Electrical Bioimpedance Phase Angle and Sarcopenia Diagnostic in Functional Elderly

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Abstract. Bioelectrical impedance analysis (BIA) directly measures the phase angle (PA). PA has been associated with nutritional parameters, strength, and muscle mass, emerging as a possible and novel diagnostic marker of sarcopenia. The aim of this study was to establish PA cut off points for diagnosing sarcopenia in functional elderly from Colombia. 255 volunteers were analyzed. PA measurements taken by BIA were used, and the level of correlation with hand grip strength (HGS) and skeletal muscle mass index (SMMI) was established. In men and women, PA had a direct correlation with SMMI (p=0.010; r=0.252) (p=0.003; r=0.237) and with HGS (p=0.038; r=0.206) (p=0.019; r=0.190) respectively. We used different statistical approaches to establish various cut off points with their sensitivities and specificities. The ROC curves and areas under curve were elaborated (0.91 in men and 0.56 in women). 6.12 ° in men and 5.74 ° in women are proposed as cut off points to diagnose sarcopenia, with good performance in men and less adequate performance in women, demonstrating the differences in body composition according to sex even within the same population and the need for further studies to relate these cut-off points with functional outcomes.

1. Introduction

Sarcopenia is the presence of low muscle mass and low muscular performance and strength. This condition is associated with adverse outcomes in elderly [1]. The SMMI is a parameter BIA-derived that has been used to diagnose low SMM [1,2], however this is calculated from formulas [3] that could be affected by the patient's hydration status, among other factors.

The PA is calculated directly from resistance and reactance, reflecting body cell mass, health, and cell wall integrity [4,5] and has been associated with adverse outcomes such as frailty [6], falls [7] and incident disability [8]. More recently it has been proposed as a marker of sarcopenia [9-12] with potential use in establishing the diagnosis of this entity.

The cut-off points for diagnosing sarcopenia should be derived from body composition data from population similar to the one they will be applied [1,5,13]. In Caldas, there are reference values to define sarcopenia in the elderly based on SMMI from a young, healthy population [2], with a study in elders from Manizales showing an association between PA and sarcopenia, without finding a good predictive capacity to make a diagnosis, probably due to small sample size in the study [14]. This lack of knowledge of reference values of PA in functional elderly and how they relate to the diagnostic categories for sarcopenia proposed by the EWGSOP European consensus on sarcopenia [1] have limited their use to diagnose this condition.

The aim of this study was to establish PA cut off points for diagnosing sarcopenia in functional elderly from Colombia.

2. Methodology

2.1. Type of study

Observational, ambispective, cross-sectional, analytical, and predictive level.
2.2. Population

Volunteers over 60 years of age, from Caldas, with functional independence in activities of daily living (ADL), defined as Barthel index equal or greater than 95 points. Persons with inability to perform manual dynamometry, users of drugs that alter BIA such as diuretics, steroids, growth hormone, dihydropyridine calcium channel blockers, anorexigens, gabapentin at high doses (600 mg/d or more), presence of edema, decompensated heart failure in the last 3 months, myxedema, lymphedema, deep vein thrombosis in the last 3 months, post-phlebitic syndrome with edema were excluded. Chronic kidney disease in renal replacement therapy, history of decompensation of chronic disease in the last 3 months, presence of major neurocognitive disorder, amputations or alterations in body geometry, lesions or skin abnormalities, presence of prostheses, pacemakers or other elements that affect the collection of BIA data were also excluded.

The patients were recruited using advertisements in groups of elderly people in the cities and from internal medicine and geriatrics outpatient clinics. Data from previous studies will also be taken as long as the patients had complete data and meet the inclusion and exclusion criteria. Sampling was non-probabilistic.

2.3. Measurements

The patient assessment was carried out in the morning. The environmental variables were measured with a thermohygrometer (13307 by Delta Trak®, ± 0.1 ºC) and controlled with an electric heater (BFH416 by BionaireTM) and a dehumidifier (BMD100 by Bionaire TM). It was confirmed that the volunteers complied with the standardized requirements before the test (fasting for at least 6 hours, empty bladder, no use of items such as a watch, bracelets that alter data collection, among others).

