Skeletal Muscle Mass Index cut-offs by bioelectrical impedance analysis to determine Sarcopenia Based on healthy young or old Populations: A Comparative Study

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Abstract. Skeletal muscle mass index (SMMI) is a component in sarcopenia. There is no universal cut-off point and therefore each population should have its own reference values. This study aimed comparing SMMI cut-off points derived from a young population with those obtained directly from an elderly population. 237 older adult community-dwelling older than 60 years were evaluated. The skeletal muscle mass (SMM) was evaluated by bioelectrical impedance analysis (BIA). SMMI was calculated as SMM/height squared. The young population consisted of 255 participants from the same locality. The cut-off points from older person for moderate low muscle mass were 6.70 (women) and 9.20 kg/m² (men). In this case, they were higher than those estimated from the young population (6.42 and 8.40 kg/m² for women and men). A similar trend was obtained when the cut-off points were set below the 20th percentile. When two standard deviations were used to determine the cut-off points, the values for older women were lower (5.90 kg/m²) than those obtained from young adults. There were no differences in the case of men. SMMI reference values from elderly persons is an option to diagnose sarcopenia, however prospective studies are necessary to establish the capacity to predict functional outcomes.

1. Introduction

Aging is associated with an increase in fat tissue and a reduction in fat-free mass (mainly bone and skeletal muscle). Longitudinal studies show that loss of muscle mass, strength and power begins around the age of 35 [1]. However, those elderly with a loss of skeletal muscle mass beyond what was expected and with a greater risk of adverse results, would have a geriatric syndrome called sarcopenia [2].

The reference method to assessment body composition is the dual energy X-ray absorptiometry (DXA), this technique emits low-emission X-rays and assesses the attenuation of these rays as they pass through different body tissues [3], however, due to its low cost, portability and adequate correlation with reference methods (including DXA), Bioelectrical Impedance Analysis (BIA) has been used as a method for estimating muscle mass at the clinical and research levels [4-6]. The estimation of low muscle mass has been made from parameters obtained with BIA. These parameters are subsequently introduced into previously published formulas [2,7] to calculate the indicator known as the skeletal muscle mass index SMMI [8]. Some authors define sarcopenia in the elderly when this index is 2 standard deviations below the average of a reference young population [9,10].

However, other authors have used definitions derived directly from healthy elderly populations, as in the study by Newman et al [11] with 2984 North American subjects aged 70 to 79 years, where the authors classified as sarcopenic the elderly in whom the lean mass was within the lowest 20% for age and sex. Another study [12] evaluated the most valid index of low SMM to assess cardio metabolic risk in a Korean older persons, low muscle mass by age and sex was defined as Z-score less than -1. A study derived from the NHANES population older than 60 years [13] established cut-off values for SMM that were related to the risk of physical disability.
The foregoing shows that despite the progress in recent years in terms of the definition of this entity, especially the importance of having its own population data to derive the cut-off points [2,14], it is still not clear if they should be derived from the young reference population or from the elderly population. Therefore, this study aimed comparing cut-off points for low SMMI derived from elderly population with usual aging with respect to those derived from healthy young subjects of the same population.

2. Methodology

2.1. Type of study and subjects
This is a study observational, retrospective, cross-sectional, analytical, relational level. Subjects older than 60 years, community-dwelling, with Barthel index greater than or equal to 95 points were evaluated. Volunteers unable to perform manual dynamometry, users of drugs (high-dose gabapentin (dose greater than 600 mg/d), growth hormone, diuretics, dihydropyridine calcium channel blockers, steroids, anorectics,) that alter electrical bioimpedance [15,16], subjects with edematous syndrome (myxedema, decompensated heart failure or chronic disease in the last 3 months, chronic kidney disease in renal replacement therapy (CKD RRT), deep vein thrombosis in the last 3 months, lymphedema, post-phlebitic syndrome with edema, diagnosis of dementia, amputations or alterations of body geometry, skin lesions or abnormalities, presence of pacemakers, prostheses, or other elements that affect the collection of electrical bioimpedance data were excluded. Data from previous studies were taken if these data were complete and met the inclusion and exclusion criteria.

255 participants were included in the young reference group (85 women and 170 men; mean age 22.4 ± 3.2 and 21.6 ± 3.6 years respectively) with no known chronic diseases or chronic drug use. The cut-off values for skeletal muscle mass indexes obtained as the 2 SD below the average of SMMI were 6.42 for women and 8.39 kg/m2 for men [7].

2.2. Sample size estimation
With base in the information registered by the City Hall of Manizales, with a population of adults aged 60 and over of 40,000 persons and a reported prevalence of 15.5%, a confidence of 95% and a precision of 5%, we calculated a sample size per proportion of 195. In total, 237 community-dwelling older persons without comorbidities were prospectively recruited.

