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Original Article

Body fat assessment by bioelectrical impedance and its correlation with different anatomical sites used in the measurement of waist circumference in children

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Abstract

Objective: To compare the different anatomical sites used in the measurement of waist circumference, as well as the effectiveness of these landmarks to predict the percentage of body fat by tetrapolar bioelectrical impedance analysis.

Methods: We evaluated 205 children from 6 to 9 years of age of both sexes. Data on weight, height and waist circumference were collected at three different sites: at the lower abdominal curvature, above the navel and at the midpoint between the last rib and the iliac crest. Nutritional status was assessed through the body mass index (BMI)/age as recommended by the World Health Organization.

Results: The sample was considered homogeneous in terms of sex, and the mean age was 7.2±1.2 years. Regarding nutritional status, 6.3% of the children had low weight, 75.1% were eutrophic, 7.3% were overweight, and 11.2% were obese. Among males, there was no statistical difference between the different sites of measurement; in females, the measurement above the navel was statistically higher. In the correlation analysis, the midpoint measurement showed the best correlation with percentage of body fat, with values of 0.50 in boys and 0.62 in girls.

Conclusion: Waist circumference measured at the midpoint between the last rib and the iliac crest presented the best correlation with percentage of body fat.

J Pediatr (Rio J). 2009;85(1):61-66: Nutritional status, obesity, children, anthropometry.

Introduction

The concern about the pattern of regional body fat distribution can be justified by an association between health complications resulting from metabolic and cardiovascular dysfunctions and a greater abdominal fat accumulation, regardless of age and total body fat.[1]

Waist circumference (WC) has been widely used to predict risk of cardiovascular disease and metabolic syndrome in adults. In children, studies have shown that WC is related to excessive abdominal body fat and also to cardiovascular risk factors, such as increased total and LDL cholesterol and low HDL cholesterol.[2,3]

Studies have shown that WC can be a safe instrument for measuring central adiposity in both adults and children.[4] Although it is a largely used anthropometric measurement, there are different descriptions for waist measurement, and,

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consequently, a consensus between researchers and the protocols issued by health authorities is currently lacking, which can generate a conflict during the decision-making process. The most commonly used anatomical landmarks are: the midpoint between the last rib and the iliac crest, recommended by the World Health Organization (WHO)[5]; the narrowest part of the waist between the thorax and the hip, recommended by the Anthropometric Standardization Reference Manual[6]; the level immediately above the iliac crests, recommended by the National Institutes of Health[7]; and the navel level.[8] The use of these different sites of measurement makes it even harder to compare results from different studies.[9]

However, there is a limitation on the use of WC in children. A cutoff point recommended worldwide for WC assessment at this age group, as the one used for adults and elderly people, is yet to be defined. Some cutoff points have been proposed for some countries, such as England, Canada, Spain and the United States. In Brazil, no studies proposing WC cutoff points have been published so far.

In view of the foregoing, the objective of the present study is to compare the different anatomical sites used in the measurement of WC and to evaluate the effectiveness of these landmarks to predict the percentage of body fat by tetrapolar bioelectrical impedance analysis.

Methods

Sample size was calculated from the equation proposed by Lwanga & Lemeshow,[10] considering: $n = P \times Q / (E/1.96)^2$, where: n = minimum sample size required; P = maximum prevalence rate; Q = 100 - P; E = margin of sampling error tolerated.

$$n = 12.4 \times (100 - 12.4)/(5/1.96)^2$$

$$n = 12.4 \times 87.6/6.5$$

$$n = 167.1 \rightarrow n = 167$$

The prevalence of obesity found in the southeastern region was 12.4% for school children.[11] These were the data used in the study, since in Viçosa, a municipality in the state of Minas Gerais, southeastern Brazil, no research has been conducted to measure prevalence of obesity at the age group of the present study.

