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Sarcopenia: The need to establish different cutoff points of fat-free mass for the Chilean population

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ABSTRACT

Objectives: International cutoff points for the diagnosis of sarcopenia are not applicable to the Chilean population due to previous evidence of a lower lean mass and strength in this population. Dual-energy x-ray absorptiometry is used to establish fat-free mass cutoff points to define sarcopenia in the Chilean population and analyze its association with handgrip strength in older adults.

Methods: Appendicular fat-free mass (AFFM) was calculated from 4062 dual-energy x-ray absorptiometries of healthy Chileans, ages 18 to 99 y. Possible cutoff points for sarcopenia were obtained using four methods: A) Normative, −2 standard deviation (SD) below mean AFFM/height^2 (AFFMI) of adults age <40 y; B) normative −1 SD, −1 SD under the average AFFMI of adults age <40 y; C) stratification, 25th percentile of the residual distribution obtained with the regression equation to predict AFFM in the entire sample; and D) percentage, −2 SD under the average skeletal muscle mass/total body mass of individuals age <40 y. Additionally, in a subsample of elderly subjects, the correlation between handgrip strength and the four calculated cutoff points was analyzed.

Results: Using the normative method, sarcopenia was defined as an AFFMI <6.4 kg/m^2 in men and <4.8 kg/m^2 in women and at −1 SD, the cutoff points were <7.5 kg/m^2 and <5.6 kg/m^2, respectively. With the stratification method, sarcopenia was defined as −1.33 kg and −1.05 kg of AFFM with respect to the expected value according to the regression equation in men and women, respectively. According to the percentage method, the cutoff points for sarcopenia were <30% and <22.9% in men and women, respectively. The concordance of the four methods was slight to moderate. Only the percentage method showed a progressive increase in the proportion of subjects with sarcopenia as age increased. The latter and the normative −1 DS predicted lower handgrip strength in elderly women, unlike the other diagnostic methods. For elderly men, only the normative −1 DS method predicted weaker handgrip strength.

Conclusions: The AFFM of young Chileans is lower than that reported in Western countries but similar to Latin American data; therefore, the use of the traditional normative method would not be appropriate with −2 SD to establish cutoff points, and using −1 DS resulted in values that are higher than Baumgartner's. Stratification is advantageous because this method throws expected values of AFFM for each population; however, overdiagnosis of sarcopenia is a possibility and thus the method requires a representative sample. The percentage method is simple and showed the expected decrease of muscle mass with age, and also correlated well with handgrip strength in elderly women. Thus, this method represented our method of choice to detect sarcopenia.

Introduction

Sarcopenia was defined first as the decrease in lean mass in older adults [1,2]. Currently, sarcopenia is described as a condition that is characterized by a decrease in muscle mass and function, independent of age [3,4] because other conditions are also

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associated with sarcopenia such as cancer cachexia, inflammatory diseases, neurodegenerative diseases, and insulin resistance [3,5–7]. The prevalence of sarcopenia due to ageing is high and affects 9% to 18% of the population age >65 y [8] and >60% in older adults (OA) age 80 y [2]. However, according to the studies reviewed, its prevalence varies depending on the age of the sample, the definition used for the diagnosis, and the methods employed for its definition [9].

In addition, given the worldwide increase in obesity, sarcopenic obesity (i.e., decrease in muscle mass together with elevated fat-mass percentage) [10,11] has become a troublesome issue, especially among the elderly who can maintain a constant fat mass while progressively decreasing muscle mass [12]. This combination is perpetuated by a proinflammatory vicious cycle that induces muscle catabolism and adversely affects functionality, which leads to physical disability [13]. Therefore, accurate assessment methods for the skeletal muscle compartment are essential to identify sarcopenic individuals independently from total body weight because being overweight frequently masks loss of lean tissues.

Muscle mass can be evaluated directly by means of costly imaging methods such as computed tomography (CT) and magnetic resonance imaging (MRI) [14–16]. However, dual-energy x-ray absorptiometry (DEXA), which is an indirect but sensitive and specific method, is currently the gold standard to study body composition at clinical and research levels. This tricompartmental method yields total and segmented estimates of fat mass, bone mass, and fat-free mass (FFM) [17,18]. Because limbs do not contain viscera, the soft tissue will consist of FM and FFM that contains mostly muscle plus skin, tendons, and connective tissue [18]. Therefore, we can consider appendicular fat-free mass (AFFM) as synonymous of appendicular muscle mass [19]. A total of 73% to 75% of total muscle mass (TMM) is found in the limbs; thus, these measurements may be accepted as a method to assess TMM [18,20,21]. Most studies present this value corrected by squared height, or appendicular fat-free mass index (AFFMI) [2].

Sarcopenia is usually defined as AFFMI <7.26 kg/m^2 in men and <5.45 kg/m^2 in women, with values derived from the Rosetta Study and carried out in the North American population [2], using as a cutoff point of 2 standard deviations (SD) below average AFFMI among 250 adults of both sexes and ages 18 to 40 y.

