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Correlation between phase angle, body composition, and bioelectrical impedance vector analysis in older adults

Correlação entre o ângulo de fase, a composição corporal e a análise vetorial de bioimpedância em idosos

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Few studies have examined the relation of phase angle (PhA) with body composition and the bioelectrical impedance vector analysis (BIVA) in older adults. The objective of this study was to investigate the correlation between PhA and body composition in community-dwelling older adults and to identify the PhA classification in the position on the RXc graph. A cross-sectional study was conducted with 144 older adults of both sexes. The body composition indicators evaluated included fat-free mass (FFM), fat-free mass percentage (FFM%), skeletal muscle index (SMI), total body water (TBW), body fat (BF), and body fat percentage (BF%). A comparative analysis of PhA and BIVA was also conducted. PhA exhibited an inverse proportional correlation with age, BF%, and TBW, as well as a positive correlation with FFM, FFM%, and SMI ($p < 0.05$). Individuals with PhA < 5º exhibited higher mean age, FFM, TBW, and SMI ($p < 0.05$). An evaluation of BIVA revealed that subjects exhibiting a lower PhA were predominantly located in the lower right quadrants for specific tolerance, indicative of a thin body and cachexia. The findings of this study indicated a correlation between PhA and various body composition markers, including FFM, FFM%, BF%, TBW, and SMI. The data presented in the RXc graph demonstrated that older adults with lower PhA were characterized as thin and cachectic. PhA and BIVA have been identified as potential parameters that could facilitate the mapping of nutritional status among older adults.
Keywords: body composition, electric impedance, older adults.

Poucos estudos examinaram a relação do ângulo de fase (AF) com a composição corporal e a análise vetorial de impedância bioelétrica (BIVA) em idosos. O objetivo deste estudo foi investigar a correlação entre o AF e a composição corporal em idosos que vivem na comunidade e identificar a classificação do AF na posição do gráfico RXc. Foi realizado um estudo transversal com 144 idosos de ambos os sexos. Os indicadores de composição corporal avaliados incluíram massa livre de gordura (MLG), porcentagem de massa livre de gordura (%MLG), índice muscular esquelético (IME), água corporal total (ACT), gordura corporal (GC) e porcentagem de gordura corporal (%GC). Também foi realizada uma análise comparativa de AF e BIVA. O AF apresentou uma correlação inversamente proporcional com a idade, %GC e ACT, bem como uma correlação positiva com MLG, %MLG e IME ($p<0,05$). Os indivíduos com AF <5º apresentaram maior média de idade, MLG, ACT e IME ($p<0,05$). A avaliação da BIVA revelou que os idosos que apresentavam AF<5º estavam predominantemente localizados nos quadrantes inferiores direitos para tolerância, o que indica magreza e caquexia. Os resultados deste estudo indicaram uma correlação entre o AF e marcadores de composição corporal, incluindo MLG, %MLG, %GC, ACT e IME. Os dados apresentados no gráfico RXc demonstraram que os adultos mais velhos com AF mais baixa foram caracterizados como magros e caquéticos. O AF e BIVA foram identificadas como parâmetros potenciais que poderiam facilitar o mapeamento do estado nutricional entre adultos mais velhos.
Palavras-chave: composição corporal, impedância bioelétrica, idosos.

1. INTRODUCTION

As older adults undergo the process of aging, they may experience a variety of physiological, emotional, and behavioral changes. It is important to note that these changes can influence the body composition of older adults. These changes are associated with the development of health problems, such as sarcopenia, obesity, and cardiovascular diseases, which may lead to a negative impact on the nutritional status and quality of life of older adults [1]. Consequently, the assessment of body composition can facilitate the identification of mechanisms that potentially contribute to active aging. In this regard, advanced methods for nutritional assessment, including phase angle (PhA) and bioelectrical impedance vector analysis (BIVA), have been examined in this population [2, 3].

The PhA has been demonstrated to directly depict the stability and integrity of cells, in addition to reflecting water distribution in intra- and extracellular spaces. Furthermore, the PhA has been associated with nutritional status and comorbidities, and it has been demonstrated to influence the potential health prognosis in older adults. This is due the fact the nutritional condition, such as malnutrition and severe diseases, decreases cell integrity. [4, 5]

As an alternative reliable method for determining body composition in older adults, scientific literature has suggested the use of BIVA as a screening tool [6]. The BIVA model is derived from a graph with resistance (R) and reactance (Xc) variables, corrected according to the body length. This approach overcomes the limitations of conventional bioimpedance analysis in developing specific equations. Consequently, BIVA offers a more comprehensive array of information concerning body hydration and cellular integrity, thus facilitating more thorough evaluation and monitoring of an individual's health conditions [6, 7].

