Skeletal muscle mass index by bioelectrical impedance analysis of self-supporting adults aged 60 years

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Abstract. Data on the prevalence of sarcopenia may differ in the same population depending on the reference values used. It is recommended to have reference values obtained from the same population. In Colombia, skeletal muscle mass (SMM) parameters are scarce. The objective was to establish normal values for the skeletal muscle mass index (SMMI) and reference values for loss of muscle mass through bioelectric impedance analysis to improve the diagnosis of sarcopenia in the region. This study involved 237 healthy community-dwelling adults over 60 years old. The cut-off values for diagnosis of loss of muscle mass were established as the mean \(-2SD\) of the population evaluated. The group included 141 females and 96 males. The mean of SMMI were 7.5 ± 0.7 and 9.6 ± 0.8 kg/m\(^2\) for women and men, respectively. The cut-off thresholds for low SMMI were 6.1 kg/m\(^2\) and 8.0 kg/m\(^2\) in females and males. The SMMI values of the self-support elderly found in this study are useful to determine when people have a muscle mass within normal limits and when they could be at risk of or have sarcopenia. Further studies from different regions of this high-rate biodiversity country are recommended to obtain national reference values.

1. Introduction
The progressive increase in aging worldwide is a reality. In 2015, 12.3% of the global population was 60 years of age or older. Every second, two people in the world turn 60 years old. For 2030, the projection is estimated at 16.5% and for the year 2092, it is expected to be 21.5\(^{[1]}\). In Colombia, the national average of the aging index reaches 34.4%, Caldas being the first department followed by Quindío, Risaralda, and Valle de Cauca. The whole region is known as Eje Cafetero de Colombia, or Coffee Cultural Landscape declared as a "World Heritage Site". It is considered an example of people's adaptation to geographic conditions of steep slopes and mountains in which a coffee culture surrounded by many peculiarities was created\(^{[2]}\).

Aging brings with it changes in body composition such as an increase in fat tissue and a reduction in muscle mass. However, when these phenomena overcome these physiological changes, they constitute pathological conditions such as obesity, sarcopenia, and sarcopenic obesity. The interest for this study is sarcopenia, a term proposed by Rosenberg in 1989 from the Greek races "sarx" or meat + "penia" or loss\(^{[3]}\). In 2010, a new concept was introduced, also comprising muscle function, represented by strength, power, and physical performance\(^{[4]}\). This is how the loss of strength and physical performance are part of the definition of sarcopenia and not only a loss of skeletal muscle.
mass, since these three components imply a risk of physical disability, loss of autonomy, frailty, poor quality of life, falls, greater morbidity and mortality, and increased health costs. On the other hand, sarcopenia is a frequent comorbidity in other diseases such as cancer, AIDS, diabetes, Chronic Obstructive Pulmonary Disease (COPD), liver and kidney failure, and malnutrition [5].

For the diagnosis of sarcopenia, three variables are considered: the size of the muscle mass, and the muscle’s strength and functionality, which are what allow the individual to carry out their daily activities. For the estimation of muscle size and a predictor of longevity in older adults, the SMMI has been adopted [6]. For the evaluation of muscular strength, the most used method is manual dynamometry, also known as handgrip strength (HGS) for physical performance, a variety of tests such as the short physical performance battery (SPPB) have been used [4]. In 2019, an update prioritized muscle strength rather than the amount of muscle to project the diagnosis of the entity [7].

Thus, the next option was to take data directly from the city of Manizales and found very different data according to the reference cut-off points that had been applied. When using the values of SMMI in the American population (NANHES III) (8.51–10.75 kg/m² for men and 5.76–6.75 kg/m² for women) the prevalence was 52.7%, while in the Asian population values (Taiwan) was applied, the number decreased to 16.8%, which is more like that described for the global prevalence. Given these discordant data, it was decided that the cut-off points be established from less than two standard deviations of a young population to apply to the older adults of the same community. The values found were 8.39 kg/m² for men and 6.42 for women [11].

However, the generational changes in the same population with respect to work activities, the way of eating and other factors such as the type of diet and the environment during development early in life, physical activity, diseases throughout life and the consequent consumption of medications, among others, could induce changes in cutoff points. In summary, the cut-off points to define ranges of normality are taken from foreign populations and are probably not valid for the Colombian population.

Globally, the prevalence of sarcopenia is estimated at 13% in people between the aged 60 to 70 years and it can increase to 50% in those over 80 years old. However, the prevalence depends on the criteria with which this entity is defined. Our group made the first approach to establish the prevalence in the city of Manizales and found very different data according to the reference cut-off points that had been applied. When using the values of SMMI in the American population (NANHES III) (8.51–10.75 kg/m² for men and 5.76–6.75 kg/m² for women) the prevalence was 52.7%, while in the Asian population values (Taiwan) was applied, the number decreased to 16.8%, which is more like that described for the global prevalence. Given these discordant data, it was decided that the cut-off points be established from less than two standard deviations of a young population to apply to the older adults of the same community. The values found were 8.39 kg/m² for men and 6.42 for women [11].