Subsequent studies have attempted to establish a diagnosis for sarcopenia in various ways and reference populations, with little or no Hispanic representation [20–24]. The present study aimed to determine AFFMI values in the young Chilean population and establish cutoff points that would define sarcopenia by subtracting 2 SD. However, as our preliminary studies had detected, lower values were compared with those published by Baumgartner [2] and we added other calculations to establish normality and defining cutoff points for sarcopenia based on these, and analyzed the concordance between these various methods.

Brazilian researchers have published data with −1 SD below the values of young adults from the Pelotas cohort as a cutoff point because this is mostly a low-economic income population group, which is a reason why AFFM would presumably be lower [25]. Notwithstanding, there are few publications that consider this cutting point. In contrast, AFFM has been found to be higher among the Turkish population compared with the European and North American populations [26].

Impairment of muscle function is also part of the definition of sarcopenia, but again, there is no agreement concerning which cutoff points and which parameters of muscle function should be employed to establish diagnosis. In 2010, two consensuses with regard to sarcopenia were published [3,15,27], which proposed gait speed and handgrip strength as the best clinical parameters to evaluate muscular functionality. Of note, two national groups had detected that handgrip strength in the Chilean population corresponded roughly to the 25th percentile of the English reference [28,29], but the OA group was underrepresented in those samples. A recent study reported handgrip strength values in a representative sample of Chilean OA [30] with an average of 18.7 ± 5.7 kg in women and 31.8 ± 8.3 kg in men. These values are similar to those in the previous ones.

The purpose of the present study is to propose AFFM cutoff points to define sarcopenia in the Chilean population using local DEXA values and analyze their association with muscle strength in a sample of older adults.

Methods

We analyzed lean body mass values from >4000 DEXAs obtained from the Institute of Nutrition and Food Technology, Dr. Fernando Monckeberg Barros and the Department of Nutrition of the North Faculty of Medicine, both the University of Chile in Santiago. The data corresponded to those of healthy volunteers ages 18 to 99 y old who had previously participated in several research studies at both institutions as control subjects without pathologies except for obesity or hypertension. We also excluded cases with a body mass index of <18.5 kg/m^2 for women and ≥35 kg/m^2 for men to avoid DEXA inaccuracies at these weight levels. Among the adults ages >60 y adults (n = 2268), 654 had simultaneous handgrip strength measurements.

The body composition of the arms and legs (i.e., lean, fat, and mineral mass) was evaluated with two DEXA equipments (Lunar iDXA series 200674 software 13.6 at the Institute of Nutrition and Food Technology, Dr. Fernando Monckeberg Barros and DEXA Lunar DPX-L software 13.5 at the Faculty of Medicine of the University of Chile [Lunar Corporation, Madison, WI]) in accordance with standardized methodology [18]. Handgrip strength was measured in a subsample of elderly subjects using a Therapeutic Instruments dynamometer (Clifton, NJ), standing and without elbow flexion, with the highest of three repetitions recorded in each hand, and without considering dominance [28]. Each volunteer had previously signed an informed consent form for several studies in which DEXAs were obtained, including a statement indicating that their data would be kept and analyzed anonymously and they were accepted to be contacted for future studies.

Descriptive statistics of the entire covered population were performed first, and in the cases of subjects ages 18 y and 40 y, the distribution of AFFM and AFFMI was established and the normative cutoff point that corresponds to −2 SD below the average values of this group was calculated for both sexes [13]. In addition, we also established a normative −1 SD cutoff point.

In addition, using available data for the entire sample, a regression equation for each sex was performed to establish an expected value of AFFM. This value was contrasted with the actual individual value obtained in each subject, and the difference between the theoretical and present values (residual) was calculated. The 25th percentile of the distribution of the residuals was considered the cutting point to establish sarcopenia and called the stratification cutoff [31]. The regression equations to predict AFFM in accordance with the stratification method were $-10.38 + (0.16 \times \text{weight}) + (14.82 \times \text{height}) - (0.07 \times \text{age})$ for men and $-3.21 + (0.12 \times \text{weight}) + (8.36 \times \text{height}) - (0.04 \times \text{age})$ for women. The adjusted R^2 of the equations were 0.67 for men and 0.58 for women (weight expressed in kg, height in m, and age in y).

The fourth cutoff point to define sarcopenia (percentage method) was based on studies by Kim et. al. who estimated skeletal muscle mass through Janssen's regression equation, validated through simultaneous MRI measurements [32], and then estimating the percentage of muscle mass with respect total body mass [33]. TMM was estimated with the equation by Kim [17]: $\text{TMM} = [1.13 \times \text{AFFM}] - [0.02 \times \text{age}] + [0.61 \times \text{sex}] + 0.97$ (sex: female = 0, male = 1). This equation was based on the prediction of the amount of skeletal muscle that was measured with MRI from AFFM that was obtained with DEXA. The percentage of muscle mass (PMM) was then calculated ($\text{PMM} = \text{AFFM} \times 100/\text{TMM}$), and the cutoff points that correspond to −2 SD below values were obtained among young adults aged 18 to 40 y.

The frequency of sarcopenic obesity was also estimated and took into account the number of subjects with a body mass index (BMI) >30 kg/m^2 whose AFFM fell below the cutoff point for sarcopenia.

