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Unveiling a hidden burden: exploring sarcopenia in hospitalized older patients through concordance and cluster analysis

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Abstract

Background Sarcopenia has been shown to be an important condition with the ability to predict negative health outcomes, especially in hospitalized older adults; hence, its accurate identification has an important role in the prognosis of older patients.

Aim The prevalence of sarcopenia among hospitalized older adults was assessed by employing three distinct diagnostic methods.

Methods Older adults who were hospitalized were recruited. Bioelectrical impedance analysis was used to assess muscle mass and body composition. Sarcopenia was diagnosed via the European and Asian criteria and via a modified approach in which the Colombian cutoff points for handgrip and gait speed were used. Finally, a cluster analysis was performed to classify the population.

Results The prevalence rates of sarcopenia and severe sarcopenia ranged from 7.3 to 31.6%. The agreement between approaches revealed substantial or almost perfect agreement in 30% of the sarcopenia comparisons and 46.6% of the severe sarcopenia comparisons. The cluster analysis defined three different clusters. The first cluster was associated with increased age, BMI and body fat and poorer functional status and muscle. The second cluster was the healthiest, with high functional status and muscle mass. The third cluster had intermediate characteristics.

Discussion This study highlights the requirements for standardized diagnostic criteria and precise body composition assessment tools in acute geriatric units and highlights the heterogeneity of older adults. Accurate assessment and well-defined diagnostic criteria will facilitate the implementation of appropriate management and interventions.

Conclusion Sarcopenia is highly prevalent in hospitalized older adults, but the adjusted criteria and the inclusion of other parameters must be considered in the assessment.

Keywords Low muscle mass, Hospitalization, Prevalence, Body composition

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Introduction

Sarcopenia, a condition characterized by loss of skeletal muscle mass and function, has been identified as a major risk factor for a range of adverse outcomes in older adults. These include falls, mobility disorders, disability, mortality, long-term care requirements, impaired quality of life, and cognitive decline [1]. In addition to these consequences, sarcopenia has also been found to increase the likelihood of hospitalization [2] and is associated with higher all-cause mortality rates among older adults who are hospitalized [3]. However, the relationship between sarcopenia and hospitalization is bidirectional, with hospitalization itself being a risk factor for the development or worsening of sarcopenia [4].

Several factors contribute to the common relationship between hospitalization and sarcopenia. First, physical deconditioning, loss of mobility, and malnutrition can occur during hospitalization. Additionally, inflammation is believed to be a contributing factor to sarcopenia and can be caused by various factors, including aging, sedentarism, diet, and chronic and acute diseases. Inflammatory markers, such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-alpha), have been linked to muscle loss and decreased muscle strength in older adults [5].

The prevalence of sarcopenia among hospitalized older adults has ranged from 10 to 40% across studies [3, 6, 7]. The variability in these estimates can be attributed to several factors, such as differences in population characteristics, hospitalization settings, timing of evaluation (at admission or discharge), and methods used to assess sarcopenia [8–11].

Limitations of the current diagnostic criteria should be considered when discussing sarcopenia in hospitalized older adults. Specifically, the same criteria used for community-dwelling older adults are often applied to hospitalized patients, such as those proposed by the European Working Group on Sarcopenia in Older People (EWGSOP) or the Asian Working Group for Sarcopenia (AWGS). Thus, discrepancies between these various criteria or diagnostic algorithms can create challenges in screening, assessing, and treating sarcopenia in this population [12]. In addition, another important consideration when assessing sarcopenia in hospitalized older adults is the impact of hospitalization on other body composition parameters other than muscle, such as body fat, visceral fat, and body water. These factors are not currently considered in the diagnostic criteria, potentially limiting the accuracy and completeness of the diagnosis [13]. The significance of diagnosing sarcopenia or conducting body composition assessments in a hospital setting remains uncertain.

This study aims to (i) estimate the prevalence of sarcopenia in hospitalized older adults via three different approaches, namely, the EWGSOP, AWGS, and a modified approach considering Colombian cutoff points for handgrip and gait speed; (ii) assess the agreement between the different approaches used to define sarcopenia; and (iii) consider the likely variations in sarcopenia prevalence and the importance of additional factors. We will conduct a cluster analysis to categorize individuals on the basis of shared characteristics, including body composition, functional variables, and inflammatory markers.

Methods

Sample and setting

We recruited older adults (≥60 years) who were hospitalized at Hospital Universitario Mayor-Méderi, Bogotá, Colombia, between April and October 2022. We included patients with stable clinical conditions who were closely able to finish hospitalization without severe dependency (Barthel Index ≥ 60 points). Patients with any of the following conditions were excluded: hospitalization for a surgical procedure; advanced cognitive impairment (Global Deterioration Scale score of 6–7); a diagnosis of SARS-CoV-2 infection or long COVID-19 at the time of recruitment; a requirement or story of management in the intensive care unit; grade 2 or higher edema; meeting the criteria for advanced disease according to the Montgomery Hospice y Prince George´s Hospice; and a requirement for high-flow oxygen support (≥4 L/minute). All participants (or their caregivers) signed the informed consent form. The Ethics Research Committee of the Universidad del Rosario and the Technician in Research Committee of the Hospital Universitario Mayor approved the protocol.

