Osteoporosis and Sarcopenia 4 (2018) 145–149

Contents lists available at ScienceDirect

Osteoporosis and Sarcopenia

journal homepage: http://www.elsevier.com/locate/afos

Original article

Correlation between muscle mass, nutritional status and physical performance of elderly people

Thiago Neves [a, *], Carlos Alexandre Fett [b], Eduardo Ferriolli [c], Milene Giovana Crespilho Souza [b], Adilson Domingos dos Reis Filho [d], Marcela Bomfim Martin Lopes [d], Neusa Maria Carraro Martins [b], Waléria Christiane Rezende Fett [b]

[a] Department of Physical Education, University of the State of Mato Grosso, Diamantino, MT, Brazil
[b] Department of Physical Education, Nucleus of Studies in Physical Fitness, Computers, Metabolism, and Sports and Health, Federal University of Mato Grosso, Cuiabá, MT, Brazil
[c] Department of Internal Medicine, Faculty of Medicine of Ribeirão Preto, University of São Paulo, Ribeirão Preto, SP, Brazil
[d] Department of Physical Education, Physical Education College, IPE Faculty of Technology, Cuiabá, MT, Brazil

ARTICLE INFO

Article history:
Received 18 August 2018
Received in revised form
5 November 2018
Accepted 11 November 2018
Available online 20 November 2018

Keywords:
Muscle mass
Functionality
Strength
Elderly

ABSTRACT

Objectives: This study evaluated the relationship between the skeletal muscle mass (SMM), obtained by predictive equations, and the body composition, nutritional aspects, functionality and physical performance in elderly people.
Methods: The sample consisted of adults aged 65 years or over from the cross-sectional study of the Brazilian Elderly Frailty Study Network, in Cuiabá, Mato Grosso State, Brazil. The anthropometric parameters, instrumental activities of daily living (IADL), Short Physical Performance Battery (SPPB), and handgrip strength (HGS) were evaluated. The SMM was estimated by 2 predictive anthropometric equations.
Results: Both SMM equations correlated with age, anthropometric indices, SPPB, IADL, and HGS. However, only HGS and neck circumference strongly correlated in both equations, being higher in SMM II.
Conclusions: It seems that both equations are sensitive to obtain the SMM, contributing to the diagnosis of sarcopenia, nutritional status, and a physical performance condition.

1. Introduction

The skeletal muscle mass (SMM) is one of the important components for the study of health conditions and nutritional status of elderly people [1,2]. It represents an important part of the fat-free mass in the human body, forming the metabolically active tissue. The value of SMM is related to the physical fitness and to the prevention of fractures [1]. It is estimated that around 15%–20% of the elderly population have a deficit in the SMM which, associated with the reduced muscle strength, characterizes the presence of sarcopenia, which has a prevalence higher than 50% in elderly people aged ≥80 years [3–5].

The SMM estimate "*in vivo*" can be performed by various methods, such as computed tomography, magnetic resonance and dual-energy X-ray absorptiometry (DXA) [3,6], which are considered as reference methods (gold standard). However, these more expensive methods become inaccessible for population studies due to the high financial costs. Approximately 75% of the body muscle mass are in the appendicular area. This fact contributed for the development of predictive equations to estimate muscle mass for the entire body, using anthropometric data [7], which procedure for collection is cheaper and more accessible, allowing the SMM calculation in epidemiological studies.

In Brazil, some studies evidenced that 2 predictive equations used to estimate the SMM of the entire body of elderly people are valid, when compared to the values obtained by DXA [8,9]. Having in mind that functional changes are often consequences of diseases and/or common problems related to elderly people, loss SMM

* Corresponding author. Department of Physical Education, University of the State of Mato Grosso, 166, Rui Barbosa Street, Eldorado Garden, ZIP Code 78.400-000, Diamantino, MT, Brazil.
E-mail address: thiagoneves@usp.br (T. Neves).
Peer review under responsibility of The Korean Society of Osteoporosis.

https://doi.org/10.1016/j.afos.2018.11.081
2405-5255/

(sarcopenia) is considered the main precursor for the development of functional dependency in activities of daily living. The worsening of this process is pointed as a strong indicator of the decline of the elderly people's performance, and it is associated to the cost of treatments and care of elderly people [4,8].