PhA and BIVA present a viable clinical approach to the evaluation of body composition and can be used as a screening tool to identify patients at risk of nutritional deficiency. It is imperative to examine the role of these indicators, given the scarcity of studies that have evaluated PhA and BIVA among older adults and the significant discrepancy in PhA between healthy and diseased states. In Brazil, the relationship between PhA in older adults and sarcopenia [8, 9], physical activity [10], functional capacity [11], and nutritional parameters [12, 13] has been the focus of several studies. However, there is a lacuna of research examining the relationship between PhA, body composition and BIVA in older adults. It is important to assess the performance of PhA and BIVA in this age group in the country. Thus, the aim of the present study was to investigate the relationship between PhA and body composition in older adults and to identify the PhA classification in the position on the RXc graph.

2. METHODS

2.1 Study design and participants

A cross-sectional study was conducted in a geriatric clinic in the city of Lagarto, state of Sergipe, Brazil, from August 2019 to January 2020. The sample consisted of older adults of both sexes, aged 60 years or older, who visited the geriatric clinic for assistance. The older adults served by the geriatric clinic were more autonomous and presented with diseases such as hypertension, diabetes, and dyslipidemia.

Currently, the clinic assists 10 older adults once a week according to a previously prepared appointment list, with an average of 480 geriatric visits per year. We evaluated the geriatric schedule for patient selection. In total, 8 out of the 10 patients on the geriatric appointment list were randomly selected to participate in our study using their appointment code. Our data collection team then interviewed the individuals who agreed to participate in the study.

This study is part of the project entitled, "Health conditions and nutritional status of older adults attending a geriatric outpatient clinic in Lagarto, Sergipe." We estimated the required sample size of our study that would achieve our main objective based on the prevalence of underweight among the geriatric outpatients. We used the official national average prevalence of underweight (14.2%) for older adults in Lagarto, obtained from the SISVAN web platform, a federal government database with information related on Brazilian nutritional assessment in all age strata (http://sisaps.saude.gov.br/sisvan/relatoriopublico/index). We used a margin of error of 0.05, a confidence interval of 95%, and a design effect of 1, as recommended when estimating simple random samples. The minimum sample size required was 135 participants but, to account for the possibility of dropouts from the study, 10% more older adults were added to the initial sample, for a total of 147 individuals. Sample size estimation of sample size was determined by calculations made using the OpenEpi software [14].

The study included older adults who were ambulatory, who met all of the recommendations for carrying out bioimpedance analysis [15], and who agreed to participate in the study by signing the free and informed consent form. The study did not include individuals with physical and/or postural limitations that precluded anthropometric measurements; individuals with cognitive limitations, pacemakers, swelling, ascites, and/or the presence of visceromegaly were also excluded.

2.2 Data Collection

Data were collected on age, nutrition (weight, body mass index [BMI], fat free mass [FFM], body fat [BF], total body water [TBW], and skeletal muscle index [SMI]), bioimpedance (PhA, R, and Xc), and BIVA.

2.3 Anthropometry

For anthropometric assessment, weight and knee height data were collected. Height was estimated using the equation of Chumlea et al. (1985) [16], and BMI was calculated (BMI= weight/height^2).

2.4 Bioimpedance Analysis

Bioimpedance was performed using a Biodynamics Model 310e analyzer (Seattle, WA, USA) with 0.1% resistance and 0.2% reactance accuracy, 800 µA electric current intensity, and 50 kHz electric current frequency. To perform the bioimpedance analysis exam, older adults were instructed according to the manufacturer's instruction and the recommendations of the European Society for Enteral and Parenteral Nutrition [15].

The resistance and reactance values were used to calculate the FFM percentage (FFM%), as described by Gonzalez et al. (2019) [17]. The FFM, in kilograms, was calculated from the FFM% in relation to body weight (kg). BF, in kilograms, was classified by subtracting the FFM from body weight. The BF percentage (BF%) was obtained by calculating the percentage of body weight corresponding to the total BF. PhA was calculated using the formula: PhA(°) = arctangent (Xc/R) x (180°/π). PhA was considered "low" if it was a value <5° [18, 19].