2.3 Measurements
All the measurements were realized in the morning. Height and weight (Heightronic-235 by Seca®, ± 0.01 cm and PP2000 by Icob-Detecto©, ± 0.1 kg, were used respectively) were measured twice. If differences greater than 0.5 cm or 0.1 kg were founded, a third measurement was taken. A protocol previously published was used to measurement BIA [17].

An electric heater (BFH416 by Bionaire™) and dehumidifier (BMD100 by Bionaire™) were used to control relative humidity and ambient temperature, respectively. These environmental variables were measured with a thermohygrometer (13307 by Delta Trak®, ± 0.1 ° C).

Measurements were made on the dominant side of the body on three occasions on a non-conductive surface with Hydra 4200 equipment by Xitron Technologies©. Lean mass was obtained with the internal equation of the bioimpedance analyzer. The estimation of skeletal muscle mass was calculated with the Janssen et al equation [8], validated for the Hispanic population as follow:

\[
SMM (kg) = [(H/R \cdot 0.401) + (gender \cdot 3.825) + (age \cdot -0.071)] + 5.102
\]  

In (1) R is the resistance of electrical bioimpedance (ohms) at 50 kHz, H is height squared (cm), the male gender is equal to 1 and the female to 0, the age is recorded in years. SMM was divided between height squared to calculate the SMMI.

2.4 Statical Analysis
Absolute and relative frequencies were used for qualitative variables, and averages with standard deviation for quantitative ones. To determine normal distribution of data Kolmogorov-Smirnov test was used. Starting from the fact that the aim is to find a quantitative cut-off point, assuming a normal distribution of the population, the average is established and different reference limits for low muscle mass are evaluated based on previous studies in the elderly [10-12]: 20th percentile, mean minus 1 standard deviation and mean -2 standard deviation. These values are compared with the current definition of low SMMI to diagnose sarcopenia (mean - 2DS from a young healthy population) [2] values derived from Caldas young population [7].

To compare means, the Student’s T test was used for variables with normal and homoscedastic distribution according to the Levene statistic. The statistical significance was considered if p-value <0.05. Analyzes statistical were performed in the IBM SPSS statistics (version 20; SPSS, Chicago, IL, USA).

3. Results
237 community-dwelling adults, 60-94 years of age, independent in activities of daily life (ADL) were analyzed. The average age was 69 years and a percentage of 59.5% (n = 141) was women (table 1).

The IMMS cut-off points derived from different populations and from elderly and young people are shown in Table 2.

Table 1. Old and young adults’ characteristics.

| Variable     | Old Women (n=141) | Old Men (n=96) | Young Women (n=170) | Young Men (n=85) |
|--------------|-------------------|----------------|--------------------|------------------|
| Age (years)  | 70.0 (5.2)        | 69.0 (4.6)     | 21.60 (3.6)        | 22.4 (3.2)       |
| BMI (kg/m²)  | 27.50 (4.4)       | 25.8 (4.3)     | 24.10 (3.72)       | 22.2 (3.35)      |
| SMMI (kg/m²) | 7.50 (0.8)        | 9.6 (0.8)      | 8.02 (0.8)         | 10.4 (0.98)      |

The data are shown as mean and standard deviation (SD).
Abbreviations: SMMI, skeletal muscle mass index; BMI, body mass index.
**Table 2.** Cut-off values for low muscle mass for old adults by sex and SMMI
derived from young and older adults.

| Country   | Mean - 2 SD from young population | Mean - 2 SD from older population | Mean - 1 SD from older population | p20 from older population |
|-----------|----------------------------------|-----------------------------------|-----------------------------------|---------------------------|
|           | M      | F      | M      | F      | M      | F      | M      | F      | M      | F      |
| Taiwan    | 8.87   | 6.42   | -      | -      | -      | -      | -      | -      | -      | -      |
| France    | 8.60   | 6.20   | -      | -      | -      | -      | -      | -      | -      | -      |
| Spain     | 8.31   | 6.68   | -      | -      | -      | -      | -      | -      | -      | -      |
| Turkey    | 8.33   | 5.70   | -      | -      | -      | -      | -      | -      | -      | -      |
| New Mexico| 7.25   | 5.45   | -      | -      | -      | -      | -      | -      | -      | -      |
| USA       | -      | -      | -      | -      | -      | -      | 7.23   | 5.67   | -      | -      |
| Australia | 6.94   | 5.30   | -      | -      | -      | -      | -      | -      | -      | -      |
| Korea     | -      | -      | -      | -      | 6.38   | 4.88   | -      | -      | -      | -      |
| Colombia  | 8.39   | 6.42   | 8.40   | 5.90   | 9.20   | 6.70   | 9.34   | 6.75   | -      | -      |

The data are shown in kg/m².