We evaluated 205 children, aged between 6 and 9 years, of both sexes, attending the Brazilian Family Health Program in the municipality of Viçosa, southeastern Brazil.

Data on weight and height were collected to calculate body mass index (BMI) and, consequently, assess children's nutritional status. The percentage of body fat was obtained by tetrapolar bioelectrical impedance analysis (BIA), which was used as a reference method in the present study. All measurements were performed by a single observer, in the case, the nutritionist responsible for the study.

Weight was measured using an electronic digital scale, with maximum capacity of 150 kg and precision to 100 g, according to the techniques recommended by Jelliffe.[12] Applying the same techniques, height was measured using a portable 2-m long vertical anthropometer with precision to 0.1 cm.

BMI was calculated from the formula: BMI = weight (kg)/height (m)^2. Nutritional status was assessed from BMI/age according to the curves proposed by the WHO.[13] The cutoff point proposed by Must et al.[14] was used.

WC was obtained during a normal exhalation using a 2-m flexible inelastic tape measure (mm). In accordance with the objectives of the study, the measurements were performed at three different sites:

- the lower abdominal curvature, between the iliac crest and the ribs;
- the midpoint between the iliac crest and the last rib;
- above the navel.

Percentage of body fat (%BF) was assessed by horizontal BIA (Biodynamics, model 310). For the assessments, participants laid supine on a nonconductive surface with their arms and legs at 45 degrees of abduction. Participants were guided through some procedures prior to the assessments in an effort to avoid possible bias in the results: 12 hours of absolute fasting; not to perform any high-intensity exercise 12 hours prior to the assessments; not to drink alcohol 48 hours prior to the assessments; not to take any medication that could affect hydroelectrolytic balance (diuretics, corticosteroids, among others) at least 7 days prior to the assessments; not to wear earrings, rings, watches and metal objects during the assessments; and urinate at least 30 minutes prior to the assessments.[15-17]

The resistance measurement obtained by tetrapolar bioimpedance was used to calculate %BF. This value was entered into the equation recommended by Kushner[18] for children aged 6-10 years to calculate total body water and, based on that, to calculate fat-free mass and fat mass and, consequently, to estimate %BF.

In male subjects, excessive body fat was considered as values greater than 20%; in females, values greater than 25%.[6]

The database was developed on the Excel software. Statistical analyses were performed using the Epi-Info version 6.04,[19] the Sigma Stat version 2.0 and the Statistical Package for the Social Sciences (SPSS) version 12 for Windows.

The Kolmogorov-Smirnov test was used to evaluate the normality of the distribution of the variables studied.

Correlations between WC and %BF measured by BIA were analyzed using Pearson correlation coefficients for variables with normal distribution and Spearman correlation coefficients for those with non-normal distribution. The magnitude

Table 1 - Anthropometric characteristics and body composition, divided by sex, of the children assessed (Viçosa, southeastern Brazil, 2008)

	Mean ± SD		Median		Minimum and maximum	
Variables	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Age (years)	7.1±0.9	7.2±1.0	7	7	6-9	6-9
Weight (kg)	25.9±6.0	24.5±4.9	24.7	24.0	17.3-48.2	16.2-41.9
Height (cm)	123.9±14.3	125.1±8.1	125.0	125.0	111.8-140.5	105.0-150.5
BMI (kg/m^2)	16.4±2.6	15.6±1.9	15.6*	15.0*	13.2-28.3	12.2-23.9
WC_LC	55.5±6.2	53.4±4.7	54.0*[a]	52.5*[a]	47.0-78.7	45.0-70.5
WC_NVL	57.5±7.6	56.3±5.8	55.5[a]	54.9[b]	47.5-86.8	46.0-79.0
WC_MP	56.1±7.0	54.5±5.7	54.5[a]	53.0[a]	47.8-82.5	44.7-80.0
%BF BIA	20.1±7.6[†]	23.3±6.9[†]	19.6	22.8	6.6-41.6	5.2-46.6