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Thus, the next option was to take data directly from self-reliant older adults, since in the region there are very few studies that account for the body composition of our population. Thus, this project aimed to establish the average differential values by sex and age of the SMMI of adults over 60 years of age. This will make it possible to improve the prevention and care models for patients and guide clinical guidelines focused on improving their functionality and prognosis.

2. Methodology

2.1. Subjects

This was a prospective, analytical study. The size of the sample was estimated using the information registered by the City Hall of Manizales, which reported the existence of 40000 adults aged 60 and over in the city. With a reported prevalence of people with sarcopenia of 15.5%, a confidence of 95%, and a precision of 5%, a sample size per proportion of 195 people was estimated. Finally, 237 community-dwelling older outpatients were prospectively recruited from the community.

Participants were intended to be broadly representative of the general adult population, and people from all socioeconomic strata were invited. To be eligible they had to be 60 or older and be self-supporting. This was evaluated in a previous telephone call in which the instructions before the exam were given and the inclusion criteria were reviewed, establishing that they could freely agree to
participate in the study and perform activities of daily living such as attending the exam and controlling sphincters. During the visit to the laboratory, it was verified that they could move, go up and downstairs, dress, and undress, use the toilet and go from a chair to a bed.

The other inclusion criteria were being a resident of the city of Manizales, being active, and not having a sarcopenia diagnosis. People with advanced or exacerbated chronic diseases, decompensate mental illnesses, partial or total amputation of a limb, with pacemakers, non-removable metal parts, or prostheses were excluded. People with moderate or severe disability, edema, current use of diuretics, or inability to walk were also ruled out.

2.2. Ethical aspects
The project was evaluated and endorsed by the ethics committee of the University of Caldas. This committee considered this study to be low risk. All patients signed informed consent.

2.3. Sociodemographic variables
Age, sex, marital status, dominant hand, and provenance were recorded.

2.4. Anthropometric Measurements
Anthropometric measurements were performed according to a reported protocol [12]. Measurements were performed early morning. In the measurements, it was confirmed that the volunteers complied with the standardized requirements [13] (fasting for at least 6 hours, having an empty bladder, not wearing jewelry that may alter data collection, among others).

Height was measured without shoes by a Heightronic-235 by Seca®, ± 0.01 cm stadiometer, to the nearest 0.1 cm, and weight were measured twice to the nearest 0.1 kg (with participants wearing light clothing) by a PP2000 by Icob-Detecto®, ± 0.1 kg scale. When there was a difference greater than 0.5 cm or 0.1 kg, a third measurement was taken, averaged and the result was the one recorded. Body mass index (BMI) was established from weight and height (Kg/m²) [14].

2.5. BIA measurements to estimate SMMI
Due to the influence that some variables have on bioimpedance measurements, relative humidity were controlled with an electric heater (BFH416 by BionaireTM) and ambient temperature were measured with a thermohygrometer (13307 by Delta Trak®, ± 0.1 ° C). Electrical bioimpedance was measured three occasions on the dominant side of the body on a non-conductive surface with Hydra 4200 bioimpedance meter Xitron Technologies® [13].

Lean mass was obtained with the internal equation of the bioimpedance analyzer. Estimation of SMMI, was performed using the data at 50 kHz with the SMMI was estimated from the resistance at 50 kHz applying a predictive equation (1) validated for the Hispanic population [10]:

\[
SMM (kg) = \left( \frac{height^2}{R_{50} \times 0.401} + (gender \times 3.825) + (age \times -0.071) \right) + 5.102. \tag{1}
\]

Where height in centimeters, the resistance of electrical bioimpedance in ohms, female is equal to 0 and the male to 1, and age is recorded in years. Then, the SMMI was calculated by dividing the SMM by height². By means of the SMMI adjusted for sex, two standard deviations were subtracted to establish the cut-off point for a low rate of SMM.

2.6. Statistical Analysis
Since there were more than 50 records, the Kolmogorov-Smirnov test was used to determine the distribution of the data. A descriptive analysis was performed for qualitative variables using absolute and relative frequencies. Quantitative variables were analyzed according to their distribution in means and standard error of the mean. SMMI was classified by age and sex. Statistics were calculated as
mean and standard deviation of the mean and the respective 95% confidence intervals, 25 percentile, and standard deviation of the mean to make it comparable to other studies.

All analyses were performed in the SPSS statistical software version 25, licensed for la Universidad de Caldas.

