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Predictors of probable sarcopenia and sarcopenia in older adults under outpatient geriatric care

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Abstract

Objectives: Sarcopenia is a prevalent systemic skeletal muscle disease common among older adults and those with chronic diseases. It is associated with poor health outcomes and economic implications, including higher healthcare costs, increased need for long-term care, and reduced productivity. Therefore, a rapid identification of older adults at high risk for sarcopenia may be a priority in all public healthcare settings. This study investigated predictive factors for probable sarcopenia and sarcopenia in older adults in outpatient care.

Methods: This cross-sectional study analyzed 511 Brazilian older adults (mean age=75.9±8.0 years, male-to-female ratio=1:1.62) followed at a public outpatient geriatrics clinic. Probable sarcopenia was defined by low skeletal muscle strength (SMS) as measured with a handgrip strength test. A diagnosis of sarcopenia was established when both SMS and calf circumference measurements were reduced. Variables were grouped according to demographic, body and appendicular anthropometric measurements, clinical, nutritional, and oral health status. Multinomial logistic regression analysis examined the relationship between independent variables and outcomes.

Results: Probable sarcopenia was predicted by higher height (OR 1.06, 95%CI 1.03–1.08), lower mid-upper arm bone-free muscle area (OR 1.74, 95%CI 1.04–2.89), and diagnosis of edentulism (OR 2.03, 95%CI 1.32–3.14). In turn, sarcopenia diagnosis was predicted by lower mid-upper arm muscle circumference (OR 0.69, 95%CI 0.58–0.81), malnutrition (OR 3.24, 95%CI 1.25–8.40), and risk of sarcopenia (OR 7.98, 95%CI 3.04–20.99), and a reduced number of functional tooth units (OR 0.92, 95%CI 0.86–0.99). Advancing age predicted both probable sarcopenia (OR 1.05, 95%CI 1.02–1.08) and sarcopenia (OR 1.05, 95%CI 1.01–1.11).

Conclusion: Appendicular anthropometric measurements and nutritional and oral health exams using reliable, low-cost, and easy-to-apply assessment methods emerged as accessible predictors of both probable sarcopenia and sarcopenia.

Keywords: health services for older adults; nutritional status; dental health surveys; sarcopenia.

INTRODUCTION

Sarcopenia is a progressive, systemic skeletal muscle disease characterized by a decrease in skeletal muscle strength (SMS) and mass (SMM) as well as reduced physical performance (PP). It may be caused by advancing age *per se* (primary sarcopenia) or by the association of aging with other chronic systemic diseases (secondary sarcopenia). The etiology of sarcopenia is multifactorial, involving both exogenous and endogenous etiologic factors.[1] Older adults with sarcopenia exhibit an increased likelihood of poor health outcomes, including bone fracture, functional decline, and mortality.[2] Globally, the prevalence of sarcopenia in older adults (≥ 60 years) ranged from 10 to 27% in older adults,[3] while in Brazil its prevalence ranged from 16 to 17% according to diagnostic criteria involving muscle mass and function assessments in older adults.[4] With the growing number of geriatric populations worldwide, sarcopenia has become a critical public health problem.[3]

The diagnosis of sarcopenia in older adults is based on findings of lower SMS, SMM, and PP; these same parameters are also used to classify severity. A low SMS now represents the main functional finding of a diagnosis of sarcopenia.[5,6] The revised consensus from the European Work Group on Sarcopenia in Older People (EWGSOP2) states that *probable sarcopenia* is present specifically when a low SMS is detected. The co-occurrence of low SMS and a low SMM establishes the *diagnosis of sarcopenia*. When lower SMS, SMM, and PP all occur together, sarcopenia is considered severe.[5]

The gold-standard techniques for SMM measurement include magnetic resonance imaging (MRI) and computed tomography (CT), while dual-energy X-ray absorptiometry (DEXA) is considered the reference standard.[7] However, these modalities often are not readily accessible in publicly funded health care services due to the high procurement and overhead costs of these devices.[1] Calf circumference (CC) measurement is a noninvasive, easy-to-perform, and reproducible anthropometrical method which is considered a good estimator of appendicular SMM; it is also highly correlated with poor functional capacity and diagnosis of sarcopenia in older adults.[8]

Protein-energy malnutrition is a multifactorial disorder characterized by a lack of energy and protein due to a deficiency of all macronutrients and many micronutrients. Frequently, malnutrition promotes body weight loss (BWL) due to wasting of skeletal muscle and fat tissues, but its causes are complex and not fully elucidated.[9] Importantly, malnutrition in older adults has been associated with poor health outcomes.[10]

Oral health is pivotal for several physical and psychological functions, as well as for social well-being. Across the lifespan, oral diseases negatively affect general health and quality-adjusted life expectancy.[11] Poor oral health status amongst older adults is clinically identified by a higher experience of dental caries, periodontal disease, tooth loss, edentulism, xerostomia, and impairment of mastication and swallowing processes.[12] A poor oral health status has been associated with anorexia, malnutrition, and BWL in older adults.[13] However, few studies have demonstrated an interaction between oral health status and sarcopenia in this population.[14]

Publicly funded health care systems are particularly interested in identifying factors predictive of sarcopenia in older adults. The early identification of sarcopenia may facilitate adoption of innovative multidisciplinary preventive and therapeutic approaches. Within this context, the present study aimed to identify predictors of probable sarcopenia and sarcopenia among a range of demographic factors, anthropometric measurements, normative oral health parameters, and high-risk status for malnutrition, for oropharyngeal dysphagia, and for sarcopenia in a representative sample of older adults.