Weight (PP2000 by Icob-Detecto®, ± 0.1 kg) and height (Heightronic-235 by Seca®, ± 0.01 cm) were measured twice. If a difference greater than 0.5 cm or 0.1 kg was observed in length and weight, respectively, a third measurement was taken. We choose the median value of the measurements.

The dominant side of the body was used to measure the multifrequency electrical bioimpedance. It was measured on three occasions on a non-conductive surface with Hydra 4200 equipment by Xitron Technologies©. Lean mass was calculated with the incorporated equation of the bioimpedance analyzer. Estimation of SMM was performed using a predictive equation validated for the Hispanic population [3]:

\[
SMM (kg) = [(H^2 / R50 \cdot 0.401) + (gender \cdot 3.825) + (age \cdot -0.071)] + 5.102.
\]

In the equation 1, H is the height in cm, R the resistance of electrical bioimpedance with an operating frequency of 50 kHz in ohms, gender is equal to 0 in women, 1 in men. Age was recorded in years. Then, to obtain SMMI, the SMM was divided between height squared. The cut-off points of the second European consensus on sarcopenia [1] were used to define low ISMM (in men < 7 kg/m²; in women < 5.5 kg/m²).

HGS was measured 3 times (the best value was used) using a Baseline® hydraulic dynamometer (±1 kg) (Fabrication Enterprises Inc. USA) based on the guidelines received from the American Association of Hand Therapists [16]. Low HGS was defined according to the second European consensus on sarcopenia (< 27 kg in men and 16 kg in women [1]. Gait speed was measured over 4 meters, and a value of less than 0.8 m/sec was taken as low gait speed.

The gold standard for sarcopenia diagnosis was based in the EWGSOP2 [1]: sarcopenia probable (low HGS); sarcopenia confirmed (low HGS + low SMMI) and sarcopenia severe (sarcopenia confirmed + low gait speed).
2.4. Statistical analysis

Qualitative variables were described using absolute and relative frequencies. To quantitative variables averages with standard deviation were used. To determine the data distribution, we use the Kolmogorov-Smirnov test. Pearson test was used to determine the correlation between quantitative variables with normal distribution and Spearman for those with non-normal distribution.

Based on the diagnostic categories of sarcopenia of the second European consensus [1] and using statistical parameters adopted by previous studies to determine low PA as a predictor of sarcopenia (tertile 1, 5th percentile, 10th percentile, and 2 SD below average) and values derived from ROC curve analysis [7,17,18], potential PA cut-off points for diagnosing sarcopenia are proposed.

Then, we calculate the sensitivity and specificity of these values and based on these we draw the ROC curve with its respective AUC disaggregated by sex to establish the cut-off point with the best diagnostic yield. Statistical significance was established when p-value <0.05. All analyses were performed in the SPSS statistical software (version 25) licensed for the Universidad de Caldas.

2.5 Ethical aspects

The ethics committee of the Universidad de Caldas approved the study (act No. 013 of 2020). The participants agreed to participate and signed the informed consent prior to the evaluations.

3. Results

255 community-dwelling adults older than 60 years, independents in ADL were analyzed. The average age was 69 years from which 60% were women (n=153) (table 1). The body mass index (BMI) was higher in women than in men (p= 0.01) and the average SMMI was higher in men than in women (p= 0.00). As it was expected, the average maximum HGS for men was greater than for women (p =0.00). The overall prevalence of sarcopenia in the population was 5.9%.

The range for PA ranged from 3.6° to 7.9°. The average PA for sarcopenic elderly was lower than in non-sarcopenic elderly (6.17° vs. 5.74°; p = 0.04). In men, the data for PA, SMMI and HGS had a normal distribution, while in women, it was normal only for PA and SMMI data.