The sample size required for the study was defined as a proportion estimation. We used a proportion of in-hospital sarcopenia of 22.6%, which Bertschi et al. defined as the prevalence parameter [11]. Assuming a power of 0.8, a significance of 0.05, a two-sided hypothesis, and losses of 20%, we calculated a minimal sample size of 192 patients. Convenience sampling was used to select the subjects.

Muscle parameter assessment

Muscle mass, strength, and physical performance were used as muscle parameters. Muscle mass was assessed via bioelectrical impedance analysis (BIA) via a Tanita Ironman body composition analyzer model BC-1500 plus. In accordance with international guidelines and validated procedures, the appendicular mass lean (ALM) was the parameter used [1, 14]. Hand grip strength and sit-to-stand five-repetition time were defined as muscle strength parameters. Finally, the short physical performance battery (SPPB) and gait speed at 2.4 m were included in the performance assessments.

Sarcopenia definition and approaches

Considering that the operative definition of sarcopenia may vary depending on the approach, we decided to use three different diagnostic approaches. First, we used the operative definition and diagnosis assessment proposed by the revised European consensus of the European Working Group on Sarcopenia in Older People (EWGSOP2) [1]. Like other approaches, the EWGSOP2 defines sarcopenia as the presence of low muscle strength and muscle mass. In our study, we used the cutoff point proposed by the consensus for muscle strength (hand grip < 27 kg in men or < 16 kg in women; sit-to-stand > 15 s) and muscle mass (ALM < 20 kg in men or < 15 kg in women; $ALM/^{height}$ < 7 kg/m^2 in men or < 5.5 kg/m^2 in women). We define two approaches, one using total ALM and the other using $ALM/high^2$. For the severe sarcopenia diagnosis, which was defined as sarcopenia plus low physical performance, the gait speed criterion (≤0.8 m/s) was used, and two approaches were used again depending on the muscle mass assessment mode.

The second approach used was the AWGS [14]. AWGS defines sarcopenia as low ALM and low muscle strength or physical performance. With respect to this definition, we consider sarcopenia when the participant presents low muscle mass ($ALM/high^2$ < 7 kg/m^2 in men and < 5.7 kg/m^2 in women) and low muscle strength (hand grip < 28 kg in men or < 18 kg in women). Severe sarcopenia, on the other hand, includes two approaches depending on the physical performance method of assessment (sit-to-stand ≥ 12 s or SPPB ≤ 9).

Finally, we propose an approach that considers cutoff points adjusted to the Colombian population for hand grip and gait speed (SarCol adjusted criteria). These cutoff points were calculated from the data of the SABE-Colombia survey, a survey of health, well-being, and aging with national representativeness in Colombia [15], starting from a similar approach to that proposed by Fried to define the frailty phenotype [16]. For hand grip strength, we adjusted the cutoff point by sex and body mass index (BMI), considering the lower hand grip quintile in every quartile of BMI in men and women. Gait speed was adjusted by height and sex (lower quintile in each group divided by the median in men and women). We used the appendicular lean mass index ($ALM/high^2$) and the relationship between ALM and BMI to define muscle mass. The latter has been defined as a reasonable and adjusted way to measure muscle mass [17]. We defined sarcopenia as low muscle mass and hand grip and severe sarcopenia as sarcopenia plus low gait speed. As we used two different approaches for measuring muscle mass, we used two measures for assessing sarcopenia and severe sarcopenia. The cutoff points of the three approaches are included in Supplemental Table 1.

Variable measurement

In addition to muscle parameters, we included other variables reported by the BIA: body fat, percentage of total water, visceral fat, and metabolic index. In addition to the SPPB, hand grip strength, gait speed, physical function and physical performance were assessed through the International Physical Activity Questionnaire Adapted to Elderly (IPAQ-E) [18]. This instrument allows the grades of physical activity (low, moderate, and intense) and the METs consumed per week to be measured. Frailty was defined considering the phenotype approach proposed by Fried [16], which uses the cutoff points for the Bogotá population of Samper et al. [19]. Nutrition was assessed through the Mini-Nutritional Assessment Short Form (MNA-SF) [20], cognition was assessed via the Mini-Mental State Examination (MMSE) [21], and activities of daily living were assessed via the Barthel Index [22]. The medical history of hypertension, diabetes, coronary disease, heart failure, cancer, COPD, and COVID-19 was collected from the participants included in the study. Inflammation was assessed through serum IL-1, IL-6 and TNF-α levels.

Statistical analysis

After a quality assessment of the database and verification of the outlier values, we performed a descriptive analysis of all populations included in the study. Continuous variables are reported as the means and standard deviations or means and interquartile ranges according to the probability distribution, and categorical variables are reported as proportions. Considering the different approaches proposed for the severe definitions of sarcopenia and sarcopenia, we constructed the respective variables, taking into account the cutoff points reported in Supplemental Table 1. After that, we compared the observed and expected prevalences to test our hypothesis.