Skeletal muscle mass (SMM) was calculated using the equation proposed by Janssen et al. (2000) [20] and corrected for height to obtain the SMI (SMI= SMM/height^2).

2.5 Bioelectrical Impedance Vector Analysis

BIVA was applied, adjusting individual vectors for height (R/H, ohm/m; Xc/H, ohm/m) to eliminate the effect of conductor length. The characteristics of an individual or sample were compared with the concentric tolerance ellipses (50%, 75%, and 95% of cases) and classified by quadrant using specific software developed by Piccoli e Pastori (2002) [21]. Allocations in the lower left quadrant correspond to obese individuals; the upper left quadrant to eutrophic individuals with an athletic profile, the upper right quadrant to thin patients, and the lower right quadrant to individuals with cachexia [21].

2.6 Statistical Analysis

Data analysis was performed using SPSS® software, version 20.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to test the normality of the quantitative variables. Descriptive data analysis was performed; quantitative variables were expressed as absolute and relative distributions, and categorical variables were expressed as mean. Student's t-test was used to compare the means of age and body composition (BMI, FFM, BF, TBW, and SMI) according to PhA classification. Spearman's correlation coefficient was used to evaluate the correlation between PhA, age, and body composition (BMI, FFM, BF, TBW, and SMI).

BIVA was performed using specific software [21], and we referred to a previous study of Italian older adults of both sexes aged 65 to 100 years [22] for comparison on the RXc graph. The Italian study population had similar characteristics to the participants in this study. At the time of writing, there is no reference population for Brazilian older adults. We performed BIVA stratified by sex based on the information available in the reference study. A significance level of $p<0.05$ was used for all analyses.

2.7 Ethical approval

This study was approved by the Research Ethics Committee of the Federal University of Sergipe (report number 559.936), in accordance with the Declaration of Helsinki. Prior to their participation, all subjects were required to sign an informed consent form.

3. RESULTS

A total of 144 older adults, 77.1% of whom were women, with a mean age of 80.2±9.2 years were included in this study. Three subjects (2.04%) were not included because they did not meet the criteria for bioimpedance analysis. The classification of PhA showed that 44.4% of the individuals had a PhA <5°. The characteristics of the participants are shown in Table 1.

Table 1. Descriptive analysis of the variables age, BMI, body composition and BIA variables in older adults.

Variables	n (%)
Sex	
Men	33 (22.9)
Women	111 (77.1)
PhA classification	
< 5º	64 (44.4)
≥ 5º	80 (55.6)
Variables	**Mean (SD)**
Age	80.2 (9.2)
BMI	23.5 (4.9)
FFM	37.7 (7.1)
FFM%	67.6 (12.6)
BF	19.8 (11.2)
BF%	32.4 (12.6)
TBW	79.4 (4.6)
SMI	6.9 (1.5)
R	599.9 (96.3)
Xc	52.8 (14.6)
PhA	5.1 (1.1)

BMI: body mass index (kg/m²); FFM: fat-free mass (kg); FFM%: fat-free mass percentage (%); BF: body fat (kg); BF%: body fat percentage; TBW: total body water (l); SMI: skeletal muscle index (kg/m²); R: resistance (ohms); Xc: reactance (ohms); PhA: phase angle (degrees); SD: standard deviation.

PhA showed a moderate and inversely proportional correlation with age (r= -0.417; p<0.01), which was better in the male subjects (r= -0.517; p<0.01). Furthermore, PhA showed a weak positive correlation with FFM (r=0.399; p<0.01), FFM% (r=0.223; p<0.01) and SMI (r=0.318; p<0.01) and a weak negative correlation with BF% (r= -0.223) and TBW (r= -0.178) (p<0.05) (Table 2).

Table 2. Correlation between phase angle, age and body composition in older adults.