Thus, the determination of the SMM may be important for the diagnosis and monitoring of pathologies related to sarcopenia and nutritional aspects [4] or for the behavior analysis of this body component in people who participate in physical exercise programs [10]. Anthropometric indicators that allow the identification of the development of heart disease [11,12], overweight and obesity [13,14] and sarcopenia [8,9] are used to determine the existing relationship between nontransmissible chronic diseases, obesity and muscle decrease. Therefore, considering the population aging and the increase in life expectancy for elderly people, there is a need for studies that focus on preventive measures, less expensive, to minimize body changes that occur due to inadequate aging.

Due to the increase in the prevalence of sarcopenia in the elderly population, this study aimed to relate the SMM to the body composition, functionality and physical performance in elderly people.

2. Methods

This study was carried out in the city of Cuiabá, Mato Grosso State, Brazil, between 2009 and 2010, consisting of a subproject of the Brazilian Elderly Frailty Studies Network/Fragilidade em Idosos Brasileiros. It is a transversal, multicentric and population-based study, performed in 17 Brazilian regions, which were selected using sampling criterion by quotas with different human development indices [15]. A total of 513 elderly people was interviewed through enrollment forms, based on Instituto Brasileiro de Geografia e Estatística's Census, which registered 17,329 elderly people [16].

As inclusion criteria, some requirements were considered, such as: 65 years old or older, not be diagnosed with diabetes mellitus and/or hypertension, no use of drugs that would change the glycemia, 75% of attendance in Coexistence Centers, sign the consent form, and finish all the research phases of this study. Participants were excluded if they presented the following characteristics: age less than 65 years, severe mental retardation, Parkinson disease in the severe or unstable stage, terminal stage, amputations, major orthopedic limitations, and not complete all stages of this research. Thus, 126 participants were excluded from the study, remaining a sample of 387 elderly, representing the elderly population of Cuiabá at that time, which was estimated by demographic calculation and included by random draws [15].

This research was carried out according to the Research Ethics Committee (protocol No. 196/96 CNS, being approved, No. 632/09).

2.1. Measurements

A questionnaire was used to obtain general information such as name, address, telephone, age, and ethnicity. The body mass was measured in kilograms (kg) and the height in meters (m), using a 180 kg capacity digital platform scale (G-Tech, GM Sales & Services, New Delhi, India), with a precision of 0.05 kg, and a rigid tape measure of 3 m and 25.4 cm (Starrett, L. S. Starrett Co., Athol, MA, USA), respectively. From body mass and height measurements, the body mass index (BMI - kg/m^2) was calculated.

A flexible and inextensible plastic tape, with a precision of 0.1 cm, was used to measure body circumference in centimeters (cm), according to conventional techniques. The arm circumference (AC) was measured at the midpoint between the acromion and the olecranon with the arm extended, the muscles relaxed and the palm of the hand facing the thigh. The neck circumference (NC) was measured at the mean height of the neck; calf circumference (CC) was measured with the elderly standing, at the largest protuberance of the calf; and thigh circumference (TC) was measured with the individual, also standing, just below the gluteal-fold.

The SMM can be obtained by validated [17] mathematical equations [7], using the following variables: age, sex, ethnicity, body mass, stature and the following circumferences adjusted by cutaneous folds [7]: corrected AC, corrected TC, and corrected CC, as shown in Table 1.

The nutritional status was evaluated by the mini nutritional assessment (MNA) [18]. MNA is composed of 4 categories: anthropometry (weight, height, AC and CC, and weight loss), general care (lifestyle, medication use, and mobility), diet (number of meals, food, and liquid intake), autonomy to eat and perception of their nutritional status. Besides, the circumferences of arm, neck, and calf can be used as an analysis of nutritional status [11,19,20].