Table 1. Anthropometric, functional, and phase angle of elderly adults.

| Variable       | Total (n= 255) | Men (n= 102) | Women (n= 153) | p*  |
|----------------|----------------|--------------|----------------|-----|
| Age (years)    | 69.2 (4.7)     | 68.6 (4.5)   | 69.5 (4.9)     | 0.12|
| BMI (kg/m²)    | 25.8 (4.3)     | 25.1 (4.4)   | 26.2 (4.2)     | 0.01|
| SMMI (kg/m²)   | 8.3 (1.6)      | 9.9 (0.1)    | 7.2 (0.1)      | 0.00|
| Gait speed (m/sec) | 0.8 (0.2) | 0.8 (0.2)    | 0.8 (0.2)      | 0.24|
| HGS (Kg)       | 27.6 (8.5)     | 36.1 (5.7)   | 21.9 (4.1)     | 0.00|
| Sarcopenia (%) ** | 5.9             | 5.9           | 5.9            | 1.0 |
| PA (°) at 50 kHz | 6.2 (0.8)     | 6.4 (0.7)    | 6.0 (0.8)      | 0.00|

The data are show as mean and standard deviation (± SD). p* value of the difference between men and women. **Refers to the presence of sarcopenia (1).

Abbreviations: BMI, body mass index; SMMI, skeletal muscle mass index; HGS, hand grip strength; PA, phase angle.

In both sex, PA had a direct correlation with SMMI (p = 0.010 in men and p = 0.003 in women) and with HGS (p = 0.038 in men and p = 0.019 in women). No correlation was found between PA and gait speed. The correlation coefficient (r) between PA and the diagnostic variables of sarcopenia in men and women was PA and SMMI 0.252 and 0.237; PA and HGS 0.206 and 0.190, respectively.

Table 2 shows the phase angle values obtained from the application of 5 statistical methods used in previous studies [7,17,18] to define PA cut-off points: tertile 1 (T1), 5th percentile (p5), 10th percentile (p10), -2 SD below average and the ROC curve analysis (figure 1). The sensitivity and
specificity were calculated (Table 2).

![Figure 1. ROC curve. The figure shows the ROC curve for women (red) with AUC 0.878 and men (black) with AUC 0.517.](image)

**Table 2.** Sensitivity and specificity of the different PA cut-off points for the diagnosis of sarcopenia.

|         | Men (n=102) | Women (n=153) |
|---------|-------------|---------------|
| **T1**  |             |               |
| PA (°)  | 6.12        | 5.61          |
| S (%)   | 83.3        | 44            |
| E (%)   | 69.8        | 68.1          |
| **p5**  |             |               |
| PA (°)  | 5.32        | 4.91          |
| S (%)   | 33.3        | 11.1          |
| E (%)   | 96.9        | 95.8          |
| **p10** |             |               |
| PA (°)  | 5.59        | 5.08          |
| S (%)   | 50          | 11.1          |
| E (%)   | 93.8        | 90.3          |
| - 2 DS of media | | |
| PA (°)  | 4.98        | 4.34          |
| S (%)   | 33.3        | 0             |
| E (%)   | 99          | 98.6          |
| Derived from ROC curve (Figure 2) | | |
| PA (°)  | 6.02        | 5.74          |
| S (%)   | 66.7        | 55.6          |
| E (%)   | 76          | 59.7          |

Abbreviations: S, Sensitivity; E, specificity; SD, standard deviation; T1, tertile 1; p5, percentile 5; p10, percentile 10; SD, standard deviation.
With the data from Table 2 the ROC curves were drawn (Figure 2) to establish the best cut off point to sarcopenia diagnosis. By means of the COR curve analysis, the cut-off point for the phase angle was established as 6.12° (sensitivity 83.3% and specificity 69.8%) for men and 5.74° (sensitivity 55.6% and specificity 59.7%) for women.