Abbreviations: SMMI, skeletal muscle mass index. SD, Standard Deviation. p20, 20th percentile. M, male. F, female

* These data correspond to values derived from young population.

The value obtained in old women and men using the average minus one standard deviation to establish moderate low muscle mass was significantly higher than that obtained in the study with young people in which the average minus two standard deviations was used (6.70 vs. 6.42 kg/m², (p=0.000) and 9.20 vs. 8.39 kg/m² (p=0.000), respectively.

By establishing the cut-off point as SMMI below the 20th percentile, the values in old women and men were also statistically higher than those reached with the study with young people (6.75 vs. 6.42 kg/m², p=0.000) and (9.34 vs. 8.39 kg/m², p=0.000) respectively.

When two standard deviations of the mean were applied, the value obtained in old women was significantly lower than that obtained in the study with young people in which the mean minus two standard deviations were used (5.90 vs. 6.42 kg/m², p = 0.000) On the other hand, the respective value in old men was not different from that obtained in the study with young people (8.40 vs. 8.39 kg/m², p=0.739).

4. Discussion

The present study provides a comparison of the cut-off point for low SMM obtained directly from the older adult persons with estimates for young adults (mean minus two SD) from the same population. It was found that when the cut-off points for low SMM were set as minus one SD from the mean or when it was set below the 20th percentile of the older adult population, the results were higher than the estimates for a young population, in which case we would establish the presence of moderately low muscle mass.

With minus two standards deviations from the mean were used to fix the cut off points, these were lower in old women that in young ones. However, in men there were no differences. In this opportunity we would establish a severe low muscle mass.

The importance of having local cut-off points is shown in Table 2 where, depending on the population in which the studies are carried out, the cut-off points vary, being inadequate to use a
universal cut-off point for all populations as other authors have suggested [14,23]. Our study shows that even age within the same population is a factor that determines changes in body composition and therefore when reference limits are derived from one or another age group it will impact on the ability to detect sarcopenia. These data highlight the problem of having cut-off points based on populations outside the population in which they will be used, because these can produce a wrong diagnosis for an individual or an overestimation/underestimation of the prevalence of sarcopenia [23].

Most studies have accepted the recommendation of the EWGSOP-2010, to derive the cut-off points for low SMM to diagnose sarcopenia from the mean minus 2 standard deviations of a young population from the same region [24], however, this recommendation is based on statistical definitions with few studies deriving cutoff points directly from the older adult population [11-13, 25-26] and to the best of the authors knowledge this is the first paper comparing cut-off point derived from young vs old adult population.

We consider that between one generation and another there can be a great difference due to diverse lifestyles, diet, past illnesses, work activity and history of physical activity, among other things these circumstances could partially explain the differences since the methods used to evaluate the young people were the same as those used to evaluate the elderly population, so the results could not be attributed to methodological differences. We also used parameters like those of other studies to make them comparable. For example, we calculated muscle mass using the Janssen 2000 formula [8] because there is also a multiplicity of articles in which it has been used.

The differences found in the cut-off values to diagnose sarcopenia may impact the sarcopenia prevalence, however this was not evaluated in this paper. A strength of the present study is the rigor of the methodology used and the prior verification that the patients did not have a diagnosis of sarcopenia. In addition, we use electrical bioimpedance analysis because it is a very useful and inexpensive technique for populations like the one evaluated in this study, and it has become very popular today. In addition, the definition of low muscle mass is that some authors choose to measure the appendicular muscle mass, that is, only estimating the muscle from the 4 extremities, while others do so by estimating the muscle mass of the whole body.

The study is not without its limitations. The fact of being a study with a cross-sectional design does not allow us to verify the capacity of these cut-off points to predict adverse outcomes in older adults. No measurements were made with reference techniques to verify that the low SMM estimated by BIA agrees, for example, with that obtained with DXA.

5. Conclusions
SMMI cut-off thresholds obtained directly from an elderly population offer a provisional option to evaluate and establish a diagnosis of low muscle mass and sarcopenia, however these results differ from those obtained from young population, being these the criteria recommend for sarcopenia diagnosis. Actually, there is no parameterized definition to define a low muscle mass state, and as shown in this study the body composition in young and old people differ, being necessary prospective studies to establish the predictive capacity of the different cut-off points for functional outcomes in elders (disability, fractures, death) and establish more realistic and clinically relevant parameters to diagnose sarcopenia.

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Conflict of interest
None declared.
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