METHODS

The *Strengthening the Reporting of Observational Studies in Epidemiology* (STROBE) recommendations were followed to ensure adequate reporting of this observational, cross-sectional study.[15]

The sample comprised 511 older adults aged ≥ 60 (mean age 75.9 ± 8.0 years, male-to-female ratio = 1:1.62) under outpatient care at a Brazilian public geriatric care service. All data were collected from participants over an 18-month period (April 2021 to October 2022). Although a non-probabilistic convenience sampling strategy was used, a simulated sample size calculation indicated the need to evaluate at least 385 individuals (considering an infinite population, 5% margin of error, 95% confidence, and 50% prevalence of the event of interest). All participants had the experimental procedures explained to them by three trained health professionals. Data were collected through validated questionnaires, tests, and examinations. The inclusion criteria were individuals aged ≥ 60 years, of either sex, not bedridden, who could answer questions and follow the instructions. The exclusion criteria were diagnosis of any acute inflammatory disease, therapeutically uncontrolled chronic disease, history or sequelae of locomotor disease, and cancer treatment in the preceding 5 years. Only participants for whom complete data were available were analyzed in this study, due to the small number of individuals (n = 3) who had missing information and were therefore removed (Figure 1). Written informed consent was obtained from all participants. This study received a favorable ethics opinion from a relevant ethics committee (CEP/CAAE: 10187919.7.0000.5146, No: 5467375).

The candidates for predictive factors of probable sarcopenia and sarcopenia in this study were divided into five domains:

demographic (age, gender, and skin color), anthropometric (height, body weight, body mass index [BMI], triceps skinfold thickness [TSF], mid-upper arm circumference [MUAC], mid-upper arm area [MUAA], mid-upper arm muscle bone-free area [UBMA], upper-arm fat area [UFA], and calf circumference [CC]), clinical (SMS, PP, polypharmacy, multimorbidity diagnosis, self-reported BWL, and at-risk status for sarcopenia), nutritional (at-risk status for malnutrition, diagnosis of malnutrition), and oral health (decay-missing-filled teeth [DMFT] index, number of remaining natural teeth [NRNT], number of healthy natural teeth [NHNT], number of filled teeth [NFT], number of decayed teeth [NDT], number of functional tooth units [FTU], number of missing teeth [NMT], edentulism, use of removable dental prostheses [RDP], and risk of oropharyngeal dysphagia [OD]).

Anthropometric measurements were obtained using standardized techniques.[16] Height was measured using a fixed stadiometer (Cescorf®, Porto Alegre, RS, BRA). Body weight was determined to the nearest 0.1 kg using a calibrated balance beam scale (HBF222-T, Omron®, Kyoto, JPN). BMI was calculated as the individual's weight (kg) divided by the square of height (m). TSF, MUAC, mid-upper arm muscle circumference (MUAMC), UFA, UBMA, and CC were measured according to international recommendations. The lowest cutoff values for the TSF, MUAC, MUAMC, and UFA variables are ≤ 5th percentile; for UBMA, values < 15th percentile were considered low.[16]

The SMM of each participant was estimated using the CC measurement. A hydraulic hand dynamometer (Jamar®, Chicago, IL, EUA) was used to measure the maximum voluntary handgrip strength (HGS). Participants were instructed to exert as much pressure as possible on the device for at least 4 s. They performed three trials with each hand, interspersed with rest periods of 20 seconds. The highest HGS measurement obtained was considered the absolute SMS value. The PP was assessed using the 4-m gait speed (4-mGS) test. The usual gait speed of each participant was determined by the best time to execute two consecutive 4-m trials.

The BWL variable was assessed using the participant's self-report recalled in the last six months, and the current body weight was measured using a scale. The diagnosis of multimorbidity (co-occurrence of two or more chronic systemic diseases) was established by assessing each participant's medical records based on evidence of treatment. Nutritional status was evaluated with the short-form mini nutritional assessment (MNA-SF) screening questionnaire, which comprises six items (decrease in food intake, BWL, mobility problems, psychological distress or acute disease, neuropsychological problems, and BMI). The maximum score is 14, with scores ≥ 11 representing normal nutritional status, scores < 11 indicating risk of malnutrition, and scores < 7 indicating malnutrition.[17] Risk of sarcopenia was assessed using the *strength, assistance with walking, rising from a chair, climbing stairs, and falling* (SARC-F) questionnaire, which is composed of five domains with one question each, and the answer scored between 0 and 2 points yielding a total score from 0 (best) to 10 (worst). Overall scores ≥ 4 are suggestive of sarcopenia and are predictive of poor health outcomes.[18]

The outcomes of interest in this study were diagnoses of probable sarcopenia and sarcopenia. According to EWGSOP2 guidelines,[5] probable sarcopenia is defined by a low SMS (HGS values < 27 kg in men and < 16 kg in women) alone. A diagnosis of sarcopenia was established by the combination