Finally, we estimated which method was the best predictor of a decrease in handgrip strength in a subsample of OAs from whom muscle strength data were obtained simultaneously with the DEXAs (482 women and 138 men) when comparing strength between the sarcopenic and non-sarcopenic subjects as diagnosed through different cutoff points. The same data were used to estimate muscle quality (i.e., handgrip strength/arm FFM).

All statistical analyses were performed in STATA version 12.0 (StataCorp LP, College Station, TX). We first analyzed the distribution of variables with a Kernel density estimate and then performed descriptive statistics, divided the AFFMI values by age intervals for each sex, and compared the results with published data. In subjects age 18 y to 40 y, we calculated average ± SD of AFFMI to establish normative cutoff values. Using data from all 4062 DEXAs, we established a lineal regression equation to estimate an expected AFFM value including age, weight, and height for each subject, and compared the data with actual the (residuals), using the 25th percentile of residuals to establish stratification cut-offs. Subsequently, we analyzed the concordance between the four methods used to define sarcopenia with the Kappa Coefficient. To compare means of handgrip strength and muscle quality of the upper limbs between sarcopenic and non-sarcopenic subjects according to each method, we used the Student's *t* test. Pearson's correlations were used to analyze the association between strength and muscle mass. Finally, we classified the nutritional status of the subsample of elderly subjects using the World Health Organization values and classified >30 kg/m^2 as obese. We also compared handgrip strength and quality between sarcopenic versus non-sarcopenic obese elderly using an analysis of variance and Kruskall Wallis, respectively.

Results

Data from 4062 subjects (1160 men ages 58 ± 19 y and 2902 women ages 59 ± 20 y) was analyzed for the study. Sixteen percent of men and 19% of women had a BMI of >30 kg/m^2 (χ^2: 9.7; $P <$ 0.01). The distribution of variables related to lean body mass were normally distributed according to kernel density estimates. Table 1 summarizes the four methods employed and the resulting cutoff points. Table 2 shows anthropometric data and AFFM expressed as absolute values and corrected by height^2 (AFFMI) as well as the calculated TMM expressed in absolute values and percentages of the entire sample separated by sex and age group.

According to the normative method with −2 SD below mean AFFMI of young adults, the resulting cutoff to define sarcopenia was 6.4 kg/m^2 in men and 4.8 kg/m^2 in women. When considering the normative −1 SD as the cutoff point, the figures were 7.5 kg/m^2 in men and 5.6 kg/m^2 in women. The 25th percentile of the residual distribution of this equation corresponded to −1.33 kg in men and −1.06 kg in women (stratification cutoffs). Finally, after calculating the TMM using Kim's formula, the cutoff points according to the percentage method corresponded to a PMM of 30% in men and 22.9% in women, considering those subjects with values under these figures as sarcopenic (Table 1).

Table 3 and Figure 1 depict the frequency of sarcopenia according to each method, by sex and age group, and show significant differences between the age groups for all methods. Concordance between the four methods to detect sarcopenia was significant but slight to moderate although statistically significant with Kappa indices between 0.20 and 0.42 in men and 0.12 and 0.52 in women (Table 4). The normative method exhibited the worse concordance with the other methods to establish a diagnosis of sarcopenia but the highest concordance was found between the normative −1 SD and the stratification method.

When analyzing the frequency of sarcopenia with regard to age intervals, an increase in numbers was observed as age progresses but only with the percentage method (Table 3; Fig. 1). In addition, among the subjects who were classified as sarcopenic with the percentage method, 60 men were obese (5.4%), 52 of whom were OA. In the group of women, 321 were classified as obese and sarcopenic (11.1%), of which 287 were >60 y.

With regard to functionality, handgrip strength among elderly women was significantly lower in those defined as sarcopenic by

Table 1
Summary of methods employed to establish cutoff points of low muscle mass using data from DEXA

Method	Calculations	Cutoff points
Normative −2 SD [2]	Below 2 SD respect AFFMI of young healthy adults (age 18–40 y)	6.4 kg/m^2 in men 4.8 kg/m^2 in women
Normative −1 SD [35]	Below −1 SD respect AFFMI of young healthy adults (age 18–40 y)	<7.5 kg/m^2 in men <5.6 kg/m^2 in women
Stratification [11]	25th percentile of the following regression equations: Men: −10.38 + (0.16 × weight) + (14.82 × height) − (0.07 × age) Women: −3.21 + (0.12 × weight) + (8.36 × height) − (0.04 × age)	−1.33 kg in men −1.06 kg in women
Percentage [33,34]	Below −2 SD percent muscle mass of young healthy adults (age 18–40 y) PMM = AFFM × 100/TMM TMM = [1.13 × AFFM] − [0.02 × age] + [0.61 × sex] + 0.97 (sex: Female = 0, male = 1	<30% in men <22.9% in women

AFFM, appendicular fat-free mass; AFFMI, appendicular fat-free mass index; DEXA, dual-energy x-ray absorptiometry; PMM, percent muscle mass; SD, standard deviation; TMM, total muscle mass.