%BF BIA = percentage of body fat by tetrapolar bioelectrical impedance analysis; BMI = body mass index; WC_LC = waist circumference measured at the lower abdominal curvature; WC_MP = waist circumference measured at the midpoint between the last rib and the iliac crest; WC_NVL = waist circumference measured above the navel.
* $p < 0.05$, Mann-Whitney.
† $p < 0.05$, *t* test.
Same letters $p > 0.05$; different letters $p < 0.05$, Kruskal-Wallis.

of the correlations was interpreted according to the classification proposed by Callegari-Jacques.[20] The Mann-Whitney test was used for comparisons between the means of two independent groups. The Kruskal-Wallis test was used to compare the means from the three WC measurements. The Kruskal-Wallis test was followed by a Dunn test for multiple comparisons. The level of significance was set at $p < 0.05$.

This study was submitted to and approved by the Research Ethics Committee of the Universidade Federal de Viçosa, Viçosa (MG), Brazil.

Results

A total of 205 children aged 6-9 years were assessed, most of them were female (50.7%), and the mean age was similar in both sexes.

Regarding nutritional status, 6.3% (13) of the children had low weight, 75.1% (154) were classified as eutrophic, 7.3% (15) were overweight, and 11.2% (23) were obese.

The girls in our sample had a mean %BF of 23.3±6.9, whereas the boys had a mean of 20.1±7.6. Thus, in the present study the boys' %BF was considered increased, although this value is within the upper borderline of the recommended cutoff point.[6]

Table 1 shows data on the variables collected in the present study in means, standard deviations, medians, maximum values, and minimum values.

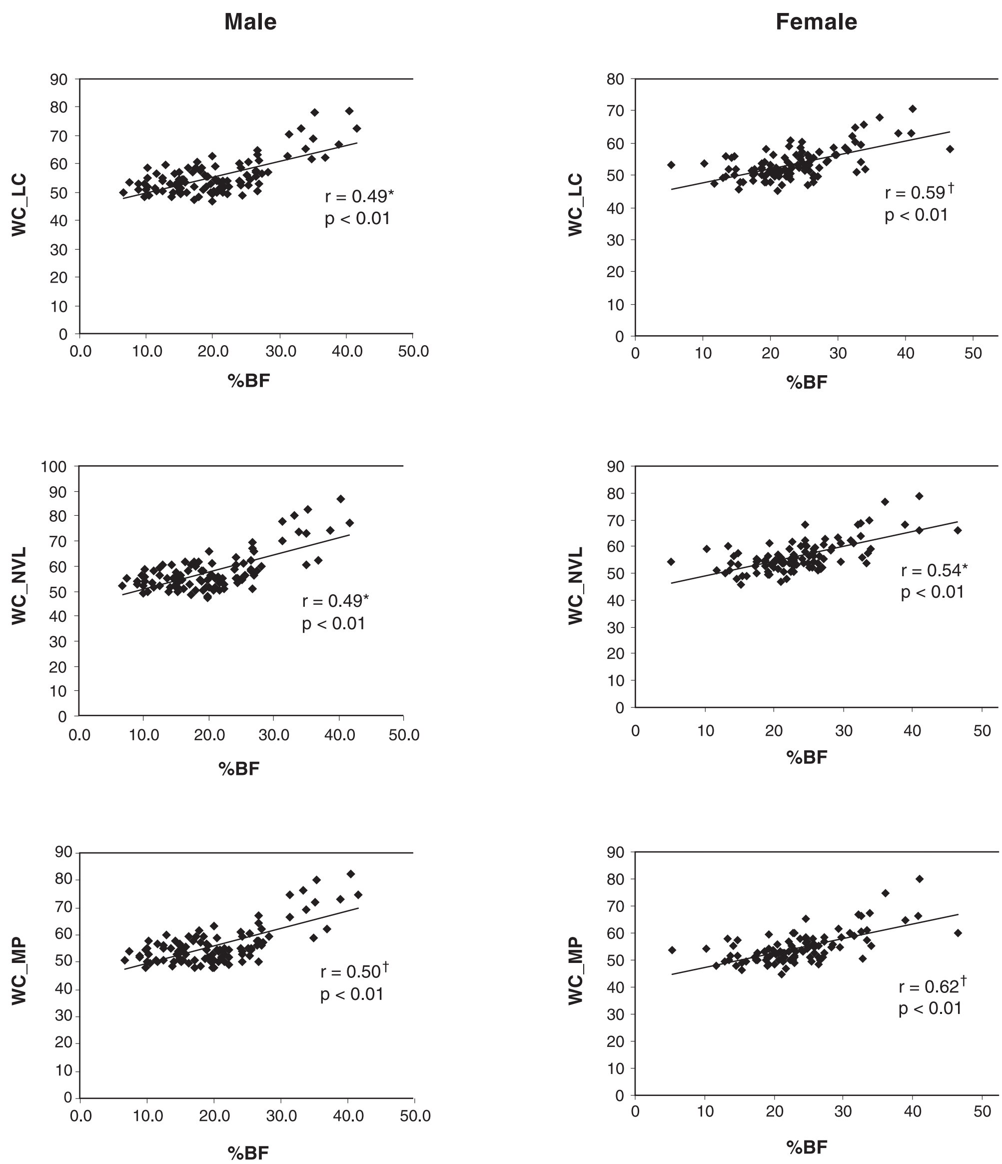
Among males, there was no statistical difference between the different sites of measurement ($p > 0.05$). In females, WC measured above the navel was statistically higher ($p > 0.05$) than the measurements performed at both the lower curvature and the midpoint. Between sexes, there was a significant difference only in the measurement at the lower curvature.