Variables	Phase Angle		
	Sample	Men	Women
	r (p)	r (p)	r (p)
Age	-0.417 (<0.001)	-0.517 (0.002)	-0.282 (0.002)
BMI	0.029 (0.731)	0.213 (0.234)	0.038 (0.689)
FFM	0.399 (<0.001)	0.389 (0.022)	0.279 (0.003)
FFM%	0.223 (0.007)	0.088 (0.627)	0.095 (0.321)
BF	-0.103 (0.217)	0.035 (0.846)	-0.042 (0.660)
BF%	-0.223 (0.007)	-0.088 (0.627)	-0.162 (0.089)
SMI	0.318 (<0.001)	0.253 (0.155)	0.168 (0.078)
TBW	-0.178 (0.034)	-0.358 (0.044)	-0.162 (0.089)

BMI: body mass index (kg/m²); FFM: fat-free mass (kg); FFM%: fat-free mass percentage (%); BF: body fat (kg); BF%: body fat percentage; TBW: total body water (l); SMI: skeletal muscle index (kg/m²); R PhA: phase angle (degrees).

Individuals with low PhA values (PhA <5°) had a lower mean age, FFM, TBW, and SMI (p<0.05). (Table 3).

Table 3. Comparison of the mean age, BMI, and body composition, according to the phase angle classification in older adults.

Variables	Phase Angle		
	< 5º (n=80)	≥ 5º (n=64)	p
Age	83.3 (8.0)	76.3 (9.4)	<0.001
BMI	23.4 (5.4)	23.8 (4.4)	0.583
FFM	35.3 (5.4)	40.8 (7.6)	<0.001
FFM%	66.0 (13.0)	69.6 (12.0)	0.090
BF	20.3 (12.4)	19.2 (9.6)	0.573
BF%	34.0 (13.0)	30.4 (12.0)	0.090
TBW	80.3 (5.0)	78.3 (3.8)	0.006
SMI	6.5 (1.4)	7.4 (1.5)	<0.001

BMI: body mass index (kg/m²); FFM: fat-free mass (kg); FFM%: fat-free mass percentage (%); BF: body fat (kg); BF%: body fat percentage (%); TBW: total body water (l); SMI: skeletal muscle index (kg/m²).
Data presented as mean (standard deviation)
Student's t-test

The RXc graph showed that the older adults were in the upper and lower right quadrants regardless of PhA values. Most of the male participants with PhA values <5° (Group 1) were outside the 75% tolerance ellipse (Figure 1).

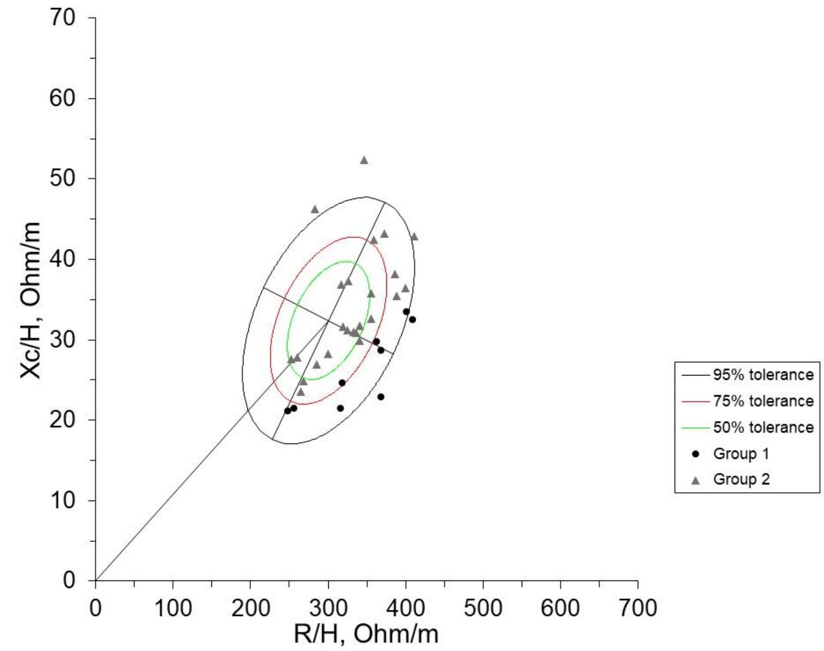

Figure 1. Vector analysis of the older adult men (n=33) with PhA<5º (group 1) and PhA >5º (group 2), according to the plot of the impedance vectors Xc/H and R/H in points, following the ellipses of tolerance (95%, 75% and 50%) of the reference population [21].

Among the female participants (Figure 2), most of those with PhA values <5° (Group 1) were outside the 75% tolerance ellipse. Female participants were evenly distributed between the upper right and lower right quadrants of the specific tolerance.