To contrast the agreement between the different approaches to defining sarcopenia and severe sarcopenia, we performed a Cohen´s kappa considering the interpretation proposed by Landis and Koch[24]: < 0.00 poor; 0.01–0.20 slight; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 substantial; 0.81–1.00 almost perfect. We considered a relevant concordance between approaches as a Cohen´s kappa > 0.60.

The cluster analysis used a K-means algorithm with the Euclidean distance method to measure the distance between the observations. Before the analysis, a standardization procedure was applied to ensure that the variables were comparable. The variables considered in the cluster analysis were age, body composition, physical function, and inflammatory markers. The number of clusters was determined by comparing multiple indices and choosing the number proposed by the majority, resulting in 3 clusters. The differences between clusters were assessed via either ANOVA or the Kruskal‒Wallis test, depending on the residual distribution and the homogeneity of variance tested via the Levene test. Scheffé's multiple comparisons approach was used for ANOVA, and the Mann‒Whitney test was used for the Kruskal‒Wallis test.

For all analyses, a significance level of 0.05 was chosen. The statistical analysis was performed via the statistical software R.

Results

Sample description

Table 1 summarizes the characteristics of the 193 participants. The mean age was 75.45 years (SD 8.94), and 50.8% of the participants were women (98 participants). The duration of hospital stay was 12.62 days (SD 10.7), with a mean of 6.61 days (SD 5.77) between hospitalization and assessment. The prevalence of hypertension (64.8%), heart failure (44%), coronary disease (42.7%), COPD (36.5%), diabetes (36.3%), and COVID-19 (22.8%) was high. Participants who consumed statins (56.5%) or vitamin D (37.4%) were also noted. The mean functional assessment scores were as follows: Barthel index 86.09 (SD 10.49), SPPB 6.1 (SD 2.43), and frailty phenotype 2.79 (SD 1.28). According to the IPAQ-E, 66.8% (129) had low physical activity levels, 24.9% (48) had medium physical activity levels, and 8.3% (16) had high physical activity levels. Descriptive analyses were also reported by sex.

Table 1 Population characteristics ($n=193$)

	Total ($n=193$)	**Men ($n=95$)**	**Women ($n=98$)**
Age, mean (SD)	75.4 (8.9)	74.6 (8.9)	76.2 (8.9)
Hospital stay, mean (SD)	12.6 (10.7)	12.5 (11.1)	12.8 (10.4)
Days until assessment, mean (SD)	6.6 (5.7)	6.9 (6.8)	6.34 (4.5)
Hypertension, n (%)	125 (10.7)	57 (60.0)	68 (69.4)
Diabetes mellitus, n (%)	70 (36.3)	29 (30.5)	41 (41.8)
Obesity, n (%)	51 (26.4)	18 (18.9)	33 (33.7)
Coronary disease, n (%)	82 (42.7)	37 (38.9)	45 (46.9)
Heart failure, n (%)	85 (44.0)	37 (38.9)	45 (46.4)
COPD, n (%)	70 (36.5)	35 (36.8)	35 (36.1)
Hypothyroidism, n (%)	75 (39.1)	29 (30.9)	46 (46.9)
Cancer, n (%)	29 (15.0)	13 (13.7)	16 (16.3)
COVID-19, n (%)	44 (22.8)	22 (23.2)	22 (22.4)
Drugs number, mean (SD)	4.6 (2.9)	4.22 (2.85)	5.14 (2.9)
Drugs with effect over muscle, n (%)			
Statins	108 (56.5)	50 (53.8)	58 (59.2)
Vitamin D	71 (37.4)	27 (29.0)	44 (45.4)
Corticoids	10 (5.2)	4 (4.3)	6 (6.1)
Chemotherapy	6 (3.1)	5 (5.3)	1 (1.0)
IL-1, mean (SD)	4.2 (15.0)	4.1 (15.2)	4.3 (14.9)
IL-6, mean (SD)	24.2 (35.3)	24.5 (35.0)	23.9 (35.8)
TNF-α, mean (SD)	1.1 (0.7)	1.1 (0.8)	1.1 (0.6)
Barthel index, mean (SD)	86.1 (10.5)	86.6 (10.5)	85.6 (10.5)
SPPB, mean (SD)	6.1 (2.4)	6.7 (2.5)	5.5 (2.2)
Frailty phenotype, mean (SD)	2.79 (1.3)	2.7 (1.4)	2.9 (1.2)
Physical activity level, n (%)			
Low	129 (66.8)	52 (54.7)	77 (78.6)
Medium	48 (24.9)	30 (31.6)	18 (18.4)
High	16 (8.3)	13 (13.7)	3 (3.1)
MNA-SF, mean (SD)	9.1 (5.0)	9.2 (2.5)	8.9 (2.6)
BMI, mean (SD)	26.0 (4.6)	24.9 (3.5)	27.1 (2.6)
Total body water (%), mean (SD)	51.4 (8.3)	55.5 (8.1)	47.5 (6.4)
Body fat (%), mean (SD)	31.6 (9.9)	26.2 (8.1)	37.0 (8.6)
Visceral fat (%), mean (SD)	12.8 (4.1)	14.6 (4.1)	11.0 (3.3)
Total muscle (Kg), mean (SD)	39.6 (7.5)	44.6 (6.3)	34.8 (4.9)
Appendicular lean mass (Kg), mean	7.7 (1.3)	20.4 (3.6)	16.8 (3.1)