Table. 2
Anthropometry and variables obtained by dual-energy x-ray absorptiometry in men and women

	Men (n = 1160)					Women (n = 2902)				
	AGE GROUPS				*P* for differences between age groups	AGE GROUPS				*P* for differences between age groups
	TOTAL	18–40 y (n = 382)	41–60 y (n = 154)	61–99 y (n = 624)		TOTAL	18–40 (n = 922)	41–60 (n = 336)	61–99 (n = 1644)	
Age (y)	54.8 ± 22.1	26.8 ± 6.5	48.4 ± 5.2	73.5 ± 6.1	< 0.001*	56.0 ± 22.0	26.9 ± 5.7	50.3 ± 5.5	73.5 ± 6.4	< 0.001*
Weight (kg)	73.7 ± 10.9	75.6 ± 11.0	74.6 ± 12.4	72.3 ± 10.3	< 0.001†	62.0 ± 9.6	60.3 ± 9.5	65.4 ± 9.8	62.2 ± 9.4	< 0.001*
Height (m)	1.67 ± 0.8	1.73 ± 0.7	1.69 ± 0.7	1.64 ± 0.6	< 0.001*	1.54 ± 0.1	1.60 ± 0.6	1.57 ± 0.06	1.50 ± 0.07	< 0.001*
BMI (kg/m^2)	26.1 ± 3.3	25.1 ± 3.2	26.0 ± 3.3	26.8 ± 3.2	< 0.001*	26.1 ± 4.0	23.6 ± 3.5	26.5 ± 3.6	27.3 ± 3.7	< 0.001*
AFFM (kg)	22.5 ± 4.1	25.8 ± 3.8	21.9 ± 4.0	20.7 ± 2.9	< 0.001*	15.0 ± 2.4	16.5 ± 2.5	15.7 ± 2.1	14.1 ± 2.0	< 0.001*
AFFMI (kg/m^2)	8.0 ± 1.1	8.6 ± 1.1	7.6 ± 1.1	7.7 ± 0.9	< 0.001†	6.3 ± 0.8	6.4 ± 0.8	6.4 ± 0.7	6.2 ± 0.8	< 0.001†,‡
TMM (kg)	26.0 ± 4.9	30.2 ± 4.3	25.3 ± 4.6	23.5 ± 3.4	< 0.001*	15.8 ± 3.0	18.1 ± 2.8	16.7 ± 2.4	14.4 ± 2.3	< 0.001*
PMM (%)	35.1 ± 5.1	39.8 ± 4.6	34.4 ± 3.9	32.4 ± 3.4	< 0.001*	25.8 ± 4.4	30.1 ± 4.1	25.9 ± 2.8	23.3 ± 2.7	< 0.001*

AFFM, appendicular fat-free mass; AFFMI, appendicular fat-free mass index; BMI, body mass index; PMM, percentage muscle mass; TMM, total muscle mass.
Variables expressed as average ± DS, considering normal distribution. Statistical significance $P < 0.01$ by one-way analysis of variance.
*Between all groups.
†Between ages 18–40 y versus >60 y.
‡Between ages 41–60 versus >60 y.

Table 3
Frequencies and proportions of sarcopenia by diagnostic method

MEN (n = 1160) AGE GROUP	18–40 y (n = 382)		41–60 y (n = 154)		61–99 y (n = 624)		χ^2	All (18–99 y)	
SARCOPENIA DIAGNOSIS	With n (%)	Without n (%)	With n (%)	Without n (%)	With n (%)	Without n (%)	*P*	With n (%)	Without n (%)
NORMATIVE	8 (2.1)	374 (97.9)	20 (13.0)	134 (87.0)	39 (6.3)	585 (93.8)	< 0.01	67 (5.8)	1093 (94.2)
NORMATIVE −1 SD	61 (16)	321 (84.0)	58 (37.7)	96 (62.3)	233 (37.3)	391 (62.7)	< 0.01	352 (30.3)	808 (69.7)
STRATIFICATION	109 (28.5)	273 (71.5)	73 (47.4)	81 (52.6)	95 (15.2)	529 (84.8)	< 0.01	277 (23.9)	883 (76.1
PERCENTAGE	5 (1.3)	377 (98.7)	17 (11.0)	137 (89.0)	126 (20.2)	498 (79.8)	< 0.01	148 (12.8)	1012 (87.2)
WOMEN (n = 2902) AGE GROUP	**18–40 y (n = 922)**		**41–60 y (n = 336)**		**61–99 y (n = 1644)**		**χ^2**	**All (18–99 y)**	
SARCOPENIA DIAGNOSIS	With n (%)	Without n (%)	With n (%)	Without n (%)	With n (%)	Without n (%)	*P*	With n (%)	Without n (%)
NORMATIVE	3 (0.3)	919 (99.7)	2 (0.6)	334 (99.4)	52 (3.2)	1592 (96.8)	< 0.01	57 (2.0)	2845 (98.0)
NORMATIVE −1 SD	146 (15.8)	776 (84.2)	38 (11.3)	298 (88.7)	333 (20.3)	1311 (79.7)	< 0.01	517 (17.8)	2385 (82.2)
ESTRATIFICATION	271 (29.4)	651 (70.6)	80 (23.8)	256 (76.2)	300 (18.2)	1344 (81.8)	< 0.01	651 (22.4)	2251 (77.6)
PERCENTAGE	26 (2.8)	896 (97.2)	42 (12.5)	294 (87.5)	699 (42.5)	945 (57.5)	< 0.01	767 (26.4)	2135 (73.6)