Muscle strength was assessed by handgrip using a manual hydraulic dynamometer (Model SH5001, Saehan Corp., Masan, Korea). For measurement, the elderly was placed in a seated position on an armless chair, with elbow flexed at a 90° angle, adducted shoulder, forearm in neutral position and wrist with an extension between 0° and 30°. Three successive measurements were taken, with a 15-second interval between them, selecting the best score out of the 3 measurements.

The Brazilian version of the short physical performance battery (SPPB) was used to compare physical performance. It is an instrument made of three tests and it assesses, in sequence, the static standing balance; the usual walking speed (measured in 2 periods in a given round trip of 4 m); and the muscle strength of the lower limbs, by means of standing up and sitting down 5 consecutive times [21]. The average speed traveled by the elderly was calculated, dividing the distance traveled by the time spent during the test.

The functional deficiency was determined using questionnaires on the instrumental activities of daily living (IADL) to classify the degree of independence/dependence for the daily life activities of this study's volunteers. The IADL questionnaire includes activities essential to maintaining personal independence [22].

2.2. Statistical analysis

The descriptive analysis was performed for the sample characterization, showing the absolute and relative frequency (percentages) as well as the values of the averages and standard deviations. The Kolmogorov and Smirnov tests were used to verify normality, and then the Spearman correlation was applied to nonparametric data. We used the *t*-test for independent samples, Mann-Whitney to verify differences between genders. All tests were performed with a significance level of 5% ($P < 0.05$) and a 95% confidence interval. We used the IBM SPSS Statistics ver. 25.0 (IBM Co., Armonk, NY, USA) in all analyses.

3. Results

In Table 2, we can verify the comparative results of the sociodemographic, anthropometric profile's characteristics and the skeletal muscle prediction of the elderly men and women studied in this research. Smoking and alcoholism were more in elderly men (17.3% and 36.7%) than in older women (8.5% and 16.9%). We notice that elderly men had superior body mass, height, and upper calf and NCs. However, elderly women had a higher BMI than elderly men. The elderly men's SMM was higher in both prediction equations when compared to the elderly women.

Men's physical performance in all physical fitness tests was

Table 1
Equations for estimating skeletal muscle mass (SMM) in elderly.

Equation	Study	Mathematical model
SMM I	Lee et al. [7]	$SMM\ (kg) = H\ x\ (0.00744\ x\ AC^2 + 0.00088\ x\ TC^2 + 0.00441\ x\ CC^2) + 2.4\ x\ G - 0.048\ x\ Age + Ra + 7.8$
SMM II	Lee et al. [7]	$SMM\ (kg) = 0.244\ x\ BM + 7.8\ x\ H + 6.6\ x\ G - 0.098\ x\ Age + Rb - 3.3$

BM, body mass; H, height; TC, thigh circumference; CC, calf circumference; AC, arm circumference; G, 1 for men and 0 for women; Ra, −2.0 for Asians, 1.1 for Afro descendants and 0 for Caucasians; Rb, −1.2 for Asians, 1.4 for Afro descendants and 0 for Caucasians.

Table 2
Comparison of the profile of elderly (n = 387).

Variable	Men (n = 141)	Women (n = 246)	p-value
Age, yr	71 (65–93)	71 (65–90)	0.92
Body weight, kg	70.9 (43.5–116.2)	62.2 (34.1–106.4)	0.00
Height, m	1.65 (1.45–1.84)	1.52 (1.29–1.70)	0.00
Body mass index, kg/m^2	26.2 ± 4.2	27.5 ± 5.1	0.01
Arm circumference, cm	29.5 (21.0–38.0)	30.0 (19.0–49.0)	0.02
Thigh circumference, cm	49.5 (32.0–93.0)	53.0 (33.0–118.0)	0.00
Calf circumference, cm	34.3 (25.5–45.0)	33.0 (23.5–49.5)	0.01
Neck circumference, cm	38.0 (31.5–55.0)	34 (15.0–67.0)	0.00
Mini nutrition assessment	25.5 (17.5–30.0)	26.0 (10.5–30.0)	0.65
Skeletal muscle mass I, kg	23.2 (14.5–36.4)	17.2 (11.4–33.5)	0.00
Skeletal muscle mass II, kg	27.3 ± 3.4	17.7 ± 3.5	0.00

Values are presented as median (range)[a] or mean ± standard deviation[b].
[a] Mann-Whitney test.
[b] t-test for independent samples.

higher than that found in women. In addition, they scored higher in the instrumental activities of the daily living score (Table 3).