COPD = Chronic Obstructive Pulmonary Disease; SPPB = Short Physical Performance Battery; MNA-SF = Mini-Nutritional Assessment Short Form; BMI = Body Mass Index; IL-1 = Interleukin 1; IL-6 = Interleukin 6; TNF-α = Tumor Necrosis Factor α

Table 2 Sarcopenia prevalence defined by different approaches

	Sarcopenia prevalence, *n* (%) (*n* = 193)		
	Total	**Men**	**Women**
	EWGSOP2		
Sarcopenia by ALMI	25(13.0)	23(24.2)	2(2.0)
Sarcopenia severe by ALMI	25(13.0)	23(24.2)	2(2.0)
Sarcopenia by ALM	61(31.6)	38(40.0)	23(23.5)
Sarcopenia severe by ALM	61(31.6)	38(40.0)	23(23.5)
	AWGS		
Sarcopenia	24(12.4)	22(23.2)	2(2.0)
Sarcopenia severe by STS	22(11.4)	20(21.1)	2(2.0)
Sarcopenia severe by SPPB	16(8.3)	15(15.8)	1(1.0)
	Adjusted cut-off points to Colombia (SarCol)		
Sarcopenia by ALM/BMI	22(11.4)	18(18.9)	4(4.1)
Sarcopenia severe by ALM/BMI	21(10.9)	17(17.9)	4(4.1)
Sarcopenia by ALMI	14(7.3)	13(13.7)	1(1.0)
Sarcopenia severe by ALMI	14(7.3)	13(13.7)	1(1.0)

EWGSOP2 = European Working Group on Sarcopenia in Older People revised consensus; AWGS = Asian Working Group for Sarcopenia; ALM = Appendicular Lean Mass; ALMI = Appendicular Lean Mass Index (ALM/Height^2); BMI = Body Mass Index; STS = Sit-to-stand test; SPPB = Short Physical Performance Battery

Table 3 Agreement between different approaches to defining Sarcopenia (*n* = 193)

EWGSOP2 ALMI				
0.46	**EWGSOP2 ALM**			
0.93*	0.44	**AWGS**		
0.35	0.32	0.36	**SarCol ALM/BMI**	
0.69*	0.26	0.71*	0.51	**SarCol ALMI**

EWGSOP2 = European Working Group on Sarcopenia in Older People revised consensus; AWGS = Asian Working Group for Sarcopenia; ALM = Appendicular Lean Mass; ALMI = Appendicular Lean Mass Index (ALM/Height^2); BMI = Body Mass Index

EWGSOP2 ALMI = European consensus sarcopenia definition using ALMI; EWGSOP2 ALM = European consensus sarcopenia definition using ALM; SarCol ALM/BMI = Colombian adjusted definition using ALM adjusted by BMI; SarCol ALMI = Colombian adjusted sarcopenia definition using ALMI

* Agreement substantial or almost perfect (≥ 0.6)

Table 4 Agreement between different approaches to defining Sarcopenia severe (*n* = 193)

EWGSOP2 ALMI					
0.46	**EWGSOP2 ALM**				
0.88*	0.41	**AWGS SPPB**			
0.70*	0.30	0.83*	**AWGS STS**		
0.41	0.29	0.46	0.50	**SarCol ALM/BMI**	
0.65*	0.24	0.72*	0.72*	0.61*	**SarCol ALMI**

EWGSOP2 = European Working Group on Sarcopenia in Older People revised consensus; AWGS = Asian Working Group for Sarcopenia; ALM = Appendicular Lean Mass; ALMI = Appendicular Lean Mass Index (ALM/Height^2); BMI = Body Mass Index; STS = Sit-to-stand test; SPPB = Short Physical Performance Battery. EWGSOP2 ALMI = European consensus sarcopenia severe definition using ALMI; EWGSOP2 ALM = European consensus sarcopenia severe definition using ALM; AWGS SPPB = Asian consensus sarcopenia severe definition using SPPB; AWGS STS = Asian consensus sarcopenia severe definition using STS; SarCol ALM/BMI = Colombian adjusted sarcopenia severe definition using ALM adjusted by BMI; SarCol ALMI = Colombian adjusted sarcopenia severe definition using ALMI