Absolute (n) and relative frequencies (%) of subjects classified as sarcopenic or non-sarcopenic according to each of the four diagnostic methods employed to establish low muscle mass. The sample was divided by sex and age group. Comparisons between the proportions of sarcopenic subjects in the different age groups performed using χ^2.

the percentage and normative −1 DS methods (Table 5). Among elderly men, the differences were significant compared with young adults when establishing sarcopenia on the basis of normative −1 SD (Table 6). Handgrip strength was positively and significantly correlated with lean mass values expressed as AFFM ($r = 0.46$ and 0.34 for men and women, respectively) or AFFMI ($r = 0.35$ and 0.14 for men and women, respectively; $P < 0.01$). A positive correlation was also detected between handgrip strength and AFFM residuals ($r = 0.23$ and 0.13 in men and women; $P < 0.01$) and percentage of muscle mass ($r = 0.17$ and 0.14 in men and women, respectively; $P < 0.05$). Muscle quality among older adults (i.e., relationship between limb strength and fat-free mass) varied widely and was similar among men and women. Paradoxically, a trend toward greater muscle quality was observed among subjects classified as sarcopenic on the basis of some of the cutoff points studied (Tables 5 and 6). Obese sarcopenic women age >60 y presented significantly lower muscle quality compared to non-sarcopenic obese women, which was a difference that did not reach statistical significance in the male OA group.

Discussion

As a result of this study, we propose establishing cutoff points to define sarcopenia based on two systems: The percentage method and normative −1 DS. When using the percentage method, the cutoffs were <22.9% of muscle mass in women and <30% in men, which coincides with Janssen's class II sarcopenia [32] and the Korean cutoff points [34]. Using the second method (−1 SD below the mean AFFMI obtained in the young population), values were <7.5 kg/m^2 in men and <5.6 kg/m^2 in women, which was almost identical to the cutoff points established in a study by a Brazilian group [35] but higher than the usual international cutoffs. However, only the first method showed the expected increase in prevalence of sarcopenia that is associated with chronological age, unlike the other methods as extensively proposed in the literature. Furthermore, calculating the proportion of lean mass with respect to total body mass (percentage method) eliminates the bias created by AFFMI, which tends to stabilize in the elderly because of decreasing height (Table 2). Both the normative −1 DS and percentage methods were able to predict a lower handgrip strength (the former in men and the latter in women). However, these two systems have been employed by few investigators so further validation studies are required. In addition, the percentage method requires a calculation of muscle skeletal mass using equations that have validated elsewhere [17,32], which increases the complexity. The lower percentage of sarcopenia in older men and women, which was obtained with the stratification method, is counterintuitive considering that this condition progresses with age. The equations only explained 50% to 60% of AFFM variation and thus can be an explanation for this unexpected result. Therefore, the stratification method, in accordance with our results, appears to be a less reliable method to diagnose sarcopenia. We have not tested these equations in other populations of Chilean patients, which should be done in the future.

As another means for the proper assessment of the lean compartment in OA, we added the estimation of muscle quality in upper limbs, which has been previously employed to correct strength by higher lean mass associated with increase in body weight as well as performance differences by sex. The results were variable but nonetheless significantly lower among women with sarcopenic obesity. We found similar results among diabetic women [36]. This trend was not significant among men, possibly due to the small number of men in this sample.

On the other hand, when comparing our results with those of several published studies, we confirm that fat-free mass among the young Chilean population is lower than that of international reference populations [2,3,15,21,22], which reaffirms the need for local cutoff points to define sarcopenia. This finding also makes the traditional normative method unsuitable to diagnose sarcopenia in our country even though this method is recommended by the 2010 European consensus and the European Working Group on Sarcopenia in Older People [15] because two SD under the average renders extremely low values, which was observed only in a minority of the studied subjects, even among OA (Table 3; Fig. 1).

Furthermore, the European consensus, which proposes to diagnose sarcopenia on the basis of the deterioration of both mass and muscle function, starts from a walking speed of <0.8 m/sec, which we observed very infrequently among our elderly adults living in the community (data not shown), so a diagnosis of sarcopenia would be too late. The prevalence of sarcopenia in Chile, using an adapted version of the European Working Group on Sarcopenia in Older People is 19.1% but depends on age and body weight [45]. Of

