Clinical Nutrition 31 (2012) 144–148

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Distribution of bioelectrical impedance vector values in multi-ethnic infants and pre-school children

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ARTICLE INFO

Article history:
Received 27 March 2011
Accepted 8 August 2011

Keywords:
Bioelectrical impedance analysis
Impedance vector
Reference values
Infant
Children
Body composition analysis

SUMMARY

Background & aims: Ethnicity may influence bioimpedance values. The goal of this study was to measure total body impedance vector in infants and pre-school children in Brazil and compare them with those reported in other countries.
Methods: We analyzed bioelectrical impedance from a sample of 255 healthy Brazilian children, aged 1–36 months, using the RXc graph method (tetrapolar analysis at 50 kHz frequency). The 95%, 75% and 50% tolerance ellipses were plotted by age group.
Results: The mean impedance vector showed migration across age groups, with progressive higher reactances and lower resistances as age increased. The mean bioimpedance vectors from the present sample of Brazilian children were different from those of European children of the same age ranges.
Conclusions: Our results confirm the importance of defining reference values of total body impedance vector for each country in view of the considerable ethnic diversity among different geographical areas.

1. Introduction

Bioelectrical impedance is a measure of the opposition of tissues to the flow of an alternating electric current in physiological conditions. It is related to water and electrolyte content of tissues as well as to the integrity and composition of cell membranes.[1,2] Since it is a non-invasive, low operating cost, safe, portable and simple method it is particularly suitable for clinical use at bedside for single or repeated measures.

Bioelectrical impedance analysis has been used primarily as an indirect method of estimating body composition. Such use is based on prediction equations established after regression analysis between the values of bioelectrical parameters and reference methods, such as densitometry and isotope dilution.[3] Some assumptions are required when using these prediction equations, including fixed tissue hydration. However, this proportion can significantly change during normal growth and aging as well as in many metabolic disorders which alter water balance[1] resulting in an unacceptable variability of the estimates for clinical purposes.[1,4,5]

A qualitative evaluation of body composition can be obtained through graphical bioimpedance analysis in its vectorial form (BIVA), which uses the values of resistance (R) and reactance (Xc) directly derived from the measurement device. The impedance vector can also be described by its components: module (M) and phase angle (PA). In clinical settings, the PA has been used as a prognostic indicator in a variety of conditions such as cancer,[6,7] critical illness,[8] HIV,[9] hemodialysis,[10] liver cirrhosis[11] malnutrition in children[12] and adults.[13] The ultimate attractiveness of BIVA[14] lies in its potential as a stand-alone procedure that allows hydration status and body cell mass assessment without the errors of regression analysis or the limitations in the accuracy of the reference method.[10,15] It is still necessary to be cautious of two unavoidable errors: the impedance measurement error and the biological variability of subjects.[16]

Abbreviations: BIVA, bioelectrical impedance vector analysis; MUAC, mid-upper arm circumference; TS, triceps skinfold; H, height; BMI, body mass index; R, resistance; Xc, reactance; PA, phase angle; M, impedance vector module.

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0261-5614/$ – see front matter
doi:10.1016/j.clnu.2011.08.006

Variations of the vector size (M) can be interpreted as changes in the body fluid content and variations in the vector direction (PA) are interpreted as evidence of changes in the body cell mass.[17,18] Clinical validation studies combining the analysis of M and PA allow the differentiation between obese (short vector and high PA) and athletic (long vectors and high PA) individuals as well as between lean (long vectors and low PA) and cachectic individuals (short vector and low PA).[15]

Few studies have established standard values for the bioelectrical impedance mean vector in children and in all cases only white individuals were examined.[17,19–21] However, as previously demonstrated in adults,[18,22,23] ethnicity may influence the impedance measurements. Since the Brazilian population is characterized by extensive multiracial origin, the validity of international reference values for Brazilian children should be examined. Thus, the purpose of the present study was to measure the bioelectrical impedance vector by the RXc graph method in a sample of pediatric multi-ethnic subjects of a Brazilian city and to compare these values with those of children from European origin. Our goal was to define reference values of bioelectrical impedance parameters to be used in Brazilian children.

2. Subjects and methods

This observational, cross-sectional study was conducted from February to August 2009, in the Pediatric Clinics of a tertiary hospital after the approval of all research-related ethical aspects by its Institutional Review Board. Data were collected after signature of the informed consent form by the parent or primary caregiver during routine visits to the pediatrician. Inclusion criteria were: 1 month to 36 month-old children born to term, with no congenital or chronic diseases according to their medical records. We excluded children who presented fever or acute illness and those with Z values of weight for age or height for age falling less than -2 or greater than $+2$ in relation to the World Health Organization growth standard curves (WHO 2006). Two hundred and fifty five children were included in the study: 103 children (47 girls) from 1 to 6 months, 55 children (29 girls) from 6 to 12 months, and 97 children (50 girls) from 12 to 36 months.

