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Osteosarcopenia later in life: Prevalence and associated risk factors

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SUMMARY

Background and aims: The identification of risk factors for osteosarcopenia in older adults is important for planning preventative strategies in clinical practice. Therefore, our study aimed to investigate the prevalence and risk factors associated with osteosarcopenia in older adults using different diagnostic criteria.

Methods: The sample included 171 community-dwelling older adults with a mean age of 79.4 ± 5.9 years and mean body mass index of 25.67 ± 4.70 kg/m^2. We analyzed sociodemographic, biomarkers, lifestyle, and health condition data from participants of the "*Projeto Idosos - Goiânia*" cohort study. The outcome osteosarcopenia was defined as the simultaneous occurrence of sarcopenia and osteopenia. Osteopenia was diagnosed by low lumbar spine bone mineral density (BMD) using dual-energy X-ray absorptiometry (DEXA). Sarcopenia was diagnosed using handgrip dynamometry and appendicular skeletal mass index assessed by DEXA following the criteria of the two European consensuses on sarcopenia (2010 and 2018). Two osteosarcopenia outcome variables were evaluated: OsteoSarc1 and OsteoSarc2 using the 2010 and 2018 European sarcopenia consensus criteria, respectively. Multivariate Poisson regression analysis was used to calculate the prevalence ratios (PRs).

Results: The prevalence of OsteoSarc1 and OsteoSarc2 were 12.8% and 7.2%, respectively, with no significant gender differences. OsteoSarc1 was associated with low potassium (PR: 3.39, 95% confidence interval [CI]: 1.10–10.43) and malnutrition (PR: 3.84, 95% CI: 1.78–8.30). OsteoSarc2 was associated with being ≥80 years (PR: 7.64, 95% CI: 1.57–37.07), >4 years of education (PR: 3.25, 95% CI: 1.03–10.22), alcohol consumption (PR: 2.41, 95% CI: 1.01–5.77), low potassium (PR: 2.22, 95% CI: 1.45–6.87), low serum vitamin D (PR: 4.47, 95% CI: 1.68–11.88), and malnutrition (PR: 5.00, 95% CI: 1.06–23.51).

Conclusions: OsteoSarc1 had a higher prevalence. The risk factors associated with the two outcomes were malnutrition and potassium level, as well as other risk factors, such as alcohol consumption and low vitamin D level. These findings may contribute to the prevention or treatment of this health condition in older adults.

1. Introduction

Osteosarcopenia is a newly described syndrome that consists of the co-existence of osteoporosis and sarcopenia, two chronic musculoskeletal conditions associated with aging [1]. Sarcopenia [2], the loss of muscle mass, strength, and function, and osteoporosis, a condition of low bone mass and micro-architectural deterioration of bone [3], often co-exist in a frail subset of the elderly population, leading to significantly worsened outcomes than seen in either condition alone [1,3–13]. Both musculoskeletal morbidities have common risk factors [6,7] that can negatively affect independence and functionality later in life [8]. Osteosarcopenia, has been associated with a higher risk of falls, fractures, frailty, and mortality compared to individuals diagnosed with only osteopenia/

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osteoporosis or sarcopenia [6,7,9,10]. Although the definition of osteosarcopenia is relatively new, advanced age has been well established as an important risk factor [6]. Recent studies have identified other risk factors [4,5], such as malnutrition [11–14], higher percentage of body fat [11,15], diabetes [11] depression [14], inactive physical activity [11,12], and lower educational level [11].

Evidence on older adults from Japan [15], Iran [11], Germany [16], Australia [14], and China [17] showed a prevalence of osteosarcopenia ranging from 4% to 29% in men and from 12% to 39% in women. The selection of the diagnostic criteria for both sarcopenia and osteopenia/osteoporosis, as well as the characteristics of the investigated population i.e., whether institutionalized, hospitalized, or community-dwelling, will influence the prevalence of osteosarcopenia and its associated risk factors. In the absence of a consensus on osteosarcopenia [11,15,17], it is important that studies use more than one diagnostic criterion to assess both its prevalence and associated risk factors.

The public health impact of osteosarcopenia later in life and the paucity of evidence on its occurrence and associated factors in community-dwelling older adults [11,15,18], particularly in Latin America with only one study carried in Chilean older adults [19] have motivated us to conduct the present analysis. Therefore, the main objective of this study was to identify the prevalence of osteosarcopenia and its associated risk factors in community-dwelling older adults. As the identification of risk for osteosarcopenia in older adults is important for planning preventative strategies in clinical practice, the present study analyzed several biomarkers, sociodemographic, and health status variables as potential risk factors. Owing to the lack of standardization of the diagnostic criteria for osteosarcopenia and the use of different criteria in previous studies [9,11,15,17], this study used two different criteria for the diagnosis of sarcopenia.