4. Discussion
Earlier reports have found that the PA could be a marker of sarcopenia and be used as a diagnostic test (9)(10). Similar to others papers (11)(12)(19)(20) we found the PA was directly associated with SMM and HGS, although the degree of association was poor, which could be partly explained by the small sample size and and the low prevalence of sarcopenia. However, the PA was lower in sarcopenic than in non-sarcopenic elderly (p = 0.04), this allow inferring that the phase angle is related to sarcopenia and therefore can be taken as a surrogate for its identification in the elderly (9)(19).

In this study, we employed data from ROC curve, and an PA of 6.12° in men and 5.74° in women are proposed as cut off points to diagnose sarcopenia in older persons. When the ROC curve is drawn and their AUC interpreted, the test's discriminative ability varies between sexes, being good in men (AUC 0.889) and poor in women (AUC 0.556). Kilic et al. (9) in 263 elders found low PA as an independent factor to sarcopenia and they proposed a cut-off value of 4.55° to detect sarcopenia, however, they did not establish cutoff points discriminated by sex.

In functional older adults in Japan, Yamada et al. (10) using ROC curve analysis established 4.05° and 3.55° as the cut-off point to identify sarcopenia, in men and women respectively, with fair accuracy in both sex (AUC in men 0.718 and in women 0.773). Another study in 4312 elderly people established a phase angle of 4.95° for men and 4.35° for women as cut-off points for predicting incident disability, with a fair performance.

In our analysis, the phase angle cutoff point in men was higher than in other populations, explained by the low comorbidity and functional study population, as well as by variations in body composition between different populations. Another source of variation is the gold standard used to establish the diagnostic performance of phase angle, as Uemura et al. (8) used a ROC curve and incident disability
risk, while other authors used diagnostic criteria for sarcopenia derived from consensuses other than EWGSOP2.

A significant finding was the difference in PA diagnostic performance in men and women. Pessoa et al. (21) in 94 women from Uberlandia and Santana et al. (22) in hospitalized elderly in Brazil found similar results in women. Among the reasons that may explain this difference could be the type of population, being functional elderly women with low prevalence of sarcopenia (similar to the population of Pessoa study), where confounding variables such as age and height could have a higher correlation with PA, however these factors were not studied in this paper. Another possible reason is small sample size with low statistical power. In the other hand low PA could be more a marker of severity than diagnosis as proposed previously (22) but it was not evaluated in the present study.

In clinical practice, the AP may be an optional tool to diagnose sarcopenia. Using in men 6.12 ° as cut off point is useful taking account its good discriminative ability. In women, the test evaluated had high specificity at the expense of sensitivity. This should be interpreted with great caution; however, in women the PA could be proposed as a confirmatory test for sarcopenia after evaluating with a test higher sensitivity, as it would reduce the number of false positives (23) and it could be potentially useful when are used sarcopenia parameter not derived from local population. However, new longitudinal studies are necessary to establish if this cut-off values can predict functional outcomes (falls, disability, fractures and death) in older person.

The present study has several strengths. Firstly, is that this is one of the first studies in our region that gives PA values in a functional elderly population. Besides, it evaluates different cut-off points based on the parameters established by other authors to define the diagnosis of sarcopenia. Secondly it associates the PA with the diagnosis of sarcopenia and its components, showing that it could be an indicator of sarcopenia since it is lower in the sarcopenic elderly.

Among the weaknesses, it could be counted as a cross-sectional study and thus not associate the PA value with outcomes such as falls, disability, or death. Most of the population was from Manizales, which limits the external validity of the data for other populations.

5. Conclusion
The use of PA with the cut-off points of 6.12 ° and 5.74, in men and women respectively, are optional approach to diagnose sarcopenia. In women, the test evaluated have high specificity being useful as a confirmatory test in populations at high risk of sarcopenia. In men the cut-off point proposed had good performance to diagnose sarcopenia. However, further studies are still required to establish the actual usefulness of this parameter in diagnosing sarcopenia given the ambiguity and various methodologies proposed for its use and especially longitudinal studies that allow us to establish the discrimination capacity of these cut-off points with the development of outcomes of interest in the elderly population.

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

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