2.1. Measurements

Anthropometric (weight, length or height, triceps skinfold – TS, and mid-upper arm circumference – MUAC) and bioelectrical (resistance and reactance) measurements were obtained in one visit by the same trained examiner in the afternoon. Body mass index (BMI in kg/m^2) and bioimpedance module ($M = \sqrt{R^2 + Xc^2}$) and phase angle ($PA = \arctan(Xc/R) \times 180/\pi$) were derived from these measures.

Infants were weighed without clothes and pre-school children in their underwear with digital scales (Filizola models E15-2B and Personal, respectively). Recumbent length was measured in children up to 2 years and height was measured in children above this age in a stadiometer (0.5 cm precision). The MUAC and TS were measured at the right side (precision of 1 mm) using an inelastic tape and a Lange® skinfold caliper (Cambridge Scientific Industries, Cambridge, MD), respectively. Averages of triplicate measurements were used in the analysis. The TS was measured at the midpoint between the projection of the acromion and the inferior margin of the ulna olecranon on a relaxed and resting arm positioned along the trunk, according to a standardized technique.[24]

Subjects were tested in the supine position with arms and legs kept from touching the body by non-conductor foam objects to prevent adduction or crossing of the limbs, which would shorten the electrical circuit and reduce the impedance values.[25] The R and Xc values were provided by the multifrequency bioimpedance analyzer (Xitron Hydra 4200, San Diego, CA, USA) at 50 kHz frequency and the device was calibrated weekly with a circuit of known impedance value provided by the manufacturer.

The BIVA measurements were conducted through the standard tetrapolar electrodes distribution. The inner arm electrode (sensor) was placed on the dorsal surface of the right wrist and between the ulna and the radius. The leg electrode was placed on the anterior surface of the right ankle between the prominent portions of the bones. The external electrodes (source or injector) were placed on the dorsal surface of the third proximal phalanx of the right hand and right foot.[3] In case of the infants, the position of the injector electrode was the same but the sensor electrode was moved proximally, leaving 5 cm of free skin between them, the minimal distance required to avoid interaction between electric fields, which could otherwise lead to an overestimation of impedance values.[26]

Bioimpedance vectors were analyzed by the RXc graph method,[14] using the BIVA software (Piccoli A, Pastori G. BIVA software, 2002, Department of Medical and Surgical Sciences, University of Padova, Padova, Italy, available at e-mail: apiccoli@unipd.it). Bioimpedance Z vector is composed by the combination of the horizontal vector R and vertical vector Xc, both expressed in Ohms. The RXc method implies that R and Xc values be standardized by the subject's height (H), resulting in R/H and Xc/H, expressed in Ohms/m. The mean values of Z were plotted with their confidence and tolerance intervals, which are ellipses on the RXc plane. The confidence ellipses represent the sample distribution of the mean vector and can be used to perform statistical comparison between groups. Two bioimpedance mean vectors have a significantly different position ($p < 0.05$) in the RXc plane if their 95% confidence ellipses do not present any intersection area, which is equivalent to a statistically significant result of the Hotelling T2 test[14] at $p = 0.05$.

The individual distribution is represented by tolerance ellipses, which can be used as reference values. Each (50%, 75% and 95%) tolerance ellipse represents a range of Z score of normality, from which any individual may be classified, similar to the nutritional classification by Z scores.

2.2. Statistical analysis

The data were initially classified by age groups as follows: month to month in the range of 0–6 months, two months intervals in the range of 6 months to 1 year and yearly in the range of 1–3 years. The mean vectors presenting any overlap in their 95% confidence ellipses indicated which groups should be combined. After pooling, the ellipses overlap was reanalyzed by gender and 50%, 75% and 95% tolerance ellipses were calculated for each resulting group. After these analyses, the following age intervals were defined: 1–6 months, 6–12 months and 12–36 months. The main effect of age was assessed by ANOVA and Student *t* tests were used to assess gender differences. Nonparametric tests were used when necessary (Mann–Whitney or Kruskal–Wallis), depending on the number of groups tested. Chi-squared test was used to analyze differences in proportions. An alpha value of 0.05 was set for statistical significance.

The data was then reclassified in age groups aligned with two other pediatric studies that used similar methodology,[20,21] for further comparisons. Since these studies used the BIA 101 RJL single frequency bioimpedance analyzer, we tested the agreement between this device and the Xitron Hydra system set at 50 kHz in a subgroup of 32 individuals. There was no statistical significant difference in the resistance values between the two instruments (paired *t*-test). Since there was a significant mean difference of 3.84 Ω between the reactance values (lower values given by the