2. Materials and methods

2.1. Design, target population, and data collection

This cross-sectional study was nested in a cohort study named "*Projeto Idosos - Goiânia*" which began in 2008 in community-dwelling individuals aged 60 or older. It evaluated 418 participants randomly recruited by multistage sampling at baseline, according to the proportion of health districts in Goiânia [20–22].

The study included only participants who underwent a dual-energy X-ray absorptiometry (DEXA) assessment in the 2018/19 follow-up to obtain the bone mineral density (BMD), a variable used to define the outcome variable osteosarcopenia. At the wave of 2018/2019, the participants were aged 70 and older.

Data collection was performed by trained interviewers and anthropometric evaluators. Anthropometric and body composition data were collected using standardized techniques. All the participants signed an informed consent form. Further details regarding the *Projeto Idosos – Goiânia* cohort are available in previous publications [20–22].

2.2. Sociodemographic characteristics

The sociodemographic variables included were sex (male and female), age group (70–79 and ≥80), skin color (white and brown/black), living with a partner (yes or no), years of the study (0–4 and >4) and socioeconomic class categorized as A/B, C, D/E (average household income = A/B > $359; C $129 to $212; D/E < $88) according to the Brazilian Association of Population Studies.

2.3. Lifestyle

The lifestyle variables investigated were smoking status (non-smoker and smoker/ex-smoker), alcohol consumption (yes or no), level of physical activity, and food consumption. The following groups were considered for physical activity level: active (very active and active) and inactive (irregular active A and B and sedentary), based on the International Physical Activity Questionnaire (IPAQ) [23].

Eating habits were obtained from the Food Frequency Questionnaire (FFQ), which was used [24] to check the daily consumption of foods, which are sources of protein, calcium, and vitamin D. The following questions were asked to categorize the consumption of these foods: "In general, how often do you eat these foods?" Before starting the questions, the participants were instructed to think about their eating habits in the previous year. The response options were as follows: 1) never, 2) rarely (less than once a month), 3) once a month, 4) 2–3 times a month, 5) 1–2 times a week, 6) 3–4 times a week, 7) 5 or 6 times a week, and 8) once a day or more [24]. For protein sources, this study considered daily consumption of four or more foods per day according to foods or food groups established in the FFQ. Three or more foods were considered sources of calcium and vitamin D.

2.4. Biomarkers

For the biochemical analysis, blood collection was performed by a qualified professional with gerontological experience. Participants were asked to fast for 12 h. Blood sample tubes were identified with tags containing the participants' data, including name, birth date, sex, and collection date. The following reference values were considered inappropriate: total cholesterol ≥200 mg/dL, high density lipoprotein-cholesterol (HDL-c) ≤ 40 mg/dL, low density lipoprotein-cholesterol (LDL-c) ≥ 160 mg/dL, and triglycerides ≥200 mg/dL [25]; potassium ≤3.4 or > 5.5 mmol/dL and calcium ≤8.4 or ≥ 11 mg/dL [26]; fasting blood glucose ≥100 mg/dL [27] and serum vitamin D < 20 ng/mL [28].

2.5. Health conditions

Nutritional status was defined using the body mass index (BMI), with the participants being classified as malnourished with a BMI <22 kg/m^2 [29]; excess adiposity was classified by percentage of body fat (%BF) ≥ 20% for men and ≥35% for women [30]. Falls and hospitalizations were self-reported by the participants and categorized as "yes" or "no" [31,32] The frailty variable was analyzed using a screening instrument for self-reported assessment in older adults previously validated in Brazil [33].

2.6. Anthropometric and body composition assessments

Body weight was measured using a previously calibrated Tanita electronic scale (UM 080 W) with a capacity of up to 150 kg and 100 g accuracy, with the participants barefoot and wearing light clothing. A portable stadiometer with a 20–205 cm scale was used to measure the height. Subsequently, the body weight and height data were used to calculate the BMI. Nutritional status was classified using BMI as recommended by the World Health Organization (WHO): underweight (<18.5 kg/m^2), normal weight (18.6–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30 kg/m^2).

