kg/m^2]) + (0.07 × waist circumference [cm]) – 13.12, showed the best performance ($r^2 = 0.64$; SEE = 3.24 kg).

In the Bland Altman comparison (Supplementary Figure 1), the fourth NHANES equation showed minimal



*Statistical difference ($p < 0.05$) between AMM measured by DXA and predicted by an anthropometric equation; AMM: appendicular muscle mass; DXA: dual-energy X-ray absorptiometry; E: equation; r^2 = coefficient of determination; SEE: standard error of estimate.
Note: Red and green text represent disagreement and agreement with validity criteria established by Pereira et al.[9], respectively.

FIGURE 1. Validation of anthropometric equations of appendicular muscle mass considering dual-energy X-ray absorptiometry as reference.

mean difference (0.26 kg) from AMMDXA, no heteroscedasticity for extreme values, and a high agreement with the reference method (lower limit: -3.90 kg; upper limit: 3.40 kg).

DISCUSSION

Our results suggest that five of the 20 tested AMM prediction equations did not differ from AMMDXA (four of the American equations and one of the Mexican equations), however none achieved an $r^2 > 0.70$, the first validity criterion. One of them (the fourth NHANES equation)[14] was closest to the second validity criterion (SEE < 3.50), and the limits of agreement (Bland Altman plot) were smaller than the original study itself.[14] This provides some reliability for it to be recommended for clinical practice.

As is the case in our work, other studies have also failed to validate some of the equations presented in this study for Brazilian women samples. For instance, Pereira et al.[9] tried to validate equations by Baumgartner et al.[6] and Tankó et al.[7] without success. Likewise, the Brazilian equations[9,10] also did not meet the criteria for validation in our sample. Therefore, our hypothesis that specific anthropometric equations from national studies should be more accurate was rejected. However, when we tested the agreement between DXA and the equation with the closest validity to our criteria (the fourth NHANES equation), it showed better results in the agreement limits of the Bland Altman plot (lower limit: -3.90 kg; upper limit: 3.40 kg) when compared to the original study (lower limit: -4.06 kg; upper limit: 4.17 kg). These results seem to support the use of this equation (with acceptable accuracy) in clinical practice for older Brazilian women. This is possibly due to the use of generic equations of greater sample representativeness (n = 15,239), with data of scientific and reliable representativeness generated by applicable models that are accurate for samples with slightly different data compared to the original study.

To the best of our knowledge, this is the first study that tried to validate many anthropometric prediction equations for AMM in Brazilian older women.

Despite the promising results obtained in this study, some limitations should be considered. The cross-sectional design could have underestimated the individual decline in AMM with aging. We also did not compare age groups in our sample. Future studies should consider a longitudinal design and probably age differences.

AMM should be applied to the clinical context of older adults for identifying sarcopenia, as AMM is recommended by the European Working Group on Sarcopenia in Older People (EWGSOP2) for the definition and diagnosis of sarcopenia.[1] The application of our findings to clinical settings should be considered with caution. Only one equation was more suitable to predict AMM in older women, thus we still do not affirm that this is the best scenario for AMM management. However, it can be well used by health professionals when DXA is not available. As implications of these findings for research, it is necessary to propose valid generalizable equations for clinical practice that are more accurate than those used in research. Equations including more variables (sex, age, BMI) are more precise, with higher r^2 to estimate AMM (Supplementary Table 1). However, the impact of other diseases in the estimation of AMM with equations has not been studied in older adults.

The older population is increasing considerably every year. It should be noted that in Brazil, a large portion of the population resides in areas of difficult access for both older people and health agents, making it difficult to implement actions to manage and improve their health. Therefore, it is important to identify new prevention tools of easy access and management for the early detection of sarcopenia, especially among older adults.

CONCLUSION

In conclusion, when specific equations for a given population are not available, the use of generic equations created from data of greater sample representativeness (eg, the American NHANES data) that were scientifically and reliably processed can be clinically applicable to estimate AMM in older women. This equation is recommended as the one with the best performance and a high agreement with the Brazilian sample.

Conflict of interest

The authors declare no conflicts of interest.

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Supplementary materials

The Supplementary Materials can be accessed in the following link: https://doi.org/10.5281/zenodo.7463429

Authors' contribution

PPA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. LB: Methodology, Writing – review & editing. APS: Visualization, Writing – original draft. LSLS: Investigation, Writing – original draft. MFTJ: Investigation, Writing

– original draft. ACRV: Investigation, Writing – original draft. NCR: Writing – original draft, Writing – review & editing. PJMP: Data curation, Writing – review & editing. JM: Software, Supervision, Writing – review & editing. DRLM: Formal analysis, Project administration, Resources, Supervision, Validation.

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