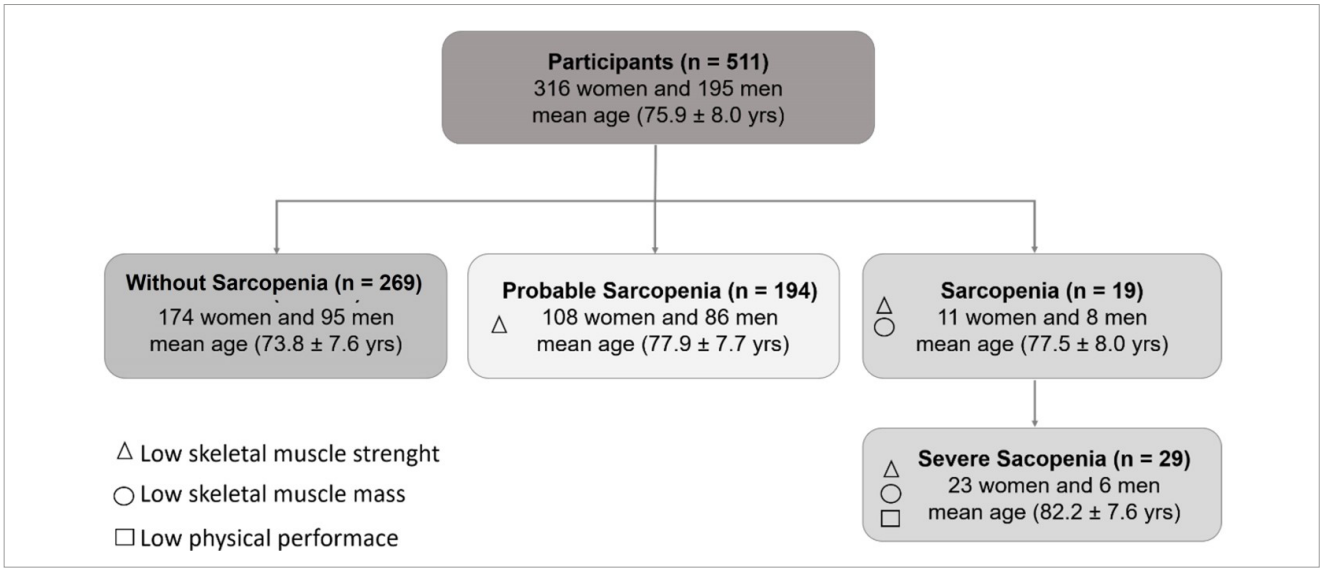

FIGURE 1. Flowchart of participant distribution according to sarcopenia staging.

of low SMS and low estimated SMM (CC cutoff values < 31 cm for both men and women). Severe sarcopenia was considered present when low SMS, low SMM, and poor PP (4m-GS test < 0.8 m/s for both men and women) all co-occurred. Individuals diagnosed with sarcopenia or severe sarcopenia were pooled into a single sarcopenia group.

For the oral and oropharyngeal health domain, two trained dentists assessed participants' normative oral health status following the World Health Organization (WHO) Oral Health Assessment criteria.[19] The DMFT index assessed the prevalence of dental caries and dental treatment needs of each participant. The dental assessment quantified the number of remaining natural teeth (NRNT), healthy natural teeth (NHNT), filled teeth (NFT), decayed teeth (NDT), and missing teeth (NMT). The NRNT considered the presence of erupted permanent natural teeth, classified dichotomously as < 20 or ≥ 20. Edentulism and use of partial or complete RDP were also assessed. The functional tooth units (FTU) index assesses occlusal status, defined as the number of pairs of natural or artificial (dental implant, fixed or removable dental prosthesis) opposing premolar and molar teeth with preserved crowns. FTU and NRNT are key determinants of the ability to chew food.[20] Quantitatively, the FTU ranges from 0 (entire absence of dental occlusion) to 12 (complete bilateral dental occlusion). Two premolars (first and second) that opposed each other were scored as 1, and two molars (first and second) that opposed each other were scored as 2. Concerning the type of occlusal contact, participants were categorized as follows: NN (occlusion exclusively performed with natural teeth), NA (occlusion between natural and artificial teeth), AA (occlusion exclusively performed with artificial teeth), and none (complete absence of occlusion). Finally, the distribution of FTUs was categorized as bilateral (presence of occlusal contacts occurring on both sides of the dental arch), unilateral (presence of occlusal contacts occurring on only one side of the dental arch), or absent. The clinical assessment for oropharyngeal dysphagia (OD) risk included the Modified Water Swallowing Test (MWST), which has 70% sensitivity and 88% specificity for detecting OD.[21] In this test, 3 ml of cold water is placed on the oral floor and the individual is instructed to swallow. Immediately after that, the participant is asked to perform two dry saliva swallows. The MWST classifies participants as follows: inability to swallow with choking and breathing changes (score 1), swallow occurs but with breathing changes (score 2), swallow occurs but with choking and wet hoarseness (score 3), swallow successful (score 4), and swallow successful with ability to perform two additional dry swallows within 30s (score 5). The worst performance of each participant was recorded for analysis.

For statistical analysis, the sample was characterized descriptively by absolute (n) and relative frequency (%) of categorical variables. Measures of central dispersion were expressed as mean (μ) ± standard deviation (SD) and 25th, 50th, and 75th percentiles for numerical variables. These independent variables were subjected to Kolmogorov-Smirnov tests of normality. Kruskal-Wallis, Pearson's chi-square, and Fisher's exact tests were applied for bivariate analysis. All variables with associations with $p < 0.20$ on bivariate analysis were selected to compose the subsequent multinomial logistic regression analysis. This type of regression is applied when the response variable is nominal with three or more categories that lack a natural order, as the proportional odds assumption for ordinal logistic regression was violated.[22] Multicollinearity between independent variables was tested (Spearman's correlation > 0.8, VIF < 10) and variables that did not meet these criteria were excluded. Multiple models were adjusted for potential confounders at a 5% significance level. Independent variables not identified as predictors were removed, and the model with the more significant percentage that explained the response variable (Nagelkerke's pseudo-R^2) was presented. Goodness of fit was assessed using the adjusted likelihood, deviance, pseudo-R^2, and Akaike information criterion (AIC) statistics. The estimated crude and adjusted odds ratios (OR) values and their 95% confidence interval (95%CI). All analysis were performed in SPSS® for Windows, version 25.0 (IBM Corp, Armonk, NY, USA).