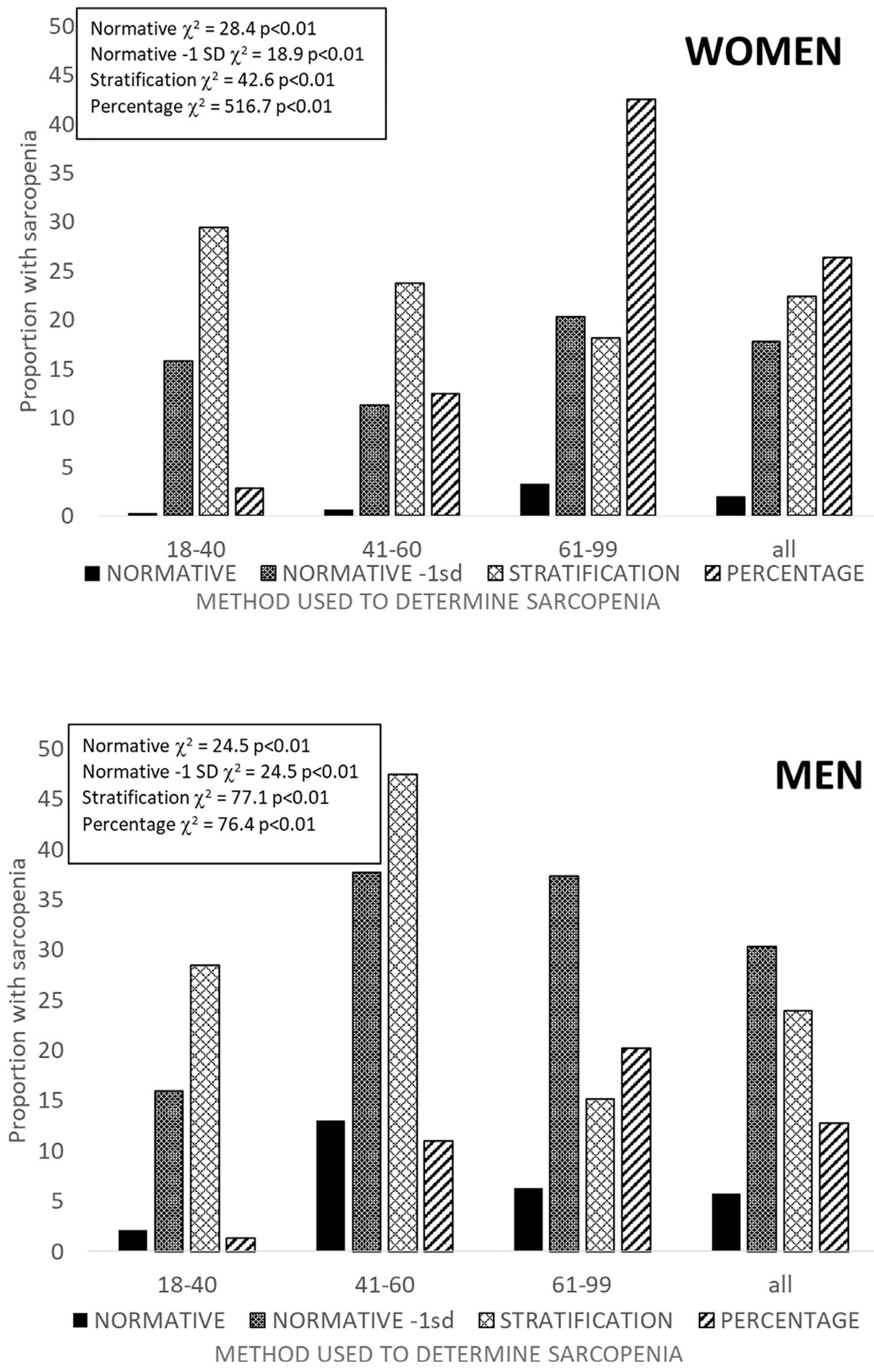

Fig. 1. Frequency of sarcopenia according to diagnostic method. Age-related increase in sarcopenia was detected only through the percentage method (fourth column).

note, our AFFM values in young people are very similar to those published by Alemán-Mateo [37] in the Mexican population and Barbosa-Silva in Brazil [35] so they cannot be attributed to measurement errors, but possibly to a common pattern among Latin Americans and Asians, given the similarity of our values compared with those of the Korean population [23].

In concordance, the cutoff points derived from the regression equations using our own data yielded the expected frequencies of sarcopenia in OA, although unexpectedly high in our younger adults. These striking low levels of AFFM among young subjects, many of whom would fall into the sarcopenia category, may be due to generational differences, and we can speculate that our elderly achieved a greater muscle mass development when young because they were less sedentary compared with the current generation. In addition, these results coincide with those from previous studies that were carried out in the Chilean population and also reported lower muscle mass and strength compared with more developed countries [28–30,38,39]. If we use the normative cutoff

Table 4
Concordance between methods to establish cutoff points for sarcopenia

	MEN	P	WOMEN	P
NORMATIVE vs. NORMATIVE −1 DS	0.25	< 0.01	0.17	< 0.01
NORMATIVE vs. STRATIFICATION	0.26	< 0.01	0.12	< 0.01
NORMATIVE −1 DS vs. STRATIFICATION	0.42	< 0.01	0.52	<0.01
NORMATIVE −1 DS vs. PERCENTAGE	0.20	< 0.01	0.16	< 0.01
STRATIFICATION vs. PERCENTAGE	0.34	< 0.01	0.30	< 0.01

Values correspond to the Kappa coefficient, considering 0.00 = poor concordance; 0.01–0.20 = slight concordance; 0.21–0.40 = fair concordance; 0.41–0.60 = moderate concordance; 0.61–0.80 = substantial concordance; and 0.81–1.00 = almost perfect concordance.

point (−2-DS) derived from the current sample, we would obtain extremely low frequencies, which tends to underdiagnose sarcopenia. As noted, considering the cutoff point in −1 DS gives intermediate frequencies but does not increase significantly with age as would be expected. Of note, −1 DS is even more strict than Baumgartner's cutoffs [2], which can seem paradoxical for the Chilean population where we demonstrate precocious lower lean body mass.