Both SMM mathematical equations correlated with age and positive correlation with anthropometric indicators (BMI, height, arm, calf, neck, and TCs) and IADL, with equation II having a stronger correlation than equation I. We found a correlation of equation I with all variables that assessed physical performance. However, equation II did not correlate only with the SPPB sitting and standing up. The handgrip was the physical fitness variable that best correlated in both equations, being stronger in equation II. The MNA did not correlate with the equations (Table 4). Did not find sex-specific correlation. Therefore, the sex-specific analysis and a similar result were observed.

4. Discussion

The main findings of the present study were that both equations presented a moderate correlation with the anthropometric indices and the handgrip, fragile with SPPB. The correlation with age was significant, but fragile, suggesting that other factors that make up a healthy lifestyle are interfering in the association, besides the age *per se*. The manual pressure force measured by the handgrip was

Table 3
Comparison between men and women of the physical performance and functionality of the elderly (n = 387).

Variable	Men (n = 141)	Women (n = 246)	p-value
SPPB balance	4 (1–4)	4 (0–4)	0.02
SPPB travel speed	4 (0–4)	3 (0–4)	0.00
SPPB sit and stand	2 (0–4)	2 (0–4)	0.02
SPPB total	10 (1–12)	9 (0–12)	0.00
Hand grip (kgf)	30.1 ± 11.1	17.1 ± 6.2	0.00
Average speed (m/s)	1.68 ± 0.47	1.34 ± 0.42	0.00
IADL	0 (0–7)	1 (0–7)	0.00

Values are presented as median (range)[a] or mean ± standard deviation[b].
SPPB, short physical performance battery; IADL, instrumental activities of daily living.
[a] Mann-Whitney test.
[b] *t*-test for independent samples.

Table 4
Relationship between skeletal muscle mass obtained by mathematical equations with anthropometric measurements, nutritional status, functionality and physical performance of elderly (n = 387).

Variable	Skeletal muscle mass I	Skeletal muscle mass II
Age	−0.179**	−0.191**
Height	0,637**	0,745**
Body mass index	0.178**	0.370**
Arm circumference	0.306**	0.371**
Calf circumference	0.464**	0.521**
Neck circumference	0.507**	0.736**
Thigh circumference	0,146**	0,116*
Mini nutrition assessment	−0.068	−0.042
IADL	−0.178**	−0.236**
SPPB balance	0.174**	0.125*
SPPB travel speed	0.245**	0.224**
SPPB sit and stand	0.162**	0.096
SPPB total	0.235**	0.185**
Hand grip	0.576**	0.625**
Average speed	0.328**	0.309**

IADL, instrumental activities of daily living; SPPB, short physical performance battery.
*$p \le 0.05$. **$p \le 0.01$.

the best correlated with the SMM equations, and the maintenance of muscle mass and strength depend on factors such as physical exercise and nutrition, reinforcing this reasoning [23].

When analyzing the body composition by anthropometric indices, in our study that BMI presented a weak positive correlation with SMM. Following this thought, another study observed that individuals with normal SMM had lower values of BMI compared to individuals with low SMM. It was also observed that SMM was associated with BMI [24]. Perhaps, this may be related to the increase in body mass, which is associated with SMM and, consequently, with physical performance [25].

Our results indicate that the circumferences of the arm, neck, and calf can be used as an analysis of nutritional status, correlated with SMM, corroborating other studies [19,20,26,27]. These relations between SMM and the circumferences may be explained by the regular health status (much of the eutrophic elderly sample) of our population. Anthropometric studies report a greater correlation between the circumferences and the total muscle mass in elderly individuals [28], malnourished or dead [26], as well as being more capable of stratifying nutritional status [15].