RESULTS

Overall, 38% (n = 194), 3.7% (n = 19), and 5.7% (n = 29) of participants were diagnosed with probable sarcopenia, sarcopenia, and severe sarcopenia, respectively; participants without sarcopenia represented 52.6% (n = 269) of the sample (Figure 1). Table 1 exhibits the descriptive findings of the variables stratified into demographic, anthropometric, clinical, and oral and oropharyngeal health status domains. A predominance of women (61.8%, mean age: 75.8 ± 8.5) was identified compared to men (38.2%, mean age: 76.0 ± 8.1). The age distribution was as follows: 60–69 years, 23.9% (n = 122); 70–79 years, 40.3% (n = 206); and > 80 years, 35.8% (n = 183), with a predominance of women in all categories. The BW and height of men and women were 67.8 ± 12.4 kg, 1.66 ± 0.07 m, and 62.4 ± 14.7 kg, 1.53 ± 0.07 m, respectively. According to the BMI, 40.5, 40.1, and 19.4% of participants were classified as eutrophic, obese, or underweight, respectively. Unintentional BWL was self-reported by 212 (48.7%) of the participants. Low cutoff values were identified for TSF (n = 104, 20.4%), MUAC (n = 119, 23.3%), MUAMC (n = 74, 14.5%), UFA (n = 258, 50.5%), UBMA (n = 146, 28.6%), and CC (n = 69, 13.5%). The mean HGS values among men and women were 27.2 ± 7.2 kg

TABLE 1. Descriptive analysis of the demographic, anthropometrical, nutritional, clinical, oral and oropharyngeal health status of older adults under outpatient care (n = 511).

Variables	n (%)	$\bar{x} \pm SD$	P25%	P50%	P75%
		Demographic			
Age (years)	-	75.9 ± 8.0	70.0	76.0	82.0
60 – 69	122 (23.9)	-	-	-	-
70 – 79	206 (40.3)	-	-	-	-
> 80	183 (35.8)	-	-	-	-
Sex					
Female	316 (61.8)	-	-	-	-
Male	195 (38.2)	-	-	-	-
Anthropometric					
Weight (kg)	-	64.4 ± 14.2	54.4	63.7	73.7
Height (m)	-	1.6 ± 0.9	1.5	1.6	1.7
BMI (kg/m²)	-	25.7 ± 5.2	22.0	25.3	28.5
Eutrophy (22-27 kg/m²)	207 (40.5)	-	-	-	-
Obesity (> 27 kg/m²)	178 (34.8)	-	-	-	-
Malnutrition (< 22 kg/m²)	126 (24.7)	-	-	-	-
TSF (mm)	-	15.8 ± 8.5	9.0	14.0	20.3
MUAC (cm)	-	29.5 ± 4.8	26.0	29.2	32.5
MUAMC	-	24.5 ± 3.4	22.2	24.2	26.7
UFA (cm²)	-	22.3 ± 14.1	11.4	18.8	29.7
UBMA (cm²)	-	40.9 ± 13.5	31.7	39.0	48.2
CC (cm)	-	35.2 ± 4.1	32.3	35.0	37.7
HGS (Kgf)	-	20.5 ± 7.7	14.8	19.4	25.2
4m-GS (m/s)	-	0.9 ± 0.3	0.7	0.9	1.1
		Clinical			
BWL					
No	262 (51.3)	-	-	-	-
Yes	249 (48.7)	-	-	-	-
Diagnoses of multimorbidity					
No	167 (32.7)				
Yes	344 (67.3)				
Nutritional risk (MNA)					
Euthrophy (≥ 24)	270 (52.8)	-	-	-	-
Risk of malnutrition (17 – 23.5)	217 (42.5)	-	-	-	-
Malnutrition (< 17)	24 (4.7)	-	-	-	-
Sarcopenia risk (SARC-F)					
No	366 (71.6)	-	-	-	-
Yes	145 (28.4)	-	-	-	-
Oral health status					
Healthy teeth	-	3.6 ± 5.0	0.0	0.0	6.0
Decayed teeth	-	0.4 ± 1.1	0.0	0.0	0.0
Missing teeth	-	26.1 ± 7.9	23.0	32.0	32.0
Filled teeth	-	1.9 ± 3.8	0.0	0.0	2.0
DMFT	-	28.4 ± 5.0	26.0	32.0	32.0
NRNT	-	5.9 ± 7.9	0.0	0.0	9.0
Edentulism					
No	246 (48.1)	-	-	-	-
Yes	265 (51.9)	-	-	-	-
Use of RDP					
No	137 (26.8)				
Yes	322 (73.2)				
Number of FTU	-	6.62 ± 5.5	0.0	8.0	12.0

Continue...

TABLE 1. Continuation.