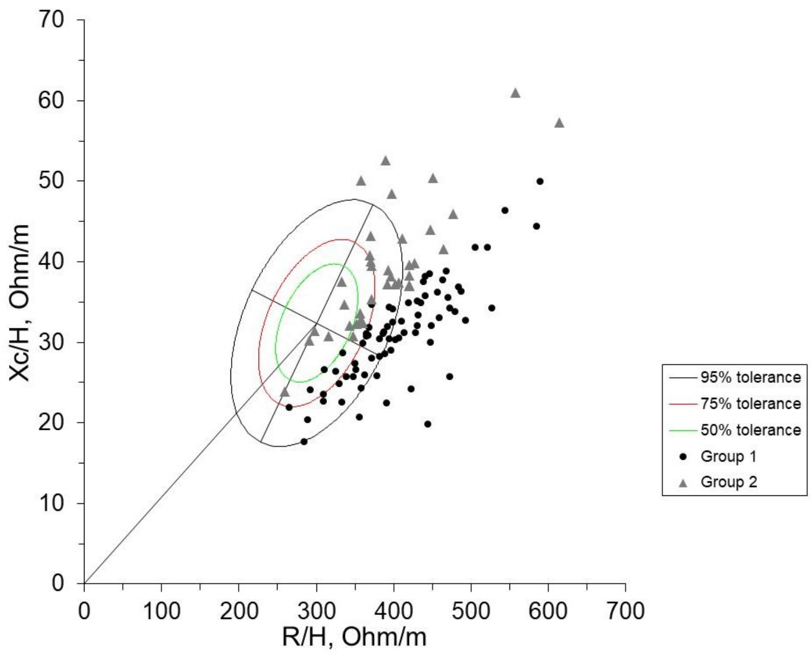

Figure 2. Vector analysis of older adult women (n = 111) with PhA <5º (group 1) and PhA> 5º (group 2), according to the plot of impedance vectors Xc/H and R/H in points, following the ellipses of tolerance (95%, 75% and 50%) of the reference population [21].

4. DISCUSSION

PhA was significantly correlated with age, FFM, FFM%, BF%, TBW, and SMI, with a stronger correlation with age and FFM. To date, there are few studies that have analyzed these aspects in older adults. In the present study, older adults of both sexes, regardless of PhA values, were located in the upper and lower right quadrants of the RXc graph, corresponding to thin body and cachexia characteristics considering the BIVA method [7].

To our knowledge, few studies in Brazil have evaluated the relationship between PhA, body composition, and BIVA in healthy community-dwelling older adults. In a study of community-dwelling older adults, Santos et al. (2023) [12] observed an association between PhA and several variables, including age, BF%, AMC, and SMI. In addition, a statistically significant association was found between reduced SMI, hypoalbuminemia, and lower PhA.

In a related study, Jansen et al. (2019) [23] observed that standardized PhA exhibited a weak correlation with arm circumference. Furthermore, studies have reported the relationship between PhA and sarcopenia, as well as its components [2, 8-11, 19], which suggests an association between PhA and cell death or a change in the selective permeability of the cell membrane with aging. The aging process has been shown to result in a decrease in both the quantity and quality of muscle mass, as well as a change in the state of hydration [4]. It is imperative to acknowledge that the interindividual variability in PhA can be attributed, at least in part, to differences in cell size, intracellular composition, or membrane permeability [7].

PhA performs a variety of functions, including the capacity to serve as a predictor of muscle abnormalities and function. The utilization of PhA has been demonstrated to facilitate the identification of individuals who are susceptible to malnutrition-related morbidity and mortality.

Conversely, with the objective of assessing the nutritional status and introducing the study of BIVA in the nutritional assessment of community-dwelling older adults in Brazil, Ribeiro et al. (2011) [13] observed using the BIVA that women with a BMI <23 kg/m^2 presented lower Xc, higher R, and, consequently, lower PhA, which were consistent with the results of this study. Furthermore, Goel et al. (2021) [3] demonstrated that an individual with a long vector and low PhA has a worse body composition and hydration than another individual of the same sex, age and BMI, with a similar vector length and higher PhA.

The BIVA method presents an alternative approach to the estimation of body cell mass and hydration, obviating the necessity for predictive equations. This method has been utilized to evaluate clinical and pathological conditions, as evidenced by Rabelo et al. (2025) [24]. In their study, BIVA models exhibited analogous trends in functionality analyses, with individuals who demonstrated stronger and more active functionality exhibiting superior bioelectrical health indicators.