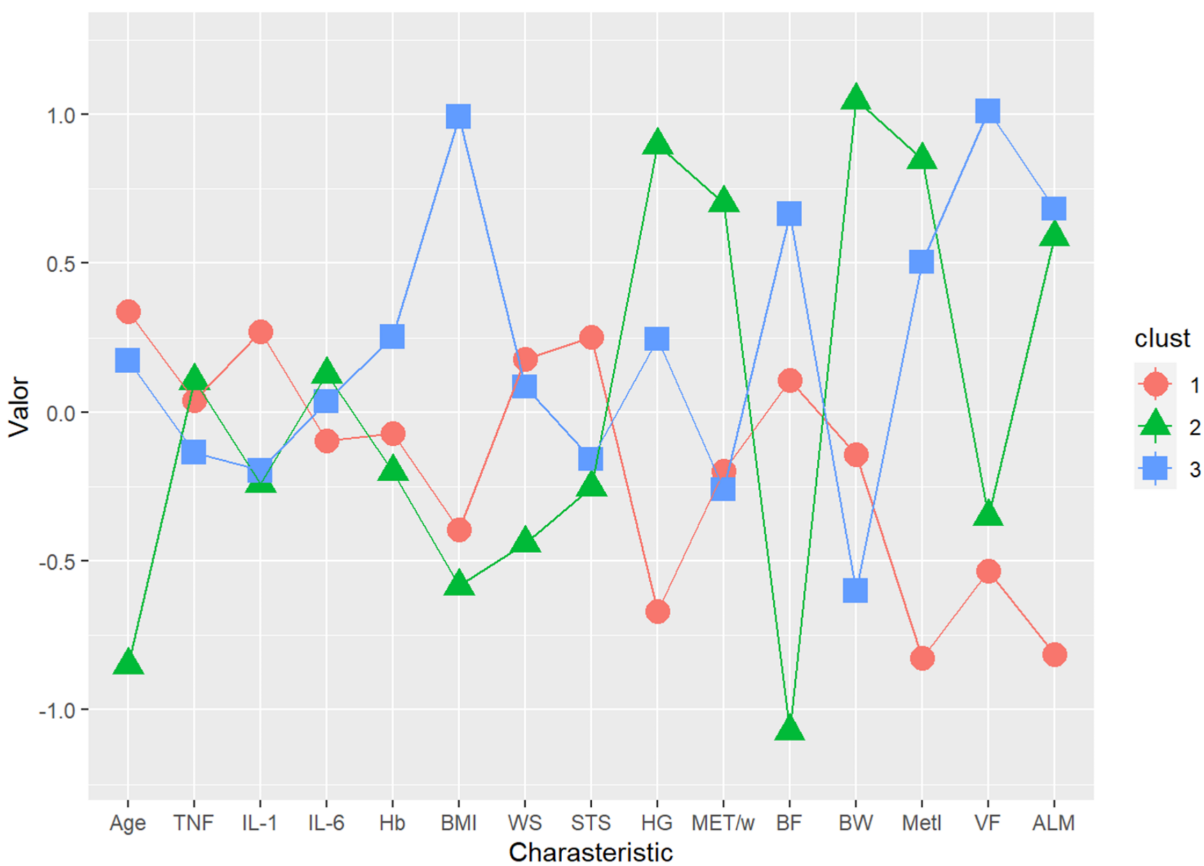
* Agreement substantial or almost perfect (≥ 0.6)

Sarcopenia incidence according to the different criteria

The prevalence rates of sarcopenia and severe sarcopenia estimated according to the approaches assessed are reported in Table 2. The prevalence of sarcopenia was estimated to be between 31.6% (EWGSOP2 using ALM in the definition) and 7.3% (SarCol using the ALM index in the definition). For severe sarcopenia, the estimated prevalence was also between 31.6% (EWGSOP2 using ALM in the definition) and 7.3% (SarCol using the ALM index in the definition). The agreement between the approaches used to assess sarcopenia and severe sarcopenia is reported in Tables 3 and 4, respectively. According to Cohen´s kappa, substantial or almost perfect agreement for the diagnosis of sarcopenia was found in 30% of the pairwise comparisons for sarcopenia and in 46.6% of the severe sarcopenia comparisons (green squares in Tables 3 and 4).

Cluster analysis: common characteristics associated with Sarcopenia

For the secondary objective, we performed a cluster analysis, and the results are reported in Fig. 1. We consider three clusters considering the following variables: age, TNF-α, IL-1, IL-6, hemoglobin, BMI, time to walk 2.44 m, sit-to-stand, hand grip, METs/week, body fat, total body water, visceral fat, and ALM. We defined the first cluster as one with worse functional status, muscle mass, and performance. This cluster was associated with increased age and IL-1 but had an intermediate BMI and body fat. The second cluster was the healthiest. This cluster had high functional and muscle mass, with a relatively high metabolic consumption of the three clusters. This cluster had the lowest BMI and body fat. Finally, the third cluster was an intermediate cluster. It is characterized by good muscle mass and moderate physical performance but high body fat and visceral fat contents. This was the cluster with the worst METs/week. The differences among the three clusters in terms of pathology, biomarkers, functional status, physical performance, and body composition are reported in Table 5.