Variables	n (%)	$\bar{x} \pm SD$	P25%	P50%	P75%
Type of FTU					
NN	63 (12.3)	-	-	-	-
NA	120 (23.5)	-	-	-	-
AA	179 (35.0)	-	-	-	-
Missing	149 (29.2)	-	-	-	-
Distribution of FTU					
Bilateral	325 (63.6)	-	-	-	-
Unilateral	37 (7.2)	-	-	-	-
Missing	149 (29.2)	-	-	-	-
Oropharyngeal health					
OD risk					
No	489 (95.7)	-	-	-	-
Yes	22 (4.3)	-	-	-	-

The distribution of data frequency was presented as a number (percent) for categorical variables, and the central tendency was measured by mean ± standard deviation and percentiles 25%, 50%, and 75% for continuous variables.

$\bar{x} \pm SD$: mean and standard deviation. n (%) case and percentage values. P: percentile. BMI: body mass index; TSF: triceps skinfold thickness; MUAC: mid-upper arm circumference; MUAMC: mid-upper arm muscle circumference; UFA: mid-upper arm fat area; UBMA: mid-upper arm bone-free muscle area; CC: calf circumference; BWL: self-reported body weight loss; HGS: handgrip strength; 4m-GS (m/s): 4 meters gait speed; MNA: mini-nutritional assessment questionnaire; SARC-F: strength, assistance with walking, rising from a chair, climbing stairs, and falling questionnaire; DMFT: decayed, missing, and filled teeth; NRNT: number of remaining natural teeth; RDP: removable dental prosthesis; FTU: functional tooth units; NN: occlusion with natural teeth; NA: occlusion with natural and artificial teeth; AA: occlusion with artificial teeth; OD: oropharyngeal dysphagia.

(range, 10.1 to 46.4 kg) and 17.7 ± 4.9 kg (range, 3.5 to 30.7 kg), respectively. A low SMS was diagnosed in 185 (42.2%) participants, detected in 48.3% of men and 38.2% of women. Mean HGS was significantly higher in men than in women ($p = 0.000$). Participants aged > 80 had a significantly lower HGS than those aged 70–79 and 60–69 ($p = 0.022$ and $p = 0.002$, respectively). A low PP (< 0.8 m/s) detected by the 4m-GS test was diagnosed in 135 (30.8%) participants: 33.18% of men and 38.9% of women. Risk of malnutrition was diagnosed in 217 (42.5%) and 24 (4.7%) participants, respectively. Risk of sarcopenia was identified in 145 (28.4%) participants (Table 1).

The distribution of participants according to oral health status showed mean numbers of decayed, missing, and filled teeth of 0.4 ± 1.1, 26.1 ± 7.9, and 1.9 ± 3.8, respectively. The mean DMFT index of participants was 28.4 ± 5.0. Stratified by sex, the DMFT index was 27.6 ± 5.5 and 27.9 ± 4.86 for men and women, respectively. Mean NHNT and NRNT values were 3.6 ± 5.0 and 5.9 ± 7.9, respectively. A NRNT ≥ 21 was diagnosed in 8% (n = 41) participants, while 92% (n = 470) individuals had < 20 NRNT. The mean FTU value was 6.62 ± 5.4. Most participants (70.8%) had some occlusal contact. Bilateral and unilateral dental occlusion was identified in 63.6% and 7.2% of participants. Only 63 (12.3%) participants had FTU performed exclusively with natural-on-natural teeth (NN); most (35%) had FTU of the AA type. Absence of FTU was identified in 29.2% of participants. Edentulism and use of RDP were diagnosed in 51.9% and 73.2% of participants, respectively. Partial and complete RDPs were used by 16.2% and 63.0% of participants. Most participants were not at risk for OD (95.7%) (Table 1). Significant differences between control participants and those with probable sarcopenia were shown for age, height, nutritional risk, DMFT, and NRNT ($p < 0.05$). Comparisons between controls and individuals with sarcopenia evinced significant differences in age, weight, height, BMI, TSF, MUAC, MUAMC, UFA, UBMA, BWL, nutritional risk, DMFT index, and NRNT ($p < 0.05$). Significant differences between older adults diagnosed with probable sarcopenia and those with sarcopenia were shown for weight, height, BMI, TSF, MUAC, MUAMC, UFA, UBMA, BWL, nutritional risk, DMFT, and NHNT ($p < 0.05$). Finally, significant differences were noted between control participants and those with probable sarcopenia for sex and edentulism categories ($p < 0.05$). The diagnosis of sarcopenia in older adults was significantly associated with age, BMI, TSF, MUAC, MUAMC, UFA, UBMA, nutritional risk, sarcopenia risk, and edentulism ($p < 0.05$) (Tables 2 and 3). Table 4 shows the multinomial logistic regression analysis between sarcopenia stages and the independent variables of interest. The final adjusted model exhibited a likelihood of 764.377, X^2 (16) = 183,673 ($p < 0.001$), deviance X^2 (1004) ($p = 1.000$), Nagelkerke's $R^2 = 0.358$, AIC = 777, and 61.8% predictive ability. According to our findings, a diagnosis of probable sarcopenia was significantly predicted by greater age, higher height, lower UBMA, and diagnosis of edentulism. In turn, sarcopenia diagnosis was predicted by greater age, lower MUAMC, at-risk status for malnutrition and sarcopenia, and lower number of FTUs (Table 4).

TABLE 2. Comparisons between numerical independent variables and clinical staging of sarcopenia in older adults of this study.