Figure 1 shows graphics of correlations between the different sites of WC measurement and the %BF assessed by tetrapolar bioimpedance according to sex.

The correlation between WC measurements and %BF by BIA was considered moderate. Among females, the correlation between %BF and the waist circumference measured at the midpoint between the last rib and the iliac crest (WC_MP) was considered strong.[19]

Discussion

Over the last years, WC has been largely studied due to its association with visceral fat and the presence of cardiovascular risk factors. The absence of an international standardization for WC measurement was one of our leading objectives into the development of the present study, since different protocols have been found in the literature. The Anthropometric Standardization Reference Manual[6] recommends the narrowest part of the waist between the thorax and the hip, the WHO[5] recommends the midpoint between the iliac crest and the last rib, the National Institutes of Health[7] guidelines suggest that WC be measured immediately above the iliac crests, whereas other studies use the navel level[21,22] and the site immediately below the last rib[8] as anatomical landmarks.



%BF = percentage of body fat; BIA = tetrapolar bioelectrical impedance analysis; WC = waist circumference; WC_LC = waist circumference measured at the lower abdominal curvature; WC_MP = waist circumference measured at the midpoint between the last rib and the iliac crest; WC_NVL = waist circumference measured above the navel.
* Spearman correlation.
† Pearson correlation.

Figure 1 - Correlation between WC measured at the lower abdominal curvature and %BF by BIA; WC measured above the navel and %BF by BIA; WC measured at the midpoint between the last rib and the iliac crest and %BF by BIA, according to the sex of the children assessed (Viçosa, southeastern Brazil, 2008)

Wang et al.[9] evaluated whether there was a difference between the anatomical sites of WC measurements in individuals aged between 7 and 83 years. The sites of WC measurement analyzed by those authors were the same sites assessed in the present study. In that study, in females, a statistically significant difference was observed among all sites used in the WC measurement. In males, a significant difference was found between the following landmarks: the lower curvature and the navel and the lower curvature and the midpoint, but with variation values between measurements lower than those found in females, which was also observed in the present study. In both sexes, the measurement at the midpoint between the iliac crest and the last rib showed the highest values, differently from the results found in the present study for the female group, in which the highest value was observed above the navel. In a study[23] carried out in the same municipality of the present study, with 190 men, aged from 20 to 59 years, significantly lower values were observed for WC measurement at the lower abdominal curvature. These findings demonstrate that comparisons between the results from different studies should be made carefully.

