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Bioelectrical impedance vectorial analysis and nutritional status of older women according to body mass index

Análise vetorial de bioimpedância e estado nutricional de idosas de acordo com o índice de massa corporal

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Abstract – The objective of the present study was to compare and discuss the nutritional status of older women according to different categories of BMI. Additionally, the study was aimed at introducing the bioelectrical impedance vector analysis (BIVA) as a tool to assess the nutritional status. Thirty-two women (60 years or older, physically independent, and with moderate level of physical activity) were divided into three groups according to BMI classification: G1 (BMI<23 Kg/m^2); G2 (23<BMI<28 Kg/m^2); and G3 (BMI>28 Kg/m^2). The following variables were analyzed as indicators of nutritional status: body mass and height to calculate BMI, waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), bioelectrical impedance (BIVA), resting energy expenditure (REE), biochemical markers of nutritional status (glucose, total cholesterol, and fractions, IGF-1, and leptin). The groups were compared using ANOVA and the Hotelling's T^2 test for vector analysis. The main findings based on vector displacement showed lower reactance and higher resistance in G1. G3 showed the highest values of CC and leptin, and also lower REE. Therefore, higher BMI suggested at the same time higher cell mass and higher risk of developing chronic diseases. In turn, lower BMI values suggested reduced fat-free body mass. These results confirm the search for specific classification of BMI for the elderly and suggest the BIVA as a viable alternative in physical and nutritional assessment.
Key words: BMI; Body composition; Elderly health; Nutritional status.

Resumo – *O objetivo do presente estudo foi comparar e discutir o estado nutricional de idosas, de acordo com diferentes categorias de IMC. Adicionalmente, objetivou-se introduzir a análise vetorial de bioimpedância (BIVA) como ferramenta na avaliação do estado nutricional. Trinta e duas mulheres (60 anos ou mais, fisicamente independentes e nível moderado de atividade física), foram distribuídas em três grupos de acordo com a classificação do IMC: G1 (IMC<23kg/m^2); G2 (23<IMC<28Kg/m^2); e G3 (IMC>28Kg/m^2). Foram analisados como indicadores do estado nutricional: massa corporal e estatura para cálculo do IMC, circunferência da cintura (CC), circunferência do quadril (CQ) e relação cintura quadril (RCQ); bioimpedância elétrica (por BIVA); - gasto energético de repouso (GER); variáveis plasmáticas indicadoras do estado nutricional (glicose, colesterol total e frações, IGF-1 e leptina). Os grupos foram comparados por ANOVA e pelo teste Hotelling's T^2 para análise vetorial. Como principais resultados, o posicionamento do vetor na bioimpedância apontou menor reactância e maior resistência para G1. O G3 apresentou os maiores valores de CC e leptina, e também menor GER. Portanto, os maiores valores de IMC, ao mesmo tempo em que apontam melhor massa celular, apontam também maior risco de desenvolvimento de doenças crônicas. Por sua vez, os menores valores de IMC indicaram redução da massa corporal livre de gordura. Os resultados ratificam a busca por classificação específica do IMC para idosos e apontam a BIVA como uma alternativa viável na avaliação física e nutricional.*
Palavras-chave: *Composição corporal; Estado nutricional; IMC; Saúde do idoso.*

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INTRODUCTION

The growing phenomenon of population aging requires further studies on the health and nutritional status of the elderly[1]. Nutritional status is defined as the balance between energy intake and nutrients, and their use by the body. Nutritional status assessment includes anthropometric measurements and body composition analysis, biochemical markers, evaluation of diet and energy expenditure. In order to make the interpretation of nutritional status more comprehensive, the possibilities of measures have been expanded, including, for example, functional tests, muscle strength, glucose metabolism, work capacity, molecular and genetic analyses, among others[2].

The assessment of nutritional status of the elderly can be considered a challenge because of all the changes associated with aging. For example, fat-free mass is reduced peripherally, and body fat tends to increase in the abdominal region. Several studies have investigated these changes; however, the reasons and the best methods and techniques to identify them are yet to be better explained by the studies on body composition[3,4].