Variables $\tilde{x}$ (IQR)	Clinical stages of sarcopenia in older adults			p-value
	Without sarcopenia (n = 269)	Probable sarcopenia (n = 194)	Sarcopenia (n = 48)	
Demographic				
Age (years)	73 (68.0 – 79.0)	78 (72.2 – 83.0)	82 (76.5 – 85.2)	**< 0.001**
Anthropometric				
Weight (kg)	66.3 (57.8 – 76.1)	63.1 (55.7 – 71.3)	45.9 (41.1 – 50.7)	**< 0.001**
Height (m)	1.56 (1.5 – 1.63)	1.61 (1.5 – 1.69)	1.51 (1.49 – 1.60)	**< 0.001**
BMI (kg/m²)	25.7(22.8 – 29.2)	25.6 (22.3 – 28.2)	20.3 (18.0 – 22.0)	**0.001**
TSF (mm)	15.0 (10.0 – 20.0)	14.0 (10.0 – 20.0)	8.0 (6.0 – 10.0)	**< 0.001**
MUAC (cm)	30.0 (27.5 – 33.0)	29.1 (26.0 – 32.5)	23.5 (21.9 – 24.9)	**< 0.001**
MUAMC (cm)	24.7 (23.1 – 27.1)	24.5 (22.2 – 26.5)	20.2 (18.9 – 22.0)	**< 0.001**
UFA (cm²)	21.5 (13.8 – 32.6)	18.6 (11.5 – 28.5)	9.0 (6.5 – 11.4)	**< 0.001**
UBMA (cm²)	40.7 (34.7 – 49.9)	38.8 (31.7 – 48.5)	25.1 (21.6 – 30.6)	**< 0.001**
Clinical				
BWL	0.0 (0.0 – 4.0)	0.0 (0.0 – 3.6)	3.0(0.25 – 5.0)	**0.002**
Nutritional risk	24.5 (22.0 – 26.5)	23.8 (21.0 – 25.5)	19.0 (16.9 – 22.0)	**< 0.001**
Oral health				
DMFT	29 (25.0 – 32.0)	32 (26.0 – 32.0)	32 (29.3 – 32.0)	**< 0.001**
NRNT	6 (0 – 12.0)	0 (0 – 7.0)	0 (0 – 6.0)	**< 0.001**
Healthy teeth	3 (0 – 7.0)	0 (0 – 6.0)	0 (0 – 2.7)	**< 0.001**
Decayed teeth	0 (0 – 0)	0 (0 – 0.0)	0 (0 – 0)	**0.014**
Missing teeth	26 (20.0 – 32.0)	32 (26.0 – 32.0)	32 (26.0 – 32.0)	**< 0.001**
Filled teeth	0 (0 – 3.0)	0 (0 – 1.0)	0 (0 – 0)	**< 0.001**
Number of FTU	11 (1.0 – 12.0)	10.0 (0 – 12.0)	1 (1.0 – 12.0)	**0.016**

Data were exhibited as median ($\tilde{x}$) and Interval interquartile (IQR). Kolmogorov-Smirnov test showed that data did not have a normal distribution. The comparison between the clinical stages of Sarcopenia and continuous variables of interest was analyzed for the Kruskal Wallis test with adjusted post-hoc Bonferroni. Differences were considered significant if $p < 0.05$.
Bold: independent variables selected for multiple model ($p < 0.2$).
BMI: body mass index; TSF: triceps skinfold thickness; MUAC: mid-upper arm circumference; MUAMC: mid-upper arm muscle circumference; UFA: mid-upper arm fat area; UBMA: mid-upper arm bone-free muscle area; CC: calf circumference; HGS: handgrip strength; 4m-GS (m/s): 4 meters gait speed; DMFT: Decayed, Missing, and Filled Teeth; NRNT: number of remaining natural teeth; FTU: functional tooth unit.

TABLE 3. Association between categorical demographic, anthropometrical, clinical, and oral and oropharyngeal health conditions variables and sarcopenia clinical stages in older adults.

Variables	Clinical stages of sarcopenia in older adults			p-value
	Without sarcopenia (n = 269)	Probable sarcopenia (n = 194)	Sarcopenia (n = 48)	
Demographic				
Sex				
Male	95 (48.7)	86 (44.1)	14 (7.2)	0.059
Female	174 (55.1)	108 (34.2)	34 (10.8)	
Age				
60 – 69	89 (73.0)	28 (23.0)	5 (4.1)	
70 – 89	113 (54.9)	82 (39.8)	11 (5.3)	**< 0.001**
> 80	67 (36.6)	84 (45.9)	32 (17.5)	
Anthropometrical				
BMI				
Eutrophy (22-27 kg/m²)	105 (50.7)	90 (43.5)	12 (5.8)	
Obesity (> 27 kg/m²)	112 (62.9)	65 (36.5)	1 (0.6)	**0.001**
Malnutrition (< 22 kg/m²)	52 (41.3)	39 (31.0)	35 (27.8)	
TSF (mm)				
Normal	231 (56.7)	159 (39.1)	17 (4.2)	**< 0.001**
Low	38 (36.5)	35 (33.7)	31 (29.8)	

Continue...

TABLE 3. Continuation.