Among the sites used in the WC measurement, those based on anatomical landmarks, such as the iliac crests and the last rib, require palpation of the bone structure and skilled examiners. Thus, in severely obese individuals, finding the midpoints may be impaired by local adipose tissue accumulation. The narrowest part of the waist between the thorax and the hip, the navel level and the highest abdominal diameter, however, are sites that can be approached more easily. Nonetheless, in some individuals with pronounced abdominal obesity, several layers of fat can be formed around the abdomen, making it harder to find the narrowest part of the waist.[23]

The correlation values between WC and BIA found in the present study were lower than those found in other studies. Daniels et al.[24] evaluated the correlation between WC measured at the midpoint between the iliac crest and the last rib and abdominal fat measured by dual-energy X-ray absorptiometry (DEXA) in 201 children and adolescents aged between 7 and 17 years. Those authors found a correlation coefficient of 0.79 for boys and 0.81 for girls. Taylor et al.[4] (2000) assessed WC sensitivity in relation to abdominal fat measured by DEXA in 580 children and adolescents aged between 3 and 19 years. The area under the ROC (receiver operating characteristic) curve for WC, in boys and girls, reached a value of 0.97; values higher than those found in this study (data not shown).

WC is considered an indicator of excessive abdominal fat, mainly of visceral fat.[25,26] However, recommended cutoff points for the classification of abdominal obesity in the pediatric population are currently lacking, reason why its use as a diagnostic tool has been limited.[27]

Some authors[4,28,29] propose cutoff points for WC in children and adolescents. The study carried out by Freedman et al.[28] proposes a cutoff value of 61 cm for boys aged 6-7 years, 75 cm for boys aged 8 years, and 77 cm for boys aged 9 years. For girls, the recommended cutoff values are as follows: 60 cm, age of 6 years; 64 cm, age of 7 years; and 73 cm, age of 8-9 years. Taylor et al.[4] proposes a cutoff value of 60.4 cm for boys aged 6 years, 62.9 cm for boys aged 7 years, 65.3 cm for boys aged 8 years, and 67.7 cm for boys aged 9 years. For girls, they suggest the following cutoff values: 59.2 cm, age of 6 years; 62.0 cm, age of 7 years; 64.7 cm, age of 8 years; and 67.3 cm, age of 9 years. The cutoff values proposed by McCarthy et al.[29] are 57.1, 58.8, 60.9 and 63.2 cm for boys aged 6, 7, 8 and 9 years, respectively. For girls, the values are 57.0, 58.7, 60.4 and 62.0 cm for the same ages. The British study[29] evaluated a representative sample of children in that country and, using the WC data, percentile curves were constructed. No correlation with percentage of body fat or with changes in the children's lipid profile was observed in that study. The study by Freedman et al.,[28] however, proposed cutoff points according to changes in the levels of LDL cholesterol, HDL cholesterol, triacylglycerol and insulin. These studies do not recommend the use of values found in other populations, because some of them carry arbitrary definitions and also because of lifestyle and ethnic diversity among these populations, which are related to the pattern of body fat distribution.[30]

Conclusion

In both sexes the measurement of WC_MP showed the best correlation with %BF by BIA, suggesting that it should be used to evaluate the excess of abdominal body fat in the children from the present study and in those with the same characteristics of the population herein studied.

Worth mentioning in this respect that waist circumference should not be used alone to predict excess of body fat, but in association with other anthropometric indicators, especially with those used to assess total body fat distribution, such as BMI and/or skinfolds.

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