	AML	Body Fat	Visceral Fat	Body Water	BMI	Hand Grip	METS/w	Met-Index	IL-1	Age
Cluster 1 Poor muscle status/low fat/Low performance	↓	↔	↓	↔	↓	↓	↓	↓	↑	↑
Cluster 2 Good muscle status/Low fat/High performance	↑	↓	↓	↑	↓	↑	↑	↑	↓	↓
Cluster 3 Good muscle status/High fat/Medium performance	↑	↑	↑	↓	↑	↔	↓	↑	↓	↑

Fig. 1 Characteristics of three defined clusters. IL-1 = Interleukin 1; IL-6 = Interleukin 6; TNF = Tumor Necrosis Factor α; Hb = Hemoglobin; BMI = Body Mass Index; WS = Walking speed; STS = Sit-to-stand; HG = Hand grip; MET/w = METS per week; BF = Body fat; BW = Total body water; MetI = Metabolic Index; VF = Visceral fat; ALM = Appendicular lean mass

Table 5 Difference between the three proposed clusters ($n = 145$)

	Cluster 1 Poor muscle status/low fat/Low performance (*n* = 64)	**Cluster 2 Good muscle status/Low fat/High performance (*n* = 35)**	**Cluster 3 Good muscle status/High fat/Medium performance (*n* = 46)**	***p*-value**	**Multiple comparisons analysis – significative differences**
Age, mean (SD)	78.97 (8.33)	68.43 (7.56)	77.50 (7.20)	< 0.001	C1-C2; C2-C3
Female, n (%)	49 (76.6)	3(8.6)	22(47.8)	< 0.001	C1-C2; C2-C3; C1-C3
Hypertension, n (%)	41 (64.1)	18 (51.4)	36 (78.3)	0.04	C2-C3
Diabetes, n (%)	23 (35.9%)	9 (25.7)	25 (54.3)	0.02	C2-C3
Coronary disease, n (%)	29 (49.3)	9 (25.7)	20 (44.4)	0.13	-
Heart Failure, n (%)	25 (39.1)	11 (31.4)	21 (45.7)	0.43	-
Cancer, n (%)	12 (18.8)	6 (17.1)	7 (15.2)	0.88	-
COPD, n (%)	26 (40.6)	11 (32.4)	21 (45.7)	0.48	-
COVID 19, n (%)	19 (29.7)	7 (20.0)	8 (17.4)	0.27	-
TNF-α, mean (SD)	1.12 (0.61)	1.17 (1.11)	0.99 (0.54)	0.44	-
IL-1, mean (SD)	8.54 (22.28)	0.68 (1.18)	1.37 (3.65)	0.17	-
IL-6, mean (SD)	20.74 (33.13)	28.66 (40.96)	25.43 (34.16)	0.41	-
Hb, mean (SD)	13.09 (2.60)	12.73 (3.40)	14.03 (2.72)	0.09	-
BMI, mean (SD)	24.05 (3.34)	23.18 (2.96)	30.40 (3.71)	< 0.001	C1-C3; C2-C3
Time to wall 2.44 mt (seg), mean (SD)	11.36 (8.48)	6.80 (3.68)	10.67 (7.10)	0.01	C1-C2; C2-C3
Sit-to-stand (seg), mean (SD)	21.00 (11.49)	15.85 (5.63)	16.82 (10.42)	0.01	C1-C2
Hand grip (kg), mean (SD)	13.82 (5.00)	26.65 (7.17)	21.30 (7.22)	< 0.001	C1-C2; C2-C3; C1-C3
Frailty phenotype, mean (SD)	3.25 (1.14)	2.11 (1.49)	2.96 (1.05)	< 0.001	C1-C2; C2-C3
MET/week, mean (SD)	427.42 (551.09)	1350.00 (1732.67)	363.82 (365.00)	< 0.001	C1-C2; C2-C3
Barthel, mean (SD)	85.24 (11.76)	88 (8.33)	84.02 (11.14)	0.25	-
MNA-SF, mean (SD)	8.67 (2.58)	8.86 (2.90)	9.73 (2.32)	0.09	-
MMSE, mean (SD)	24.41 (5.78)	26.89 (4.27)	25.83 (4.24)	0.06	-
Body fat (kg), mean (SD)	32.98 (8.45)	21.17 (6.62)	38.55 (7.09)	< 0.001	C1-C2; C2-C3; C1-C3
Total body water (%), mean (SD)	50.29 (6.14)	60.11 (8.43)	46.52 (5.09)	< 0.001	C1-C2; C2-C3; C1-C3
Metabolic index (kcal), mean (SD)	1683.02 (175.75)	2291.51 (306.02)	2166.76 (267.03)	< 0.001	C1-C2; C1-C3
Visceral fat (kg), mean (SD)	10.64 (2.73)	11.40 (2.94)	17.03 (3.35)	< 0.001	C1-C3; C2-C3
ALM (kg), mean (SD)	15.44 (1.75)	20.54 (3.29)	20.88 (2.73)	< 0.001	C1-C2; C2-C3
ALMI, mean (SD)	6.96 (0.79)	7.82 (0.21)	8.52 (0.90)	< 0.001	C1-C2; C2-C3; C1-C3