Variables	Clinical stages of sarcopenia in older adults			p-value
	Without sarcopenia (n = 269)	Probable sarcopenia (n = 194)	Sarcopenia (n = 48)	
MUAC (cm)				
Normal	233 (59.4)	148 (37.8)	11 (2.8)	**< 0.001**
Low	36 (30.2)	46 (38.7)	37 (31.1)	
MUAMC (cm)				
Normal	246 (56.3)	161 (36.8)	30 (6.9)	**< 0.001**
Low	23 (31.1)	33 (44.6)	18 (24.3)	
UFA (cm^2)				
Normal	152(60.1)	99 (39.1)	2 (0.8)	**< 0.001**
Low	117 (45.2)	95 (36.8)	46 (17.8)	
UBMA (cm^2)				
Normal	217 (59.5)	132 (36.2)	16 (4.3)	**< 0.001**
Low	52 (35.6)	62 (42.5)	32 (21.9)	
		Clinical		
Diagnosis of comorbidities				
No	96 (57.5)	60 (35.9)	11 (6.6)	0.178
Yes	173 (50.3)	134 (39.0)	37 (10.8)	
Nutritional risk (MNA)				
No	166 (61.5)	97 (35.9)	7 (2.6)	**< 0.001**
Malnutrition	103 (42.7)	97 (40.2)	41 (17.0)	
Risk of sarcopenia (SARC-F)				
No	222 (60.7)	137 (37.4)	7 (1.9)	**< 0.001**
Yes	47 (32.4)	57 (39.3)	41 (28.3)	
		Oral health		
Edentulism				
No	155 (63.0)	76 (30.9)	15 (6.1)	**< 0.001**
Yes	114 (43.0)	118 (44.5)	33 (12.5)	
Use of RDP				
No	196 (52.4)	148 (39.6)	30 (8.0)	0.153
Yes	73 (53.3)	46 (33.6)	18 (13.1)	
Type of FTU				
NN	45 (71.4)	14 (22.2)	4 (6.3)	**< 0.001**
NA	72 (60.0)	42 (35.0)	6 (5.0)	
AA	91 (50.8)	73 (40.8)	15 (8.4)	
Missing	61 (40.9)	65 (43.6)	23 (15.4)	
Distribution of FTU				
Bilateral	186 (57.2)	116 (35.7)	23 (7.1)	**0.004**
Unilateral	22 (59.5)	13 (35.1)	2 (5.4)	
Missing	61 (40.9)	65 (43.6)	23 (15.4)	
		Oropharyngeal health		
Risk of OD				
No	259 (53.0)	186 (38.0)	44 (9.0)	0.354
Yes	10 (45.5)	8 (36.4)	4 (18.2)	

Variables were exhibited as number of cases (n) and percentual (%) values. Statistical differences were detected with χ^2 or Fisher's exact test. Differences were considered significant if $p < 0.05$.

Bold: independent variables selected for the multiple models ($p < 0.2$)

BMI: body mass index; TSF: triceps skinfold thickness; MUAC: mid-upper arm circumference; MUAMC: mid-upper arm muscle circumference; UFA: mid-upper arm fat area; UBMA: mid-upper arm bone-free muscle area; CC: calf circumference; MNA: mini-nutritional assessment questionnaire; SARC-F: strength, assistance with walking, rising from a chair, climbing stairs, and falling questionnaire; DMFT: Decayed, Missing, and Filled Teeth; NRNT: Number of Remaining Natural Teeth; RDP: removable dental prosthesis; FTU: Functional Tooth Units; NN: occlusion with natural teeth; NA: occlusion with natural and artificial teeth; AA: occlusion with artificial teeth; OD: oropharyngeal dysphagia.

TABLE 4. Adjusted multinomial logistic regression model with independent variables tested for predicting probable sarcopenia and sarcopenia in older adults.

Variables	n (%)	Clinical stages of sarcopenia in older adults	
		Probable sarcopenia	Sarcopenia
		OR (95%CI)	OR (95%CI)
UBMA (cm^2)			
Normal	365 (71.4)	1	1
Low	146 (28.6)	**1.74 (1.04 – 2.89)***	2.04 (0.82 – 5.07)
Nutritional risk			
No	270 (52.8)	1	1
Yes	241 (47.2)	1.41 (0.93 – 2.12)	**3.24 (1.25 – 8.40)***
Sarcopenia risk			
No	366 (71.6)	1	1
Yes	145 (28.4)	1.28 (0.77 – 2.13)	**7.98 (3.04 – 20.99)†**
Edentulism			
No	246 (48.1)	1	1
Yes	265 (51.9)	**2.03 (1.32 – 3.14)***	2.09 (0.85 – 5.18)
Variables	**x̃ (IQR)**	**Probable sarcopenia**	**Sarcopenia**
		OR (95%CI)	**OR (95%CI)**
Age (years)	76.0 (70.0-82.0)	**1.05 (1.02 – 1.08)†**	**1.05 (1.01 – 1.11)†**
Height (m)	1.6 (1.5-1.7)	**1.06 (1.03 – 1.08)***	0.99 (0.95 – 1.01)
MUAMC (cm)	24.2 (22.1-26.7)	1.01 (0.94 – 1.08)	**0.69 (0.58 – 0.81)†**
Number of FTU	8.0 (0.0-12.0)	0.98 (0.95 – 1.02)	**0.92 (0.86 – 0.99)***

OR: odds ratio; 95%CI: 95% confidence interval; x̃ (II): median and interquartile range (IQR).
Statistical differences between groups were detected with multinomial logistic regression analysis.
Bold: differences were considered significant if *$p < 0.05$ and †$p < 0.001$.
UBMA: mid-upper arm bone-free muscle area; MUAMC: mid-upper arm muscle circumference; FTU: functional tooth unit.

DISCUSSION

In this study, greater height, lower UBMA, and a diagnosis of edentulism predicted the diagnosis of probable sarcopenia in older adults from an outpatient geriatric care sample. In turn, lower MUAMC measurement, reduced number of occlusal contacts, and increased odds for malnutrition and sarcopenia risk predicted the diagnosis of sarcopenia. A greater age was significant predictive factor for both probable sarcopenia and sarcopenia. Advanced age is a classic risk factor for sarcopenia.[1] In our sample, the odds ratios for both probable sarcopenia and sarcopenia increased 5% with each year of an individual's life.