Whole body composition was evaluated using a DEXA device with a Lunar® whole body scanner (DPX-MD PLUS), software version 7.52.002 DPX-L, which was calibrated daily. The participants were fasting, not using diuretic medication, had body mass below 110 kg and height below 1.90 m, and performed no vigorous physical

activity in the 24 h prior to the test. They were asked to lie down in a supine position and remain stationary during the test. The variables considered for this study were BF% and kg, appendicular skeletal mass, and lumbar spine BMD (L1 to L4). Appendicular skeletal mass was adjusted by the height squared to determine the variable appendicular skeletal mass index (ASMI) [2].

2.7. Osteosarcopenia assessment

The outcome measure was evaluated by the presence of osteopenia and sarcopenia [1], according to the parameters described below. All the body composition variables were evaluated using DEXA.

For the diagnosis of osteopenia, the BMD in the lumbar spine region (L1 to L4) was evaluated using data expressed as relative values (t-score). Therefore, the World Health Organization diagnostic criteria was used to classify the participants with osteopenia using a t-score value of $-2.5 < T < -1$ [3].

Sarcopenia was identified using the two criteria established by the European Working Group on Sarcopenia in Old People (EWGSOP) 1 and 2 [2,34]. According to the EWGSOP 1 criteria, the cutoff points were as follows: ASMI <7.23 kg/m^2 for men and <5.67 kg/m^2 for women; muscle strength (handgrip strength using a JAMAR® dynamometer, HandMonometer, Sammons Preston, Inc., Bolingbrook, IL [35]) < 30 kgf for men and <20 kgf for women. For the EWGSOP 2 criterion, the cutoff points were as follows: ASMI <7.0 kg/m^2 for men and <5.5 kg/m^2 for women; muscle strength <27 kgf for men and <16 kgf for women.

Osteosarcopenia was defined as the presence of osteopenia concomitant with sarcopenia using one of the two criteria for sarcopenia, which can be classified as follows.

(i) OsteoSarc1: Older adults with osteopenia and sarcopenia according to the EWGSOP 1.
(ii) OsteoSarc2: Older adults with osteopenia and sarcopenia according to the EWGSOP 2.

2.8. Statistical analysis

Double-entry data were registered for greater reliability. Statistical analyses were performed using the STATA/SE software version 12.0. First, we investigated the distribution of variables regarding their normality using the Kolmogorov–Smirnov test. After the descriptive analysis, the prevalence of osteosarcopenia was estimated and, as a measure of effect, the prevalence ratio (PR) with their respective 95% confidence intervals (CIs) were calculated.

The association of the outcomes with exposure variables was estimated using a simple Poisson regression analysis with robust variance. Variables with a p-value <0.20 in the bivariate analysis were included in a hierarchical multivariate analysis model using the Poisson regression. The variables were classified into three distal-proximal levels: First level: sociodemographic variables, second level: lifestyle variables, and third level: health and biochemical variables. Variables presenting a p-value ≤0.05 were included in the model.

3. Results

The study sample comprised 171 participants. The mean age was 79.4 ± 5.9 years (69–96 years) and the mean BMI was 25.67 ± 4.70 kg/m^2. Women comprised 65.1% of the sample. Regarding their nutritional status, 7 (4.1%) were underweight, 55 (32.2%) eutrophic, 55 (32.2%) overweight and 54 (31.6%) obese.

The prevalence of OsteoSarc1 was 12.8% and OsteoSarc2 7.2%, respectively. There was no difference ($p = 0.824$) in OsteoSarc1 between women (13.3%) and men (12.1%). Likewise, OsteSarc2 showed no significant difference ($p = 0.222$) between men (10.3%) and women (5.3%) (Fig. 1). The prevalence of osteopenia, osteoporosis, and sarcopenia is shown in the supplementary file.

Age ≥80 years ($p = 0.008$) was associated with OsteoSarc2. Other sociodemographic and lifestyle variables were not associated with OsteoSarc1 and OsteoSarc2 (Table 1). Inadequate potassium levels ($p = 0.045$) and adequate triglyceride levels ($p = 0.048$) were associated with OsteoSarc1 (Table 2). OsteoSarc2 was associated with inadequate vitamin D levels ($p = 0.047$) (Table 2).

Considering the health condition variables, malnutrition was significantly associated ($p < 0.001$) with both outcomes, OsteoSarc1 and OsteoSarc2 (Table 3).