COPD = Chronic Obstructive Pulmonary Disease; BMI = Body Mass Index; SPPB = Short Physical Performance Battery; MNA-SF = Mini-Nutritional Assessment Short Form; MMSE = Mini-Mental State Examination; IL-1 = Interleukin 1; IL-6 = Interleukin 6; TNF-α = Tumor Necrosis Factor α; ALM = Appendicular lean mass; C1 = Cluster 1; C2 = Cluster 2; C3 = Cluster 3

Discussion

This study revealed that the prevalence of sarcopenia and severe sarcopenia was between 7.3% and 31.6% in hospitalized older adults. The difference between the approaches was also reported in the agreement analysis. This analysis revealed that only 30% of the comparisons in the sarcopenia group and 46.6% in the severe sarcopenia group had substantial or almost perfect agreement (Cohen´s kappa index > 0.6). These discrepancies were related to the different cutoff points used to define muscle function and mass. With respect to the muscle quantity component, we found greater agreement between the approaches that included the assessment of muscle mass by the Appendicular Lean Mass Index (ALM/height^2), including the approach defined using the adjusted cutoff points in older Colombian adults. However, although the ALMI has been used as a measure to define low muscle mass in different studies and with a consensus, including in the EWGSOP2 and AWGS, standardized cutoff points have not been defined. In a revision performed by Walowski et al., the range of cutoff values for the ALMI measured by DXA was between 5.86 and 7.40 kg/m^2 in men and between 4.42 and 5.67 kg/m^2 in women [24]. The relationship between ALM and BMI has also been proposed as a validated method to define low muscle mass in sarcopenia patients. Indeed, the FNIH Sarcopenia Project recommended this relationship in sarcopenia assessment [25], considering the total ALM as an alternative. The FNIH defined this cutoff point through a statistical approach with a regression tree classifying the muscle mass index value that was related to weakness and slowness.

Nevertheless, considerable differences can be found between these approaches when they are applied to the same population. Using data from the Korea National Health and Nutrition Examination Survey (KNHANES) from 2008 to 2010, Kim et al. compared different indices and approaches to assess muscle mass in men and women older than 10 years. In this analysis, they reported differences in muscle mass trajectories according to sex and differences in trajectories according to sex by index [26]. Interestingly, there was a difference in the ALM index between men and women. In women, the ALM index decreases slowly after 60 years of age, whereas in men, the slope of the curve rapidly decreases after this same point [26]. Considering these approaches, the authors found differences in the prevalence of sarcopenia by sex depending on the muscle mass definition used. When the ALM index approach was used, the prevalence of sarcopenia in men was 9.3%, whereas that in women was 0.2%. This difference by sex was not observed when the ALM/BMI index was used (26.8% in men and 27.9% in women). In our study, we found a marked difference by sex when the ALM index and ALM/BMI index were used in the definition of sarcopenia, but this difference was not found with the use of total ALM. These discrepancies highlight the need for a standardized method of reference to define low muscle mass [27].

With respect to the muscular function parameters used to define sarcopenia, we propose the use of adjusted cutoff points for walking time and hand grip. These cutoff points were calculated from data from the populational Colombian aging study, SABE, Colombia. Both walking time and hand grip strength were considered in the Position Statements of the Sarcopenia Definition and Outcomes Consortium [28] for the definition of sarcopenia. One of the position statements in the consensus was that the performance characteristics of a sex-specific cutoff point for low grip strength and low gait speed (or time to walk, as in our case) may vary by age, race, disease condition, and other factors. Defining the appropriate cutoff points in Latin American populations is especially important considering the differences in body composition, body size, and muscular function. Similarly, a paper published by Gomes-Fernandes et al. reported lower cutoff points for the parameters used to define sarcopenia than the international consensus [29]. The use of a cutoff point adjusted to the population characteristics is needed to compare the data between studies and have real value for determining the prevalence of sarcopenia. In this way, the first step is the standardization of the defining terms used in the diagnosis of sarcopenia [30, 31].

Considering the discrepancies in sarcopenia incidence and the relevance of other variables, such as fat mass and inflammation biomarkers, we proposed a cluster analysis to group the population of the study according to similar characteristics. In our analysis, we identified three different clusters. The first cluster included people with worse functional status and performance, low muscle mass, and intermediate body fat. The second cluster included people with better functional and performance status, high appendicular muscle mass, and lower fat mass. The third group was an intermediate group and was characterized by good muscle mass and medium physical performance but with the highest body and visceral fat contents. This cluster also had worse METs/week, time to walk, and hand grip than did the second group, which could be consistent with a sedentary lifestyle. These findings suggest the relevance of fat mass in the maintenance of muscular health, which may be related to a proinflammatory effect. IL-6 and TNF-α are proinflammatory cytokines that are involved in the development of sarcopenia and frailty [32]. However, in this study, we found a reduction in muscular function parameters in older adults with high-fat masses even though they had high ALM. The relationships between fat mass and functional parameters were researched by Merchant et al., who reported associations between fat mass index and free fat mass index with hand grip and gait speed [33]. However, the relationship between fat mass and muscle mass extends beyond sarcopenia. In a paper published by de Santana et al., the value of ALM adjusted by fat mass was associated with all causes and cardiovascular mortality in older adults [34]. The proinflammatory effect of adipose tissue on muscle has been extensively studied and is directly correlated with insulin resistance and cardiometabolic adverse outcomes [35]. These findings highlight the relevance of a complete body composition assessment in older adults and consider an individualized approach depending on the function of the body composition state. On the other hand, the difference between clusters, especially between the second and third clusters, confirms the importance of muscle function over muscle mass. Additionally, the difference in muscle function in the third cluster could be related to the presence of intramuscular adipose tissue, which has been associated with worse muscle function and low recovery of functional capacity after a stressor [36, 37]. These considerations are relevant when defining the target of the proposed interventions.