It is known that elderly individuals with lower CC have a greater deficiency and less physical function [19], besides being a measurer to identify the decrease of muscle mass in the elderly [29]. However, in our study, the NC was the one that best correlated with SMM. It has recently been found that elderly people with greater NC enable the identification of overweight and obesity [13,14] and there is a higher risk of developing cardiovascular diseases [11,12]. Therefore, being more reliable than traditional risk markers, such as the BMI [30], which had a weaker correlation, and the MNA that had no correlation with the SMM equations, suggesting that anthropometric measures are more efficient for stratification of nutritional status [15].

In addition, scholars highlighted that SMM loss associated with decreased muscle strength and/or physical performance has an impact on the functional abilities of the elderly and may reflect especially on activities that require greater mobility and resistance [4]. In the present study, the applied tests used physical valences involved for the adequate performance of daily tasks, being of low risk, it can be tested in several environments. For that matter, the SMM equations that help estimate sarcopenia were related to physical tests, with handgrip being the variable that was most strongly related to SMM.

Other studies, with common objectives, found the relationship between the decline in strength and muscle mass of lower and upper limbs, with the decline of mobility in walking activities [31,32], and activities of going up and down steps, with reduced performance to get up and down [33] and the occurrence of falls [34]; in accordance with our findings, they also found stronger handgrip ratio.

The SMM obtained by equation II presented a weak correlation with the self-reported functional deficiency. Both equations I and II presented weak correlation with the other elderly's physical fitness variables. However, a moderate correlation with the muscular performance in the handgrip showed compliance with other findings, where they highlighted that the superiority of muscle mass was decisive for better physical performance [35]. Low SMM correlates with functional disability [36], dependence on daily life activities, and mobility decrease [23,37,38].

As found in our study, others have identified that hand strength correlates with upper extremity strength and general body strength [39,40]. This can be justified by the relation between the strength in the handgrip and the preservation of lean mass, demonstrated by the good correlation presented between this variable and the SMM of the legs, arms and appendicular muscle mass [40].

First, because of the transversal design, we cannot make any causal inferences about the relation between SMM, physical performance, and nutritional status. Second, these results cannot be generalized to institutionalized older adults, who represent the most functionally disadvantaged segment of the population. Finally, there is no standardized and established quantitative definition of sarcopenia based on SMM, strength and/or physical performance, whether used in clinical practice or as an accepted therapeutic indication. Once the standardized methodology for the clinical evaluation of sarcopenia is established, the normal and abnormal measuring values need to be determined by considering biological and physiological measures of a reference population or distribution percentile in a population.

5. Conclusion

Apparently, both equations are sensitive to obtain SMM, aiding in the sarcopenia diagnosis, nutritional status and physical performance condition of the elderly. Simple anthropometric measures used in the SMM equations may aid in the sarcopenia diagnosis and possibly be associated with future functional disabilities in the elderly. For the prognosis and follow-up of the muscle mass loss in this population, the most promising measures are the neck, arm, CCs, and palmar grip strength test.

Population studies, such as ours, on factors associated with decreasing muscle mass may provide more cost-effective strategies for establishing more effective and better preventive interventions and treatments. Thus, that can minimize disability and increase the independence of elderly people, being used as a reference standard for muscle mass indicators, nutritional status, and functional performance of the elderly.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

This research was supported by the National Council of Scientific and Technological Development - CNPq (nº 17/2006) and by the Foundation for Research Support of the State of Mato Grosso - FAPEMAT (002.017/2007). ORCID. Thiago Neves: https://orcid.org/0000-0003-4946-3105; Carlos Alexandre Fett: https://orcid.org/0000-0002-7522-7985; Eduardo Ferriolli: https://orcid.org/0000-0002-5028-2451; Milene Giovana Crespilho Souza: https://orcid.org/0000-0003-1447-3821; Adilson Domingos dos Reis Filho: https://orcid.org/0000-0003-0955-6665; Marcela Bomfim Martin Lopes: https://orcid.org/0000-0003-0700-7005; Neusa Maria Carraro Martins: https://orcid.org/0000-0001-9071-4258; Waléria Christiane Rezende Fett: https://orcid.org/0000-0002-6938-6365.