The variables included in the multivariate analysis ($p \leq 0.20$) considering the outcome OsteoSarc1 were age group (first level), smoking and consumption of foods rich in calcium (second level), triglycerides, potassium, HDL-c, and malnutrition (third level). OsteoSarc2 included the variables age group and years of education (first level), consumption of alcoholic beverages and food protein sources (second level), and total cholesterol, potassium, vitamin D, HLD-c, and malnutrition (third level).

In the multivariate analysis, the factors significantly associated with OsteoSarc1 were inadequate potassium levels (PR: 3.39, 95% CI: 1.10–10.43) and malnutrition (PR: 3.84, 95% CI: 1.78–8.30). OsteoSarc2 was associated with six factors: age ≥80 y (PR: 7.64, 95% CI: 1.57–37.07); >4 years of education (PR: 3.25, 95% CI: 1.03–10.22); alcohol consumption (PR: 2.41, 95% CI: 1.01–5.77); inadequate potassium levels (PR: 2.22, 95% CI: 1.45–6.87); inadequate vitamin D levels (PR: 4.47, 95% CI: 1.68–11.88); and malnutrition (PR: 5.00, 95% CI: 1.06–23.51) (Table 4).

4. Discussion

To the best of our knowledge, this is the second study in the world and the first in the American continent to analyze the prevalence of osteosarcopenia and its associated risk factors in community-dwelling older adults using two diagnostic criteria for sarcopenia [2,34]. The prevalence of osteosarcopenia in community-dwelling older adults was identified using two diagnostic criteria. In addition, we evaluated a wide range of covariates as potential risk factors for osteosarcopenia that are still poorly

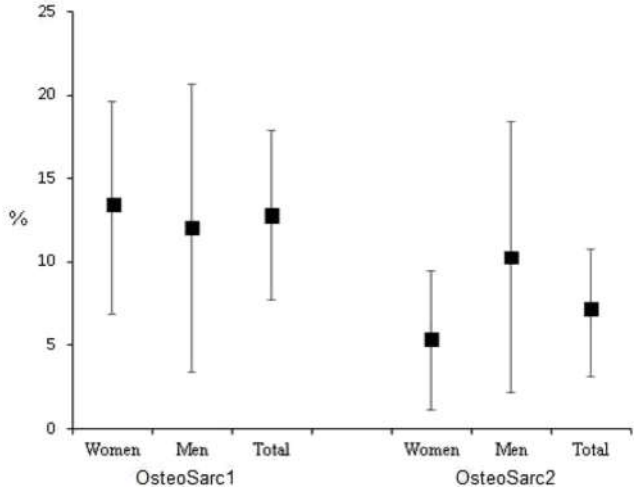

Fig. 1. - Prevalence of osteosarcopenia by sex in community-dwelling older people.

Table 1
Prevalence of osteosarcopenia associated with sociodemographic and lifestyle variables in community-dwelling older people.