Pfrimer et al. (2014) [25] constructed the RXc graph for Brazilian older adults and found differences in PhA and in the RXc graphs when compared with other studies of older adults with the same age range, thereby demonstrating the difference in body composition and hydration. However, the authors' evaluation was limited to individuals aged 60 to 70 years, precluding a direct comparison with our study, which also evaluated individuals aged $\geq$80 years.

The trend exhibited by the Z vector was predominantly attributable to the diminution of the capacitive component, which subsequently led to a reduction in the PhA. Components of the Z vector (R/H and Xc/H) demonstrated sexual dimorphism. The findings of this study differ from those of a study conducted in a population of Italian older adults [22]. This discrepancy is likely attributable to the instrumental differences affecting the BIA measurements and age-related bioelectrical variability, as demonstrated by Goes et al. (2021) [3]. The results of the study indicate a decline in soft tissue mass with advancing age, a phenomenon that is particularly pronounced after the eighth decade of life. In addition to these quantitative changes, the electrical properties of the tissues may also undergo alterations due to the reduced number of cells in the skeletal muscle of the limbs [4].

The results of this study indicated that subjects with a lower PhA exhibited a higher propensity to be situated in the lower right quadrant of the RXc graph. This lower right quadrant was recognized as corresponding to cachexia according to the BIVA method. As demonstrated by studies conducted in other countries, the findings related to BIVA's in body composition estimation for older adults are encouraging when applied to this age group. The findings indicate that the impedance vectors suggest a decline in soft tissue associated with age, particularly among individuals aged 80 years or above. As indicated by the results of other studies, the implementation of BIVA has been shown to be effective in older adults suffering from sarcopenia, Alzheimer's disease, post-acute myocardial infarction, and physical performance impairment [22, 26-28].

The findings of the present study suggest that correlations between PhA and body composition indicators may facilitate the identification of biological parameters in the nutritional assessment of healthy individuals. Additionally, the performance of BIVA in body composition assessment, as well as its relationship with PhA, must be considered. However, the study's modest sample size constitutes a potential limitation, as it precluded the execution of subgroup analyses for PhA and BIVA. Additionally, the application of reference data from an Italian population may impose limitations on the interpretation of the results for this sample. Further studies are necessary to determine reference values for the Brazilian population.

Subsequent studies employing stratified analyses by age, race/ethnicity, and according to disparate clinical outcomes are necessary to establish reliable and effective parameters to estimate the body composition of healthy older adults. This is particularly salient given that the majority of extant studies have assessed individuals who are afflicted with illness. Furthermore, there is a necessity for large-scale studies that allow the standardization of BIVA values reference for the Brazilian population, taking into account the contextual variations of the aging process across different countries.

As previously delineated, PhA is influenced by age and sex, which engenders challenges in comparing the results obtained in disparate studies. One potential solution to this challenge is the implementation of standardized PhA. In the context of Brazilian data, the suggested cutoff point is -1.65, which corresponds to the fifth percentile for the Brazilian population. Values below this threshold are indicative of malnutrition [29]. However, the utilization of this standardized PhA in our study was deemed inappropriate, as the reference for the Brazilian population [29] was estimated based on individuals aged between 18 and 89 years. In contrast, the present study involved individuals between the ages 60 and 100 years (mean age: 80.2 years), with the majority (60%) of the subjects being ≥80 years of age (n = 87).

We highlighted the relevance of BIVA in the nutritional assessment of older adults, as this method proposes to evaluate the body composition and nutritional and hydration status of older adults with precision, thereby overcoming the limitations observed in conventional bioimpedance analysis. The implementation of PhA and BIVA facilitates a more precise assessment in older adults, thereby enabling the identification of alterations in body composition.

5. CONCLUSION

PhA was correlated with body composition markers, including FFM, FFM%, BF%, TBW, and SMI. Furthermore, subjects exhibiting low PhA values were categorized as lean or cachectic using the BIVA method when plotted on the RXc graph. The utilization of PhA and BIVA has been demonstrated to process considerable potential in facilitating nutritional assessment, as evidenced by its sensitivity to changes in body composition and cellular changes that occur with advancing age. Further research is recommended to evaluate BIVA and PhA in the assessment of body composition along with other prognostic in the older adult population.

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