References

[1] Rolland Y, Lauwers-Cances V, Cristini C, Abellan van Kan G, Janssen I, Morley JE, et al. Difficulties with physical function associated with obesity, sarcopenia, and sarcopenic-obesity in community-dwelling elderly women: the EPIDOS (EPIDemiologie de l'OSteoporose) Study. Am J Clin Nutr 2009;89:1895–900.
[2] Lang T, Streeper T, Cawthon P, Baldwin K, Taaffe DR, Harris TB. Sarcopenia: etiology, clinical consequences, intervention, and assessment. Osteoporos Int 2010;21:543–59.
[3] Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998;147:755–63.
[4] Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European working group on sarcopenia in older people. Age Ageing 2010;39:412–23.
[5] Han P, Kang L, Guo Q, Wang J, Zhang W, Shen S, et al. Prevalence and factors associated with sarcopenia in suburb-dwelling older Chinese using the Asian Working Group for Sarcopenia Definition. J Gerontol A Biol Sci Med Sci 2016;71:529–35.
[6] Kim J, Wang Z, Heymsfield SB, Baumgartner RN, Gallagher D. Total-body skeletal muscle mass: estimation by a new dual-energy X-ray absorptiometry method. Am J Clin Nutr 2002;76:378–83.
[7] Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. Am J Clin Nutr 2000;72:796–803.
[8] Rech CR, Dellagrana RA, Marucci M de FN, Petroski EL. Validade de equações antropométricas para estimar a massa muscular em idosos. Rev Bras Cineantropom Desempenho Hum 2012;14:23–31.
[9] Gobbo LA, Cyrino ES, Petroski ÉL, Cardoso JR, Carvalho FO, Romanzini M, et al. Validação de equações antropométricas para a estimativa da massa muscular por meio de absortometria radiológica de dupla energia em Universitários do Sexo Masculino. Rev Bras Med Esporte 2008;14:376–80.
[10] Janssen I, Heymsfield SB, Baumgartner RN, Ross R. Estimation of skeletal muscle mass by bioelectrical impedance analysis. J Appl Physiol (1985) 2000;89:465–71.
[11] Ben-Noun L, Laor A. Relationship of neck circumference to cardiovascular risk factors. Obes Res 2003;11:226–31.
[12] Zanuncio VV, Pessoa MC, Pereira PF, Longo GZ. Neck circumference, cardiometabolic risk, and Framingham risk score: population-based study. Rev Nutr 2017;30:771–81.
[13] Premanath M, Basavanagowdappa H, Mahesh M, Suresh Babu M. Forum for injection technique and therapy expert recommendations, India: the indian recommendations for best practice in insulin injection technique. 2017 Indian J Endocrinol Metab 2017;21:308–15.
[14] Fett C, Fett W, Fabbro A, Marchini J. Dietary re-education, exercise program, performance and body indexes associated with risk factors in overweight/obese women. J Int Soc Sports Nutr 2005;2:45–53.
[15] Silva Rodrigues RA, Martinez Espinosa M, Duarte Melo C, Rodrigues Perracini M, Rezende Fett WC, Fett CA. New values anthropometry for classification of nutritional status in the elderly. J Nutr Health Aging 2014;18:655–61.
[16] Instituto Brasileiro de Geografia e Estatística - IBGE. Sinopse do Censo Demográfico de 2010. Rio de Janeiro (Brasil): Instituto Brasileiro de Geografia e Estatística; 2011.
[17] Rech CR, Salomons E, Rodrigo L, Lima A De, Petroski EL, Grossa P, et al. Estimativa da Massa muscular esquelética em mulheres idosas: validade da impedância bioelétrica. Rev Bras Med Esporte 2010;16:95–8.
[18] Guigoz Y. The Mini Nutritional Assessment (MNA) review of the literature–What does it tell us? J Nutr Health Aging 2006;10:466–85.
[19] Rolland Y, Lauwers-Cances V, Cournot M, Nourhashémi F, Reynish W, Rivière D, et al. Sarcopenia, calf circumference, and physical function of elderly women: a cross-sectional study. J Am Geriatr Soc 2003;51:1120–4.
[20] Sánchez-García S, García-Peña C, Duque-López MX, Juárez-Cedillo T, Cortés-