Variables	n (%)	OsteoSarc1.		*p*-value*	OsteoSarc2.		*p*-value*
		Prevalence n (%)	PR (95% CI)		Prevalence n (%)	PR (95% CI)	
Sex				0.825			0.230
Female	113 (66.1)	15 (13.3)	1.10 (0.47–2.55)		6 (5.3)	1.0	
Male	58 (33.9)	7 (12.1)	1.0		6 (10.3)	1.94 (0.65–5.79)	
Age group				0.151			**0.008**
70–79	102 (59.6)	10 (9.8)	1.0		2 (1.9)	1.0	
≥80 years old	69 (40.4)	12 (17.4)	1.77 (0.81–3.88)		10 (14.5)	7.39 (1.66–32.84)	
Skin color				0.454			0.855
White	104 (60.8)	15 (14.4)	1.38 (0.59–3.21)		7 (6.7)	1.0	
Pardo/black	67 (39.2)	7 (10.5)	1.0		5 (7.5)	0.90 (0.29–2.73)	
Living with a partner				0.906			0.889
No	68 (39.8)	9 (13.2)	1.04 (0.47–2.32)		5 (7.35)	1.08 (0.35–3.28)	
Yes	103 (60.2)	13 (12.6)	1.0		7 (6.80)	1.0	
Economic class				0.461			0.894
A/B	27 (15.8)	5 (18.5)	2.34 (0.61–9.02)		2 (7.4)	1.40 (0.21–9.43)	
C	106 (62.0)	14 (13.2)	1.67 (0.50–5.52)		8 (7.5)	1.43 (0.31–6.48)	
D/E	38 (22.2)	3 (7.9)	1.0		2 (5.3)	1.0	
Years of study				0.210			0.094
0–4	115 (68.9)	12 (10.4)	1.0		5 (4.3)	1.0	
<4	52 (31.1)	9 (17.3)	1.65 (0.74–3.69)		6 (11.5)	2.65 (0.84–8.33)	
Smoking				0.171			0.235
Non-smoker	85 (49.7)	14 (16.5)	1.77 (0.78–4.01)		8 (9.4)	2.02 (0.63–6.49)	
Smoker/ex-smoker	86 (50.3)	8 (9.3)	1.0		4 (4.6)	1.0	
Alcoholic beverage consumption				0.674			0.074
No	145 (84.8)	18 (12.4)	1.0		8 (5.5)	1.0	
Yes	26 (15.2)	4 (15.4)	1.23 (0.45–3.37)		4 (15.4)	2.78 (0.90–8.62)	
Sitting hours during 1 day of the week				0.857			0.805
<8	118 (69.8)	15 (12.7)	1.0		8 (6.8)	1.0	
≥8	51 (30.2)	7 (13.7)	1.08 (0.46–2.49)		4 (7.8)	1.15 (0.6–3.68)	
Physical activity level				0.226			0.878
Inactive	94 (57.7)	9 (9.6)	1.0		6 (6.3)	0.90 (0.26–3.10)	
Active	69 (42.3)	11 (15.9)	1.66 (0.72–3.80)		4 (5.8)	1.0	
Daily consumption of food sources of calcium				0.108			0.643
Inadequate	148 (87.6)	17 (11.5)	1.0		10 (6.7)	1.0	
Adequate	21 (12.4)	5 (23.8)	2.07 (0.85–5.04)		2 (9.5)	1.40 (0.32–6.02)	
Daily consumption of food sources of protein				0.230			0.171
Inadequate	89 (53.0)	9 (10.1)	1.0		4 (4.5)	1.0	
Adequate	79 (47.0)	13 (13.5)	1.62 (0.73–3.60)		8 (10.1)	2.25 (0.70–7.22)	
Daily consumption of food sources of vitamin D				0.954			0.400
Inadequate	139 (82.3)	18 (12.9)	1.0		11 (7.9)	2.37 (0.31–17.8)	
Adequate	30 (17.7)	4 (13.3)	1.02 (0.37–2.83)		1 (3.3)	1.0	

Notes: PR: Prevalence ratio; 95% CI: 95% confidence interval; *Wald's test.
OsteoSarc1 definition of sarcopenia by the 2010 European Society and Osteopenia/Osteoporosis by the World Health Organization (WHO) (1994).
OsteoSarc2 definition of sarcopenia by the 2018 European Society and Osteopenia/Osteoporosis by the WHO (1994).

investigated, such as food consumption, alcohol consumption, biochemical and micronutrient tests, and some health conditions prevalent later in life. Older age, years of education, drinking alcoholic beverages, inadequate levels of potassium and vitamin D, and malnutrition were risk factors for the occurrence of osteosarcopenia, which makes an important contribution to the field of knowledge.

A study on community-dwelling older Chilean adults reported a prevalence of osteosarcopenia of 16% using the 2010 European consensus criteria, corroborating the present study, which was 12.8% for OsteoSarc1 [19]. Other studies with community-dwelling older adults reported a higher prevalence than in this study, with 28% in pre-frail older German adults [16] and 37% in older adults with a history of falls in Australia [14]. That is, participants with different characteristics from our sample.

The main findings of the present study indicate no significant gender difference in the prevalence of osteosarcopenia. However, a tendency for OsteoSarc1 to be higher in women and OsteoSarc2 higher in men was observed, although without significant differences. Regarding the prevalence according to sex, a previous study [11] found related results, with a tendency for higher prevalence of OsteoSarc1 in women (30.6% women and 29.5% in men), with no significant difference compared to that in men. However, for OsteoSarc2, although there was no significant difference between the sexes, the results showed a slightly higher prevalence in men. As most of the participants were women (65.1%), the number of men in the sample was insufficient to find any significant association in some comparisons, such as the prevalence according to OsteoSarc2 between men and women (10.3% vs. 5.3%, respectively), which despite an important percentage difference, there was no significant difference between groups ($p = 0.230$).

Older age (≥80 years), a longevity indicator, was associated with OsteoSarc2, a result like that of a study in community-dwelling older individuals in China [17] and Iran [11]. Considering that after 60 years of age, there is a bone mass loss of 1–1.5% [36] and an approximately 5% reduction in muscle strength after 50 years of age [37], our findings demonstrate a higher prevalence with older age. The association with age is only with the outcome OsteoSarc2 and not with OsteoSarc1. It could be due our sample which include only older adults with 70 years and older."