Among the different methods and techniques for body composition analysis, bioelectrical impedance analysis (BIA) is considered practical, non-invasive, and its instruments are easy to operate[5]. However, in certain populations or under certain conditions, BIA has limitations for the development of specific equations[6]. With the purpose of minimizing this problem, BIA vector analysis (BIVA) has been proposed. With this method data interpretation is performed simply based on the graph of resistance (R) and reactance (Xc) [divided by height (H)] and the resultant vector. There is no need to use equation in this type of interpretation[7,8].

The BIVA has received attention as a valuable tool to analyze the state of hydration and cell mass[7,8], and it has demonstrated prognostic value in conditions such as preoperative period, cancer, immunodeficiency virus infection or Alzheimer's disease[9-11]. As a fundamental concept for interpreting the data, Xc is considered as the resistive effect produced by tissue interfaces and cell membranes. In turn, R is the pure opposition to the electric current and phase angle (resultant vector) reflects the capacitance. Buffa et al.[12] suggested that the use of the BIVA can evaluate the changes typical of body compartments during the aging process.

In the investigation of methods and techniques of body composition and aging, anthropometric measurements and their relationships also deserve to be commented. Body mass index (BMI = body mass/height^2) has significant correlation with body fat mass and development of chronic diseases. Thus, high BMI values are associated with higher morbidity and mortality risk[13]. Conversely, some studies have shown higher survival rates in higher BMI values[14-16]. Energy reserves in old age are supposed to be important to cope with physical and psychological stress[14,15].

A multicenter cross-sectional study involving Latin American elderly (Health and Welfare in the Old Age Project-SABE)[17], planned with the participation of the Pan American Health Organization (PAHO), used the following BMI ranges for data collection and analysis: low ($\leq$ 23); normal (23>BMI<28); and high (28>BMI>30) and obesity ($\geq$ 30). Therefore, it is clear that in this study the range classified as "normal" is different from the known cutoff points for young adults (which is between 18.50 to 24.99 Kg/m^2)[18].

In summary, some studies suggest that elderly patients with higher BMI have a greater chance of survival. Based on this statement, the present study hypothesizes that higher BMI is related to a better state of health, which means a better nutritional status. As many variables as possible should be investigated to confirm a better nutritional status.

Thus, the objective of the present study was to compare and discuss the nutritional status of elderly women according to different categories of BMI. Additionally, we intend to introduce the BIVA in nutritional status assessment.

METHODS

Participants

This study was conducted at a Senior Center at the East Region of the city of São Paulo, state of São Paulo, Brazil. Volunteers were recruited by means of posters and lectures. Therefore, it was a non-probability convenience sample. Only women over 60 years with moderate level of physical activity were included. Women who reported use of drugs that could modify the basal metabolic rate (e.g., drugs for weight loss or thyroid hormones), or who reported acute or chronic illnesses that could interfere with data collection were excluded. It is worth highlighting that the elderly women who reported type II diabetes, hypertension or hypercholesterolemia were not excluded because these diseases are highly prevalent in the elderly.

All participants signed an informed consent form, and the project was approved by the Research

Ethics Committee at the Universidade São Judas Tadeu, protocol number 048/2004.

Data collection

The participants underwent a comprehensive analysis of their nutritional status according to the variables described and explained below.

General information

Acute and chronic diseases, as well as great changes in body weight may indicate an imbalance in the nutritional status.[2] To collect such information, the participants were asked about changes in their body weight in the previous six months and history of acute and chronic diseases. They were also asked about demographic data.

Level of physical activity

Physical inactivity is associated with a number of chronic diseases and poor nutritional status[19]. Therefore, in order to control some variables, we included women with moderate level of physical activity, which was classified according to the International Physical Activity Questionnaire-IPAQ[20], short version.