Our study was based on hospitalized older adults. This population deserves special consideration because sarcopenia could be a risk factor for hospitalization, but at the same time, sarcopenia could be a risk factor for developing or worsening sarcopenia [6, 7, 13]. Sarcopenia-related hospitalization has been associated with both adverse outcomes in the short term, such as all-cause mortality3, and long-term, such as 1-year mortality and admission to the emergency department [9]. These adverse outcomes could be explained by the effects of hospitalization on body composition and muscular function. In a population-based cohort, older adults with a history of hospitalization in the past year had greater decreases in total mass, lean mass, fat mass, and strength than did those who did not require hospitalization [13]. However, although the bidirectional relationship between sarcopenia and hospitalization has been defined and adverse outcomes have been clearly studied, the assessment of body composition and functional status in hospitalized older adults has not been standardized [38]. For this reason, the assessment of sarcopenia in hospitalized older adults was performed via the consensus definition and statements with cutoff points proposed for community-dwelling people.

Using these approaches, the prevalence of sarcopenia in hospitalized older adults reported in different studies has a wide range. Using the first version of the EWGSOP, Perez-Zepeda et al. reported that the prevalence of sarcopenia was 40.1%[10]. Considering the same criteria, Cerri et al. reported a prevalence of 24.1%. The prevalence of sarcopenia was lower than that reported by Gariballa and Alessa, who also used the EWGSOP and reported that 10% of the participants included in their study had sarcopenia [10]. With the criteria of the EWGSOP2, Bertschi et al. reported a prevalence of 24.6% for probable sarcopenia and 22.6% for confirmed sarcopenia [11]. These discrepancies, as we highlighted previously, were also reported in our study.

This study has several strengths. This is the first study in Colombia focused on estimating the prevalence of sarcopenia in hospitalized older adults via different approaches, including an adjusted cutoff point for functional parameters in the diagnosis of sarcopenia. On the other hand, the data were analyzed to group the population by common characteristics, revealing the relevance of other variables that are not taken into account in the assessment and diagnosis of muscular health in older adults. Nevertheless, the study has several limitations that must be considered. First, the population was not followed to define associations between different sarcopenia approaches and adverse outcomes. Second, although cluster analysis is an interesting statistical approach for grouping samples, the characteristics of the three clusters identified in this study cannot be considered diagnostic criteria. Third, convenience sampling was used, which may not represent the broader population and could lead to selection bias. The study was conducted in a single hospital, which may limit the generalizability of the results to other settings. Finally, we did not measure other factors that could impact the development of sarcopenia, such as dietary habits or comorbidities, which could restrict the interpretability of the results.

Our study focused on the importance of defining diagnostic criteria for sarcopenia and the need for a standardization method to determine the cutoff points for these criteria that consider the characteristics of the population where the criteria are applied. Additionally, our study highlights the relevance of fat mass to muscular function. However, future and more robust studies are needed to determine this relationship and its association with adverse outcomes in the short and long term. Finally, this paper calls attention to defining criteria for sarcopenia in hospitalized older adults, considering special characteristics, assessing other factors such as fat mass and inflammatory biomarkers, concomitant diseases, and accessing technology to measure body composition in each setting. These criteria must be easy to apply to health care providers without specified geriatric training.

Conclusion

Sarcopenia is highly prevalent in hospitalized older adults beyond the diagnostic criteria used. However, considering the low agreement between the different approaches and considering that these approaches were generated and validated in the community-dwelling population, the definition of standardized diagnostic criteria and body composition assessment as part of the comprehensive geriatric assessment in acute geriatric units are needed. On the other hand, the inclusion of other variables in the assessment of muscle status in older hospitalized patients must be considered. The correct assessment and diagnostic defined criteria will allow us to perform the right rehabilitation interventions to prevent future adverse outcomes.

Supplementary Information

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Supplementary Material 1

Author contributions

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Data availability
The dataset used to in this analysis can be request to the author in the following link https://zenodo.org/records/10283305.

Declarations

Human ethics and consent to participate
All participants (or their caregivers) signed the informed consent form. The Ethics Research Committee of the Universidad del Rosario and the Technician in Research Committee of the Hospital Universitario Mayor approved the protocol. This study did not imply any intervention, so not registration in clinical trials is needed.

Conflict of interest
All the authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or nonfinancial interest in the subject matter or materials discussed in this manuscript.

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