The association between OsteoSarc2 and having four or more years of education differs from that of a previous study [10]. More advanced education was associated with a more active and healthier lifestyle than less education [38]. A cross-sectional study

Table 2
Prevalence of osteosarcopenia and association with the biochemical variables in community-dwelling older people.

Variables	n (%)	OsteoSarc1		*p*-value*	OsteSarc2		*p*-value*
		Prevalence n (%)	PR (95% CI)		Prevalence n (%)	PR (95% CI)	
Total cholesterol				0.576			0.064
Adequate	102 (60.0)	12 (11.7)	1.0		4 (3.9)	1.0	
Inadequate	68 (40.0)	10 (14.7)	1.25 (0.57–2.73)		8 (11.7)	3.0 (0.93–9.60)	
Triglycerides				**0.048**			0.210
Adequate	112 (65.9)	19 (16.9)	3.27 (1.00–10.66)		10 (8.9)	2.58 (0.58–11.47)	
Inadequate	58 (34.1)	3 (5.1)	1.0		2 (3.4)	1.0	
HDL-c				0.096			0.133
Adequate	119 (70.0)	19 (15.9)	2.71 (0.83–8.79)		1 (1.9)	1.0	
Inadequate	51 (30.0)	3 (5.8)	1.0		11 (9.2)	4.71 (0.62–35.77)	
LDL-c				0.969			0.323
Adequate	154 (91.1)	20 (12.9)	1.0		10 (6.4)	1.0	
Inadequate	15 (8.9)	2 (13.3)	1.02 (0.26–3.98)		2 (13.3)	2.05 (0.49–8.55)	
Fasting blood glucose				0.246			0.321
Adequate	104 (61.1)	16 (15.3)	1.69 (0.69–4.11)		9 (8.6)	1.90 (0.53–6.80)	
Inadequate	66 (38.8)	6 (9.1)	1.0		3 (4.5)	1.0	
Potassium				**0.045**			0.067
Adequate	**169 (94.7)**	19 (11.8)	1.0		10 (6.21)	1.0	
Inadequate	**9 (5.3)**	3 (33.3)	2.82 (1.01–7.82)		2 (22.2)	3.57 (0.91–14.01)	
Calcium				0.983			0.379
Adequate	138 (81.7)	18 (13.0)	1.01 (0.36–2.78)		11 (7.9)	2.47 (0.32–18.54)	
Inadequate	31 (18.3)	4 (12.9)	1.0		1 (3.2)	1.0	
Vitamin D.				0.289			**0.047**
Adequate	31 (21.1)	6 (19.3)	1.60 (0.66–4.47)		5 (16.1)	3.11 (1.01–9.58)	
Inadequate	116 (78.9)	14 (12.0)	1.0		6 (5.1)	1.0	

Notes: PR: Prevalence ratio; 95% CI: 95% confidence interval; HDL-c: high density lipoprotein-cholesterol; LDL-c: low density lipoprotein-cholesterol; *Wald's test.
OsteSarc1 definition of sarcopenia by the 2010 European Society and Osteopenia/Osteoporosis by the World Health Organization (WHO) (1994).
OsteSarc2 definition of sarcopenia by the 2018 European Society and Osteopenia/Osteoporosis by the WHO (1994).

Table 3
Prevalence of osteosarcopenia and association with health conditions in community-dwelling older people.

Variables	n (%)	OsteoSarc1		*p*-value*	OsteoSarc2.		*p*-value*
		Prevalence n (%)	PR (95% CI)		Prevalence n (%)	PR (95% CI)	
Excess adiposity (%BF)				0.978			0.734
No	23 (13.5)	3 (13.0)	1.01 (0.32–3.17)		2 (8.7)	1.28 (0.29–5.52)	
Yes	148 (86.5)	19 (12.8)	1.0		10 (6.7)	1.0	
Malnutrition				< **0.001**			< **0.001**
No	140 (82.3)	11 (7.8)	1.0		4 (2.8)	1.0	
Yes	30 (17.7)	10 (33.3)	4.24 (1.97–9.09)		7 (23.3)	8.16 (2.54–26.23)	
Falls				0.459			0.502
No	98 (57.3)	11 (11.2)	1.01		9 (8.1)	1.48 (0.46–4.77)	
Yes	73 (42.7)	11 (15.0)	1.34 (0.61–2.93)		4 (5.4)	1.0	
Hospitalization				0.951			0.636
No	133 (77.8)	17 (12.7)	1.0		10 (7.5)	1.42 (032–6.26)	
Yes	38 (22.2)	5 (13.1)	1.02 (040–2.61)		2 (5.2)	1.0	
Frailty				0.251			0.602
No	39 (24.8)	3 (7.6)	1.0		2 (5.1)	1.0	
Yes	118 (75.1)	18 (15.2)	1.98 (0.61–6.39)		9 (7.9)	1.48 (0.33–6.62)	