Anthropometric measurements

The classification of the nutritional status also includes two anthropometric indicators[2]. Body mass (BM; Filizola 0.1 g-precision scale) and height (H; Secca, 0.1 cm range stadiometer) were measured to calculate body mass index (BMI in kg/m^2). Waist circumference (WC) and hip circumference (HC) were measured, and the waist-hip ratio (WHR) was calculated[21]. All procedures for taking the anthropometric measurements were based on Lohman, Roche and Martorell[22] and the measurements were performed by a single examiner.

Bioelectrical impedance analysis with vector analysis (BIA and BIVA)

We postulate in the present study that the analysis of cellular integrity and hydration evaluated using BIA may be an important tool in nutritional status assessment. BIA was performed in the morning after a night's rest and before eating. The participants arrived at the laboratory between 7 and 9 am. They had been previously told not to perform strenuous physical exercise, not to modify their eating habits on the previous day, and to drink water as usual. The analysis (Biodynamics 450e®) was performed with the subjects in the supine position on a nonconductive surface, with electrodes placed in their hands and feet, always on the right. All measuring procedures by bioelectrical impedance were performed by the same evaluator. Resistance (R) and reactance (Xc) data were plotted on an R/H Xc/H graph using specific software[23].

Resting energy expenditure (REE)

Some studies, as reviewed by Manini[24], have described the reduction in resting energy expenditure (REE) with aging, which may be associated with changes in the nutritional status. In our study, REE was measured immediately after BIA, always by the same evaluator. We used the metabolic analyzer VO2000 (Inbrasport®). The participants rested on a stretcher for 30 minutes before the test. They were instructed to remain relaxed but awake, avoid coughing, talking or moving during the measurement period. The record of the gas exchange measurements only started after adaptation, defined as the period of five consecutive minutes during which the coefficient of variation (CV) was at most 10% for oxygen consumption (VO_2) and carbon dioxide (VCO_2) and 5% for RQ (respiratory quotient). After reaching this acclimatization, the measurements were recorded for a period of 30 minutes. REE for 24 hours was estimated according to equation by Jequier & Shultz[2].

Biochemical analysis

Biochemical markers are sensitive indicators of the nutritional status, especially for being able to detect nutritional problems in their initial state.[2] In the present study, biochemical analysis was performed from blood plasma. Blood samples were collected the day after the anthropometric analyses, BIA, and REE. The samples were collected in the period between 8 and 10 am, after a fasting period of least 8 and at most 12 hours. The samples were analyzed for: glucose, total cholesterol, HDL and LDL [enzymatic method (Labtest® and Doles®) and using Friedewald equation]. We also determined the concentrations of the following hormones: IGF-I [DSL (acid ethanol) IRMA 87/518 double antibody; with intra-assay coefficient of variation (CV) = 6.3% and 4.9% for minimum and maximum controls, respectively; and inter-assay CV = 8.0 and 9.0% for minimum and maximum controls, respectively]; leptin [radioimmunoassay (RIA), HL81 K Linco Research Inc®, intra-assay CV = 1.2% and 3.0% for minimum and maximum controls, respectively; inter-assay CV = 8.6% and 4.2% for minimum and maximum controls, respectively].

Groups for data analysis

Based on the results of the anthropometric measurements, women were divided into three groups according to the following BMI categories: G1 (BMI<23 Kg/m^2); G2 (23<BMI<28 Kg/m^2) and G3 (BMI>28 Kg/m^2). This definition of categories is a modification of the document of the PAHO - SABE Project[17].

Statistical analysis

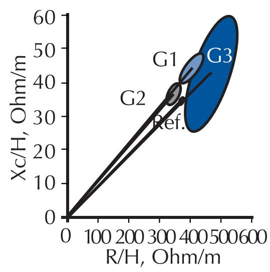
Data are presented as mean ± standard deviation (SD); the three BMI groups were compared using one-way ANOVA followed by Bonferoni test as post hoc. The analyses were performed using the computer program Statistica 7.0 (Statsoft, Inc.). The significant differences between the vectors of the groups according to Hotelling's T^2 test for vector analysis and Mahalanobis distance (D), which is the distance between two groups, were analyzed using specific software for the BIVA[23]. The acceptable level of significance was $p < 0.05$ for all analyses.