Aging is accompanied by progressive morphofunctional changes in muscle tissue, which are responsible for both SMM and SMS losses. However, a conflict has been highlighted between the critical achievement of a greater human life expectancy and the growing increase of financial expenditures caused by the increased use of public social and health care services. Anthropometric measurements have been used as reliable indicators of nutritional status, body composition, health and dietary status, and future disease risk in older adults.[23] According to our findings, a decrease of one square centimeter for both UBMA and MUAMC measurements increase the likelihood of probable by 74% and of sarcopenia by 31%. In older adults, appendicular anthropometric measurements are good SMM estimators and predictors of malnutrition and sarcopenia.[24] The MNA-SF is the most validated tool for assessment of malnutrition risk in older adults.[9] Moreover, the ability of malnutrition to predict sarcopenia in older adults has been established.[10] Our findings showed that older adults with malnutrition have a 9.4-fold higher likelihood of a sarcopenia diagnosis. A systematic review with meta-analysis carried out with most cross-sectional studies showed that older adults with malnutrition exhibited a low mean number of present teeth and lower number of FTUs.[25] In our study, tooth loss, edentulism, and use of RDP were identified in 47.2%, 27.0%, and 35.2% of older adults with malnutrition, respectively (data not shown), which highlights the close relationship between malnutrition and poor oral health status. Furthermore, older adults with higher SARC-F scores were 27.6 times more likely to present with sarcopenia. The SARC-F has been reported to have variable performance, exhibiting low-to-moderate sensitivity but a very high specificity in screening older adults for sarcopenia.[26] The questionnaire has been combined with specific markers to obtain a higher sensitivity. Incorporating the CC measurement into the SARC-F questionnaire promoted greater sensitivity and higher discrimination ability without compromising specificity for diagnosis of sarcopenia in older adults.[27]

Although the oral health of older adults has improved over the past decade worldwide, poor oral health status was particularly evident among our participants. In our sample, the diagnosis of edentulism doubled the odds of a diagnosis of probable sarcopenia, while a lower FTU number increased the odds of sarcopenia by 8%. Although edentulism was diagnosed by around 50% of participants in this study, 73.2 of these individuals were users of partial or complete RDP (data not shown). The association between edentulism and sarcopenia in older adults has been established,[28] as has the association between FTU losses and risk of sarcopenia.[29] Both malnutrition risk and sarcopenia risk may result from reduced chewing ability restrictions due to tooth loss and masticatory muscle weakness in older adults.[30] Although oral health interventions are usually not part of the general medical care of older adults,[10] it is important that all health professionals understand the importance of oral health conditions as drivers of malnutrition and sarcopenia pathogenesis in these individuals.

Some limitations of this study are worth noting. Initially, we had a cross-sectional design, which was inappropriate for establishing cause-effect relationships. The sample size is rather small; however, all participants were recruited from a public geriatric outpatient care setting. The occurrence of bias in the study due to the influence of unmeasured behavioral and clinical variables must also be considered. There are many reasons for using CC measurement to estimate SMM estimate. However, there are also reasons to consider using CC to estimate SMM, notably the reliability of the SMM estimate provided by reference and gold- standard imaging techniques. On the other hand, the findings of this study were obtained in a sample of older adults that were autonomous and independent. All participants were users of public health services accessible to the entire population, including those in situations of greater socioeconomic vulnerability.

CONCLUSIONS

In conclusion, mid-upper appendicular anthropometric measurements, examination of occlusion status and tooth loss, and assessments of malnutrition and sarcopenia risk emerged as accessible predictors of both probable sarcopenia and sarcopenia, highlighting the importance of integrating oral, nutritional, and anthropometric assessments to provide reliable, cost-effective, easy-to-apply, and noninvasive sarcopenia screening in high-risk older adults in public health care settings. Future longitudinal studies will be appropriate to investigate causal relationships between variables and validate findings in diverse geriatric populations and different public health service scenarios.

DECLARATIONS

Conflict of interest

The authors declare no conflicts of interest.

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Author´s contributions

Hérika Maria Silveira Ruas: data curation, investigation, writing – original draft. Luciana Mara Barbosa Pereira: data curation, formal analysis, methodology. Carla Dayane Durães Abreu: investigation. Yara Cristina de Paiva Maia: writing – review & editing. SHSS: investigation, writing – review & editing. Eli Carlos Pereira de Jesus: data curation, investigation. Luciana Colares Maia: investigation. Renato Sobral Monteiro-Junior: formal analysis, investigation. Sérgio Henrique Sousa Santos: writing – review & editing; Desirée Sant´Ana Haikal: conceptualization, formal analysis, writing – review & editing. Alfredo Maurício Batista de Paula: conceptualization, data curation, funding acquisition, project administration, writing – original draft.

Ethical approval and informed consent

All individuals participating in this study signed a consent form which informed them about the research. This study received a favorable ethics opinion (CAAE: 10187919.7.0000.5146, No. 5467375).

Data availability statement

Data from this study may be available to other researchers upon reasonable request. The authors also plan to make appropriate standard format metadata available through the public repository hosted on the UNIMONTES website after publication of the study.

Reporting standards guidelines

This manuscript has been prepared following the STROBE checklist for for reporting cross-sectional studies.

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