Notes: PR: prevalence ratio; 95% CI: 95% confidence interval; BF: body fat; *Wald's test.
OsteoSarc1 definition of sarcopenia by the 2010 European Society and Osteopenia/Osteoporosis by the World Health Organization (WHO) (1994).
OsteoSarc2 definition of sarcopenia by the 2018 European Society and Osteopenia/Osteoporosis by the WHO (1994).

of older people in Iran showed that each year of education was associated with a 3% lower prevalence of osteosarcopenia in men [11]; however, the categorization of education and diagnostic criteria for osteosarcopenia in the present study was considered based on that study [11].

There is no other study on osteosarcopenia analyzed its association with alcohol consumption, which was observed as a risk factor in the present study. Excessive alcohol intake can directly affect bone homeostasis, in addition to causing bone remodeling and changes in the osteoblast activity [39]. Chronic ingestion of alcoholic beverages can lead to protein synthesis inhibition and promote a pro-inflammatory environment, contributing to muscle tissue degradation and, consequently, the onset of sarcopenia [40].

This is also the first study to investigate the association of potassium with osteosarcopenia, with a significant association observed in community-dwelling older adults. Previous studies have identified that increased potassium intake decreases the risk of sarcopenia and reported a higher prevalence of sarcopenia in older people ingesting insufficient amounts of potassium [41]. This can be explained by the acid-base state ratio, since metabolic acidosis stimulates nitrogen loss owing to the rapid degradation of muscle protein, decreasing protein synthesis, and inducing negative nitrogen balance [42,43]. In addition, potassium plays a key role in the bone health of older adults. A previous study showed that adequate potassium levels in the diet can prevent osteoporosis [44], which can also be explained by the acid-base theory.

Table 4
Analysis of factors associated with osteosarcopenia according to two diagnostic criteria by hierarchical multiple Poisson regression in community-dwelling older people.

Variables	OsteoSarc1	*p*-value*	OsteoSarc2	*p*-value*
	Adjusted PR (95% CI)		Adjusted PR (95% CI)	
First level				
Age group (years)				**0.012**
70–79			1.0	
≥80 years old			7.64 (1.57–37.07)	
Years of study				**0.043**
0–4			1.0	
<4			3.25 (1.03–10.22)	
Second level				
Alcoholic beverage consumption				**0.047**
No			1.0	
Yes			2.41 (1.01–5.77)	
Third level				
Potassium		**0.033**†		**< 0.001**
Inadequate	3.39 (1.10–10.43)		2.22 (1.45–6.87)	
Adequate	1.0		1.0	
Vitamin D.				**0.003**
Inadequate			4.47 (1.68–11.88)	
Adequate			1.0	
Malnutrition		**0.001**		**0.041**‡
No	1.0		1.0	
Yes	3.84 (1.78–8.30)		5.00 (1.06–23.51)	

Notes: 95% CI: 95% confidence interval; PR: prevalence ratio; *: Wald's test; †: adjusted for age group and malnutrition; ‡ adjusted for variables that remained in the model + sex.
OsteoSarc1 definition of sarcopenia by the 2010 European Society and Osteopenia/Osteoporosis by the World Health Organization (WHO) (1994).
OsteoSarc2 definition of sarcopenia by the 2018 European Society and Osteopenia/Osteoporosis by the WHO (1994).

Potassium is believed to neutralize the acidic conditions of the body and reduce calcium loss from the bones [45].

There was an association between inadequate vitamin D levels and osteosarcopenia, corroborating a previous study in which older people with osteosarcopenia had lower vitamin D levels [12]. Older age can result in a decline in the vitamin D receptors and affect the musculoskeletal system [46]. Vitamin D deficiency can increase bone marrow adipogenesis and fat infiltration into the muscle tissue [46], decrease calcium absorption [47], and reduce bone and muscle tissue function. In addition, this micronutrient helps regulate cellular proteins and growth factors through the release of IGF-1 and inhibition of the parathyroid hormone, thereby increasing calcium absorption [48]. As these are similar metabolisms, they are related to both bone and muscle tissue.