3. Results
None of the variables had a normal distribution according to the Kolmogorov-Smirnov test for a sample. In Table 1 and table 2 shows demographic data as mean and standard error of the mean of BIA parameters by age and sex. Table 3 describes the SMMI for women and table 4, for men. Figures 1 and 2 illustrate the SMMI means and standard deviation (SD) by age groups and sex.

### Table 1. Sociodemographic variables.

| Condition | Frequency (n) | Percentage (%) |
|-----------|---------------|----------------|
| Sex       |               |                |
| Women     | 141           | 59.5           |
| Men       | 96            | 40.5           |
| Provenance|               |                |
| Urban     | 236           | 99.6           |
| Rural     | 1             | 0.4            |
| Dominant hand |       |                |
| Right-handed | 225         | 94.9           |
| Left-handed  | 12           | 5.1            |
| Age (years) |             |                |
| 60 a 64.9  | 20            | 8.4            |
| 65 a 69.9  | 129           | 54.4           |
| 70 a 74.9  | 65            | 27.4           |
| 75 a 79.4  | 12            | 5.1            |
| ≥80        | 11            | 4.6            |
| Total      | 237           | 100.0          |

### Table 2. BMI and BIA parameters by age and sex.

| Condition | BMI (kg/m²) | R50 (kHz) | FFM (kg) | FFMI (kg/m²) | SMM (kg) |
|-----------|-------------|-----------|----------|--------------|----------|
| 60 a 64.9 | Women 9     | 30.5 1.6  | 516.8 17.1| 20.7 0.5     | 8.9 0.4  | 19.0 0.7 |
| Men 11    | 26.5 0.8   | 511.2 14.0| 24.1 0.5  | 8.3 0.2      | 27.5 0.7 |
| 65 a 69.9 | Women 79    | 26.6 0.5  | 558.2 6.2 | 18.8 0.2     | 8.2 0.1  | 16.9 0.2 |
| Men 56    | 25.7 0.7   | 466.9 5.9 | 23.8 0.5  | 8.5 0.1      | 28.6 0.5 |
| 70 a 74.9 | Women 41    | 28.2 0.7  | 523.1 10.4| 19.7 0.3     | 8.5 0.2  | 18.1 0.4 |
| Men 24    | 26.0 0.6   | 460.9 6.9 | 23.4 0.4  | 8.6 0.1      | 27.5 0.5 |
| 75 a 79.4 | Women 10    | 26.3 1.2  | 548.4 15.2| 18.8 0.5     | 8.1 0.2  | 16.7 0.6 |
| Men 2     | 28.3 0.2   | 494.8 23.2| 23.1 0.2  | 9.5 0.1      | 23.2 0.5 |
| ≥80       | Women 8     | 30.0 1.4  | 527.2 13.0| 19.7 0.7     | 9.0 0.3  | 15.8 0.8 |
| Men 3     | 25.1 4.3   | 538.4 45.4| 20.8 2.5  | 9.0 0.8      | 20.6 2.7 |
| All 70.2  | Women 141   | 27.5 0.4  | 542.9 4.9 | 19.2 0.2     | 8.4 0.1  | 17.3 0.2 |
| Men 96    | 25.8 0.4   | 473.3 4.8 | 23.7 0.3  | 8.5 0.1      | 27.8 0.4 |

Abbreviations: BMI, body mass index; SMM, skeletal muscle mass; FFMI, fat-free mass index.
Table 3. SMMI for women.

| Age     | n  | Mean | Mean CI 95% | 25th Percentile | Mean -1 SD | Mean -2 SD |
|---------|----|------|-------------|-----------------|------------|------------|
| 60 a 64.9 | 9  | 8.1  | 7.5         | 8.7             | 7.4        | 7.3        | 6.5        |
| 65 a 69.9 | 79 | 7.4  | 7.2         | 7.6             | 6.8        | 6.7        | 6.0        |
| 70 a 74.9 | 41 | 7.8  | 7.5         | 8.1             | 6.9        | 6.8        | 5.8        |
| 75 a 79.4 | 10 | 7.2  | 6.8         | 7.7             | 6.7        | 6.6        | 5.9        |
| ≥ 80     | 8  | 7.2  | 6.8         | 7.7             | 6.7        | 6.7        | 6.2        |
| All      |    | 7.5  | 7.1         | 7.9             | 6.9        | 6.8        | 6.1        |

The data are shown as mean and standard deviation (SD).