RESULTS

The study included 37 women. Age did not differ significantly between the groups: G1=68.7± 5.1 years; G2=68.4± 7.5 years; G3=67.7± 5.0 years (p=0.90). Regarding the overall information provided by the participants, 56.8% reported there was no change in body mass over the previous six months, 35.4% reported they had intentionally reduced body mass, and 8.1% could not answer the question. Only 16.2% reported not using any medication, whereas the remaining 83.9% usually used drugs for diabetes, hypertension, and hypercholesterolemia, all under medical supervision.

The anthropometric and BIA variables are described in Table 1. We found that G3 showed higher values of WC, HC, WHR, and reactance, and lower resistance value.

Figure 1 shows the vector position of the three groups and also the reference population for the age group. G1, G2, and G3 had significantly different vector position from each other; G1 showed lower Xc, higher R, and consequently lower phase angle. The difference between the three groups was significant compared to the reference population, but we found that G3 was the most similar to this population (D value).



Groups	T2	p-value	Valor D
G1 *vs.* G2	15.3	0.0060	1.89
G1 *vs.* G3	46.0	0.0000	3.00
G2 *vs.* G3	20.9	0.0005	1.73
G1 *vs.* ref.	25.6	0.0000	1.93
G2 *vs.* ref.	17.2	0.0002	1.27
G3 *vs.* ref.	10.0	0.0073	0.74

Figure 1. Vector position of the groups. D = Mahalanobis distance between two groups; R/H = resistance divided by height; T^2 = Hotelling's test; Xc/H = reactance divided by height. Reference: U.S. population of similar age analyzed in the National Health and Nutrition Examination Survey (see ref. 23).

According to Table 2, G3 had lower oxygen consumption and consequently lower REE. Table 3 shows that G1 showed the highest values for fasting glucose, but all values were within the reference range. G3 showed the highest values of leptin. The other variables showed no difference between the groups.

DISCUSSION

The present study compared the nutritional status of elderly women according to different BMI values, using, among other indicators, the BIVA. We found lower lean mass in the BMI value below 23 Kg/m^2

Table 1. Anthropometric and body composition variables (mean± SD)*

Variables	G1	G2	G3
Anthropometric measures and indices			
BMI (Kg/m^2)	20.6± 1.9^{a}	26.0± 1.3^{b}	31.6± 2.5^{c}
Waist circumference (cm)	73.6± 3.4^{a}	78.4± 9.6^{a}	96.1± 7.1^{b}
Hip circumference (cm)	92.4± 2.4^{a}	98.7± 3.9^{b}	111.3± 6.5^{c}
WHR	0.79± 0.03^{a}	0.79± 0.09^{a}	0.86± 0.06^{b}
Bioelectrical impedance analysis variables			
R/H	466.0± 61.8^{a}	403.9± 39.3^{b}	346.1± 35.0^{c}
Xc/H	42.5± 12.0^{a}	44.0± 4.8^{a}	36.3± 5.1^{b}
Phase angle (º)	5.2± 1.1	6.2± 0.5	6.0± 0.7

*superscript letters represent the statistical analysis: different letters mean significant differences with p<0.05. BMI = body mass index; WHR = waist/hip ratio; R/H = resistance divided by height; Xc/H = reactance divided by height.

Table 2. Variables related to resting energy expenditure (mean± SD)*

Variables	G1	G2	G3
Gas exchange variables at rest			
O_2 (mL/Kg/min)	3.05± 1.05	3.03± 1.11	2.36± 0.88
O_2 (mL/FFM/min)	0.09± 0.03[a]	0.09± 0.04[a]	0.05± 0.02[b]
RQ	0.898± 0.064	0.902± 0.089	0.900± 0.089
Estimation of resting energy expenditure			
REE (Kcal/day)	1106± 295	1210± 381	1220± 545
REE (Kcal/Kg of BM/day)	26.4± 6.7[a]	22.3± 7.0[a]	15.0± 6.5[b]
REE (Kcal/Kg of FFM/day)	35.6± 10.6	34.2± 12.5	27.2± 11.0

*superscript letters represent the statistical analysis between the groups; different letters mean significant differences with p<0.05. REE = resting energy expenditure; BM = body mass, FFM = fat free mass; RQ = respiratory quotient.