Malnutrition was associated with both diagnostic criteria for osteosarcopenia, being the variable with the strongest association, proving to be an important risk factor regardless of the definition criteria used and corroborating previous studies [12,13]. Research conducted in countries with distinct population characteristics, such as Australia [14], Japan [15], and Iran [11] also considered low BMI as an increased risk for osteosarcopenia. Several factors can inhibit appetite in this population and decrease food intake. This decline may involve central and peripheral factors, such as decreased taste; increased satiety with adaptive relaxation of the fundus of the stomach; increased cholecystokinin levels, which also lead to greater satiety; as well as cytokine accumulation and inflammatory disorders that potentially favor the onset of anorexia [49], contributing to a caloric deficit that can be directly associated with muscle mass loss and an increased risk of osteoporosis.

Physical inactivity was not associated to osteosarcopenia. This fact may be due to the type of instrument used to assess physical activity in the present study, which is a potential limitation, despite the instrument being frequently used in older adults. Physical inactivity has been well documented in previous studies as a risk factor for osteosarcopenia [1,11,12]. No associations between osteosarcopenia and food consumption were identified, which can be explained by the difficulty in evaluating the eating habits. However, this is a characteristic of the instrument used (FFQ), which is another limitation of this study.

We did not find a significant association between frailty and osteosarcopenia as the Korean study [5]. The lack of association with the outcome OsteoSarc2 could be attributed to the small number of older adults with frailty and OsteoSarc2 (n = 9). Moreover, the lack of association with the outcome OsteoSarc1 is difficult to explain because there is no previous study with community-dwelling older adults in Brazil or Latin America and the difference could be attributed to regional variables [5].

This study has several strengths that have been previously described. However, there are some potential limitations that should be acknowledged. First, the lack of information on fracture history as we only collected data on fracture due to falls. Second, we did not perform thoracolumbar radiography. Since both fracture history and thoracolumbar radiography are relevant to the osteoporosis assessment, these two variables should be included in future research. However, osteopenia was assessed in the present study using t-score which is an approach widely used in research on this topic ensuring comparability of our findings with previous studies.

The use of two criteria to investigate the prevalence and risk factors associated with osteosarcopenia makes the present study unique. At present, there are no standard diagnosis criteria for osteosarcopenia, while the diagnosis of sarcopenia has two important criteria i.e., EWGSOP 1 and 2. The use of different cut-offs and criteria diagnosis leads to the identification of diverse risk factors in clinical practice and public health services, like our key findings. The risk factors for OsteoSarc1 were inadequate potassium and malnutrition while for OsteoSarc2 we also identified inadequate vitamin D, alcoholic beverage consumption, schooling years and age ≥80 years old. This distinction and the identification of risk factors will help to promote healthy aging by preventing osteosarcopenia.

5. Conclusions

The prevalence of osteosarcopenia using the 2018 European consensus criteria was lower than that of the 2010 European consensus. However, it provided better discrimination of the associated risk factors. Therefore, it is essential to standardize the osteosarcopenia criteria and definitions in future research to reduce discrepancies in the results i.e., both to assess its prevalence and associated risk and protective factors.

Some risk factors for osteosarcopenia are not modifiable, such as older age. However, many of them are modifiable and can be used to prevent this syndrome, such as adequate nutritional interventions to minimize malnutrition and inadequate levels of potassium and serum vitamin D, in addition to the consumption of alcoholic beverages, which can also be modified using multidisciplinary interventions.

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Statement of authorship

EAS: participate in the conception and design the study, methodology, funding acquisition, acquisition of data, data analysis and interpretation, drafting the article.

GVS: participate in the conception and design the study, methodology, acquisition of data, data analysis and interpretation, drafting the article.

CCP: participate in the conception and design the study, data analysis and interpretation, drafting the article.

CO: funding acquisition, acquisition of data, data analysis and interpretation, drafting the article.

MN: participate in the conception and design the study, methodology, funding acquisition, acquisition of data, data analysis and interpretation, drafting the article.

VP: participate in the conception and design the study, data analysis and interpretation, drafting the article.

All authors revised the article critically for important intellectual content and approved the final version.

Declaration of competing interest

None to declare. The authors have no relevant financial or non-financial interests to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2023.08.030.

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