Núñez AR, Reyes-Beaman S. Anthropometric measures and nutritional status in a healthy elderly population. BMC Publ Health 2007;7:2.
[21] Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85–94.
[22] Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontol 1969;9:179–86.
[23] Tieland M, Trouwborst I, Clark BC. Skeletal muscle performance and ageing. J Cachexia Sarcopenia Muscle 2018;9:3–19.
[24] Bouchard DR, Héroux M, Janssen I. Association between muscle mass, leg strength, and fat mass with physical function in older adults: influence of age and sex. J Aging Health 2011;23:313–28.
[25] Bouchard DR, Dionne IJ, Brochu M. Sarcopenic/obesity and physical capacity in older men and women: data from the Nutrition as a Determinant of Successful Aging (NuAge)-the Quebec longitudinal Study. Obesity 2009;17:2082–8.
[26] Martin AD, Spenst LF, Drinkwater DT, Clarys JP. Anthropometric estimation of muscle mass in men. Med Sci Sports Exerc 1990;22:729–33.
[27] Baumgartner RN, Stauber PM, McHugh D, Koehler KM, Garry PJ. Cross-sectional age differences in body composition in persons 60+ years of age. J Gerontol A Biol Sci Med Sci 1995;50:M307–16.
[28] Santana FD, Farah BQ, Soares AH, Correia MD, Dos Prazeres TM, Filho AL, et al. Anthropometric parameters as predictors of muscle mass in older women. Motricidade 2015;11:107–14.
[29] Pagotto V, Santos KFD, Malaquias SG, Bachion MM, Silveira EA. Calf circumference: clinical validation for evaluation of muscle mass in the elderly. Rev Bras Enferm 2018;71:322–8.
[30] Koppad AK, Kaulgud RS, Arun BS. A study of correlation of neck circumference with framingham risk score as a predictor of coronary artery disease. J Clin Diagn Res 2017;11:OC17–20.
[31] Pisciottano MV, Pinto SS, Szejnfeld VL, Castro CH. The relationship between lean mass, muscle strength and physical ability in independent healthy elderly women from the community. J Nutr Health Aging 2014;18:554–8.
[32] Garcia PA, Dias JM, da Silva Rocha AS, De Almeida NC, de Macedo OG, Dias RC. Relação da capacidade funcional, força e massa muscular de idosas com osteopenia e osteoporose. Fisioter Pesqui 2015;22:126–32.
[33] Carmeli E, Imam B, Merrick J. The relationship of pre-sarcopenia (low muscle mass) and sarcopenia (loss of muscle strength) with functional decline in individuals with intellectual disability (ID). Arch Gerontol Geriatr 2012;55:181–5.
[34] Antero-Jacquemin JD, Santos P, Garcia PA, Dias RC, Dias JM. Comparação da função muscular isocinética dos membros inferiores entre idosos caidores e não caidores. Fisioter Pesqui 2012;19:39–44.
[35] Shin H, Panton LB, Dutton GR, Ilich JZ. Relationship of physical performance with body composition and bone mineral density in individuals over 60 years of age: a systematic review. J Aging Res 2011;2011:191896.
[36] Janssen I, Baumgartner RN, Ross R, Rosenberg IH, Roubenoff R. Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. Am J Epidemiol 2004;159:413–21.
[37] Reid KF, Naumova EN, Carabello RJ, Phillips EM, Fielding RA. Lower extremity muscle mass predicts functional performance in mobility-limited elders. J Nutr Health Aging 2008;12:493–8.
[38] Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, et al. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol (1985) 2003;95:1851–60.
[39] Rantanen T, Guralnik JM, Foley D, Masaki K, Leveille S, Curb JD, et al. Midlife hand grip strength as a predictor of old age disability. J Am Med Assoc 1999;281:558–60.
[40] Rolland Y, Lauwers-Cances V, Pahor M, Fillaux J, Grandjean H, Vellas B. Muscle strength in obese elderly women: effect of recreational physical activity in a cross-sectional study. Am J Clin Nutr 2004;79:552–7.