Table 3. Biochemical markers of nutritional status (mean±SD)*

Variables	G1	G2	G3
Glucose ($mL.dL^{-1}$)	98.8± 34.1[a]	69.8± 8.5[b]	80.0± 14.2[b]
Total cholesterol ($mL.dL^{-1}$)	213.1± 34.8	185.9± 38.1	201.2± 29.7
HDL-Cholesterol ($mL.dL^{-1}$)	50.3± 14.8	42.4± 13.9	47.4± 11.3
LDL-Cholesterol ($mL.dL^{-1}$)	148.1± 36.3	125.5± 32.2	133.2± 29.2
VLDL-Cholesterol ($mL.dL^{-1}$)	14.7± 6.0	18.0± 7.7	20.6± 6.0
Triglycerides ($mL.dL^{-1}$)	73.6± 29.9	88.7± 40.4	103.2± 30.4
Leptin ($ng.dL^{-1}$)	7.71± 7.26[ab]	19.01± 12.38[a]	28.22± 13.78[b]
IGF-I ($ng.dL^{-1}$)	449± 704	1119± 2020	686± 1134

*superscript letters represent the statistical analysis between the groups; different letters mean significant differences with p<0.05.

and risk of developing chronic diseases coupled with better cell state in the BMI values above 28 Kg/m^2.

The group with the highest BMI value had higher anthropometric measures indicative of chronic disease risk. Additionally, this group also had the lowest REE, which may mean lower metabolic activity, with consequent increased risk of developing chronic diseases[26]. The higher plasma concentration of leptin in this group may also indirectly suggest a possible leptin resistance, as typically occurs in obese individuals[27].

The somatotropic axis, assessed in the present study by IGF-I, showed a tendency to lower values in G1 (although not statistically significant). Lower levels of IGF-I may indicate lower protein synthesis and consequently a possible relationship with lower lean body mass[28]. In addition, in this group with lower BMI, the bioelectrical vector showed the lowest phase angle, reflecting a reduction in cell mass. Experimental data have demonstrated reduced phase angle, with length equal to or greater than the reference values in elderly with sarcopenia[9,11]. Therefore, these results may indicate that G1, despite having shown better results related to body fat, showed lower lean body mass, which may mean an impaired nutritional status and beginning the process of sarcopenia.

Other results in this study may enhance the possibility of lower lean body mass in G1 compared with the other groups. The higher glucose values may mean the development of insulin resistance processes. Data in the literature show an association between insulin signaling and inflammation[29], and between inflammation and sarcopenia[30]. In other words, there is the possibility that lower BMI values may be associated with a chronic inflammatory state, greater insulin resistance, and consequently higher risk for reduction of lean mass. However, these data is only speculative, since they require more specific biochemical analysis.

All information obtained in the two extreme groups – lowest and highest classifications of BMI – lead us to suppose, based on the results of our study, a normal range in the intermediate group (G2), with values between 23 and 28 Kg/m^2. This range agrees with previous studies[16,17].

It is important to highlight the limitations of the present study. Only women were included, and we cannot state that the results are representative of the Brazilian elderly population. Furthermore, as previously stated, the use of serum biochemical markers (glucose, leptin, IGF-I) are not sufficient to support some molecular mechanisms discussed. Regarding the drugs taken by the participants, they might have generated bias in the interpretation of the results. Finally, studies with larger probability samples and including other variables of body composition, such as DEXA (dual X-ray energy, considered the gold standard), could help interpret the results.

CONCLUSION

The present study showed differences in the nutritional status according to BMI in elderly women, which reinforces the need for specific cutoff points for this population group. Additionally, we consider the BIVA as a coherent analysis of body composition in these individuals.

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