Another notable result was the observation that AFFMI, the parameter commonly used to define sarcopenia, does not progressively decrease with ageing, which probably results from an artificial increase of this parameter that is associated with age-related progressive decrease of height. Therefore, the associations with muscle strength were better when calculated with the absolute values of AFFM than when corrected by squared height (data not shown). The above raises the inconvenience of using the AFFMI to define sarcopenia, which could artificially mask the actual decrease of AFFM that occurs in OA. This coincides with the assessments by the Foundation for the National Institutes of Health sarcopenia project [40], which recommends the employment of AFFM that is corrected by BMI instead. However, most publications still use the AFFMI; therefore, AFFMI was used for comparison with published data.

As an alternative, the cutoff point by stratification has the advantage that the entire population studied, including the elderly, is considered when the equation is performed so the fall in FFM in relation to the expected values for this population are better reflected. A theoretical value of AFFM for an individual is also proposed on the basis of their sex, height, weight, and age, which makes its application very useful in clinical and population studies.

However, several limitations of this regression equation must be mentioned. The equation could lead to overdiagnoses because, by definition, 25% of the sample will be classified as sarcopenic. In addition, the equation requires validation that employs the gold standard methodology as well as a representative sample of a certain population and as such, cannot be extrapolated necessarily. The unexpected fact that, when using regression equations, the prevalence of sarcopenia in a population age <60 y is higher than that of the OA could be explained by the fact that age is already incorporated in the equation, with an expected lower AFFM among the elderly, which more closely resembles the real value of the OA and thereby decreases the residual. In contrast, among younger adults, age would not be such an important factor to explain muscle mass variability. In any case, these are values that derive from the same population and would be more representative than international data.

In contrast, the PMM calculation is an indicator of muscle mass in relation to the total mass of each individual, and exhibited a progressive age-related fall as expected. Thus, the frequencies of sarcopenia that were observed in the different age groups are similar to those reported in the literature. The only complexity is that this requires the calculation of muscle mass that is derived from equations obtained with the values of DEXA [17] or bioelectrical impedance analysis [32] rather than measured directly. Using the same method, we calculated the frequency of sarcopenic obesity, which was 5.4% in men and 11.1% in women ages >60 y as well as the preliminary numbers of this phenomenon that are so relevant among OA. The reported figures fluctuate between 7% and 10% using bioelectrical impedance analysis [41,42] and depending on sex and the index used, >13% with DEXA [43]. However, in our sample, given the small number of subjects with sarcopenic obesity and simultaneous measurement of handgrip strength, we cannot draw clear conclusions about their relevance in functionality.

The agreement between the four methods used in this study was slight to moderate although statistically significant (Table 4)

Table 5
Handgrip strength in sarcopenic and non-sarcopenic elderly women by diagnostic method and the presence of sarcopenic obesity

TOTAL SAMPLE (n = 482)	HANDGRIP STRENGTH (kg)* 20.6 ± 4.1		MUSCLE QUALITY (kg/kg)& 11.5 (4.2–25.8)	
NORMATIVE METHOD		***P***		***P***
NON SARCOPENIC (n = 476)	20.6 ± 4.1		11.5 (4.2–18.1)	
SARCOPENIC (n = 6)	17.5 ± 3.6	0.07	11.5 (10.8–25.8)	0.6
NORMATIVE METHOD −1 SD				
NON SARCOPENIC (n = 410)	20.8 ± 4.1		11.4 (4.2–17.9)	
SARCOPENIC (n = 72)	19.1 ± 3.8	< **0.01**	12.6 (8.6–25.8)	< **0.01**
STRATIFICATION METHOD				
NON SARCOPENIC (n = 425)	20.7 ± 4.2		11.4 (4.2–18.1)	
SARCOPENIC (n = 57)	19.5 ± 3.8	0.06	12.0 (7–25.8)	< **0.01**
PERCENTAGE METHOD				
NON SARCOPENIC (n = 320)	21.1 ± 4.1		11.5 (4.2–18.1)	
SARCOPENIC (n = 162)	19.5 ± 3.9	< **0.01**	11.4 (4.3–25.8)	0.87
ACCORDING TO THE PRESENCE OF SARCOPENIC OBESITY				
WITHOUT SARCOPENIC OBESITY (n = 413)	20.7 ± 4.1		11.7 (4.2–25.8)	
WITH SARCOPENIC OBESITY (n = 69)	19.7 ± 4.2	0.07	10.6 (4.3–15.3)	< **0.01**

Comparison of handgrip strength and upper limb quality (handgrip strength/arm fat-free mass by dual-energy x-ray absorptiometry) between women age >60 y classified as sarcopenic or non-sarcopenic according to the four methods employed in this study.
Comparison of handgrip strength and upper limb quality (handgrip strength/arm fat-free mass) between obese elderly women, with or without sarcopenia according to the percentage method.
Muscle strength: *average ± standard deviation; muscle quality: &median (range, minimum–maximum). Significant if $P < 0.05$, using analysis of variance for muscle strength and Kruskal Wallis for quality.