Table 4. SMMI for men.

| Age     | n  | Mean | Mean CI 95% | 25th Percentile | Mean -1 SD | Mean -2 SD |
|---------|----|------|-------------|-----------------|------------|------------|
| 60 a 64.9 | 11 | 9.5  | 9.0         | 9.9             | 9.2        | 8.8        | 8.1        |
| 65 a 69.9 | 56 | 10.2 | 9.9         | 10.4            | 9.4        | 9.3        | 8.5        |
| 70 a 74.9 | 24 | 10.2 | 9.9         | 10.4            | 9.5        | 9.5        | 8.8        |
| 75 a 79.4 | 2  | 9.5  | 4.6         | 14.5            | 9.2        | 9.0        | 8.4        |
| 80 y más | 3  | 8.9  | 5.8         | 12.0            | 7.6        | 7.6        | 6.4        |
| All      |    | 9.6  | 7.8         | 11.5            | 9.0        | 8.8        | 8.0        |

The data are shown as mean and standard deviation (SD).

Figure 1. SMMI means and SD for women by age groups.
Figure 2. SMII means and SD for men by age groups.

4. Discussion
The average normal values for the SMII and those that would establish a low muscle mass in this study with 237 elderly (60 to 94.4 years) were 7.5 and 6.1 kg/m² and 9.6 and 8.0 kg/m² in women and men respectively. These data are lower than those reported by Bahat, et al [15], who assessed a group of 406 older subjects (mean age 65 to 99 years old) from Turkey’s community.

The corresponding data found by these authors were 9.0 ± 0.8 and 7.4 in women and 11.0 ± 0.9 and 9.2 kg/m² in men. On the other hand, Janssen, et al [16], found mean values more similar to those found in the present study. In 2276 women and 2223 men, participants from the Third National Health and Nutrition Examination Survey (1988–1994) representing the non-Hispanic White, non-Hispanic Black, and Mexican American communities, in the United States, the researchers described a mean value of SMI of 7.04 (±1.11) and 9.86 (±1.18) for women and men.

Consequently, they established cut-points of <8.50 kg/m² in men and <5.75 in women as having severe muscle mass loss and high physical disability risk thresholds. They used the same BIA equation as the one in this study to determine the SMI. This BIA equation was constructed and validated in a study where magnetic resonance imaging was the gold standard and the correlation of the results between both techniques was 0.93 with a standard error of the estimate of 9 percent [17].

However, in this, that study the ages of the participants ranged between 18 to 86 and the definition of low muscle mass was made with SMII values of two standard deviations or more below the young adult mean and not as the current study where it was reported <2 SD of the mean of elders. Moreover, Baumgartner et al, [18] published cutoff points for sarcopenia similar to ours, 5.9 in women and 8.1 kg/m² in men to establish sarcopenia, nevertheless, they used appendicular muscle mass as a basis for their cutoff points and not whole-body muscle as in the present study.

As can be inferred, these differences may be due to genetic characteristics of the populations; anthropometric and occupational differences, types of methodologies that include different measurement devices and the statistical analysis used to suggest the cutoff points [19].
These same factors explain why universal cutoff points for diagnosing low muscle mass have not yet been established. Even more, within the same country, as in Colombia, where there is wide ethnic variability and, in turn, differences in the aging index, it may be necessary to define regional cutoff points. In this case, perhaps the older adults of the coffee region could be an example to indicate successful aging associated with a specific average of SMMI but on the other hand, due to this high rate of aging, sarcopenia may be more prevalent.

Therefore, it is important to use proper cutoff points to allow more accurate estimates of the prevalence of sarcopenia, which, in turn, stimulates the development of more effective medical interventions for the prevention and timely management of this geriatric syndrome.

The present work is not without limitations. The results were not validated by a reference technique such as DXA or MRI, however, the technique that has been highly correlated with these methods it is considered by the EWGSOP consensus as a good portable alternative [4]. Another difficulty has to do with the small number of participants in the oldest five-year periods, which is why it is suggested to expand the sample for these cases in future studies.

In another way, there is strength to the study. Although due to its low-cost and easy-to-use characteristics, the BIA technique can be a good option for the evaluation of loss of muscle mass, it has several requirements before and during its use that must be met for the results to be reliable, such as hydration status, temperature, time of measurement, body position, among others. These factors were rigorously satisfied following a previously published protocol [20]. This is how the findings of this work should be viewed under these limitations and strengths. Even so, we feel that the values found for SMMI may be more in line with reality, having been obtained directly from the population of older adults, and are very similar (slightly lower) to those found from young people of the same population [11].

5. Conclusions
BIA is suitable for body composition assessment of SMMI in elderly Colombians. Our study suggests cutoff thresholds for SMMI in a region of the Colombian population. Further studies from other regions of the country are needed to obtain national reference values for populations and have more valid data on sarcopenia prevalence. Consequently, the results may allow an earlier diagnosis and a more timely medical intervention for sarcopenia, a condition that produces many disabilities, high healthcare costs, and takes many lives.

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Conflict of interest
No conflicts of interest are declared by authors.

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