Table 6
Handgrip strength in sarcopenic and non-sarcopenic elderly men by diagnostic method and the presence of sarcopenic obesity

TOTAL SAMPLE (n = 138)	HANDGRIP STRENGTH (kg)* 33.7 ± 6.3		MUSCLE QUALITY (kg/kg)& 11.8 (3.5–17.2)	
NORMATIVE METHOD		**(*P*)**		**(*P*)**
NON SARCOPENIC (n = 136)	33.8 ± 6.3		11.8 (3.5–17.2)	
SARCOPENIC (n = 2)	29.0 ± 2.8	0.29	13.9 (12.0–15.7)	0.21
NORMATIVE METHOD −1 DS				
NON SARCOPENIC (n = 90)	35.2 ± 5.9		11.6 (6.7–16.1)	
SARCOPENIC (n = 48)	30.9 ± 6.0	< **0.01**	12.3 (3.5–17.2)	**0.02**
STRATIFICATION METHOD				
NON SARCOPENIC (n = 124)	33.8 ± 6.4		11.7 (3.5–16.1)	
SARCOPENIC (n = 14)	32.8 ± 5.5	0.56	12.6 (8–17.2)	0.20
PERCENTAGE METHOD				
NON SARCOPENIC (n = 118)	33.9 ± 6.4		11.8 (3.5–16.5)	
SARCOPENIC (n = 20)	32.4 ± 5.4	0.29	12.2 (8–17.2)	0.84
ACCORDING TO THE PRESENCE OF SARCOPENIC OBESITY				
WITHOUT SARCOPENIC OBESITY (n = 128)	33.8 ± 6.4		11.9 (3.5–17.2)	
WITH SARCOPENIC OBESITY (n = 10)	32.3 ± 5.2	0.4602	10.3 (8–14.2)	0.2241

Comparison of handgrip strength and upper limb quality (handgrip strength/arm fat-free mas by dual-energy x-ray absorptiometry) between men age > 60 y, subjects classified as sarcopenic or non-sarcopenic according to the four methods employed in this study.
Comparison of handgrip strength and upper limb quality (handgrip strength/arm fat-free mass) between obese elderly men with or without sarcopenia according to the percentage method.
Muscle strength: *Average ± standard deviation; muscle quality: &median (range, minimum−maximum). Significant if $P < 0.05$, using analysis of variance for muscle strength and Kruskal Wallis for quality.

so to try and clarify which method would be most advisable, we evaluated the relation of each of them with muscular strength in a subgroup of OA. Again, the percentage method allowed for a better identification of OA with decreased handgrip strength, at least among women (most represented group in this sample). When evaluating this parameter among OA classified as sarcopenic, absolute strength was observed to be lower when using the normative cutoff point, which suggests that individuals are classified as sarcopenic when there is a greater deterioration not only of muscle mass but also of muscular strength. In contrast, muscle strength was higher among sarcopenic OA who were classified with the stratification and percentage methods (Tables 5 and 6), which could reaffirm that these methods would be better cutoff points to be applied to the population because they involve establishing a diagnosis before the occurrence of marked deterioration of muscle strength, especially if we consider that our standards of muscle strength are lower than the international standards. Although there is an association between strength and muscle mass, the degree of association is low and thus, several other explanatory factors are at play.

Our study had the strength of including a significant number of determinations with a wide range of ages; however, apart from its retrospective nature, the main weakness of the study is its sample, which was not previously selected in a stratified form to achieve a homogeneous representation of the general population and age groups. Another important limitation is that handgrip strength was only measured in a subsample of elderly subjects and not in every subject included. Therefore, the final verification of these results will require a study with a similar methodology but performed on a healthy population with an adequate statistical sampling.

Conclusions

This study confirms the existence of a lower AFFM in the Chilean population compared with international standards, especially among young adults. Therefore, the use of international cutoff points to diagnose sarcopenia derived from absolute values of DEXA that are obtained in other populations from which 2 SD are subtracted is inappropriate. The use of cutoff points that are derived from our population (stratification method) allowed for the detection of a decrease in muscle mass in a greater number of individuals and more precociously. However, might these values not be applicable to other populations.

Our results suggest that the most appropriate system is the percentage method because this method accounts for the progressive decrease of muscle mass due to ageing and predicts low handgrip strength. Prospective studies will be necessary, using DEXA in Chilean and/or Latin American population that are representative of each sex and age group and ideally with simultaneous measurements of muscle strength or other tests of muscular function. This would allow for the distribution of normal AFFM values to be established, as well as verification of which point compromises strength and walking capacity or other functions. Thus, a better diagnosis of sarcopenia could be made due to better marks of deterioration in functionality, dependence, and mortality [44]. These values are urgently required as a reference for the diagnosis of sarcopenia associated with diseases such as cancer, diabetes, and rheumatoid arthritis in the Chilean population.

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