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Body mass index and waist circumference are good indicators for classifying children's nutritional status

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Abstract *This study aimed to investigate the relationship between anthropometric indicators - body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR) - and the sum of skinfold thicknesses in 7-10-year-old children attending a public school in São Paulo (SP). Height, weight, WC and triceps, biceps, subscapular and suprailiac skinfolds were measured, and the sum of skinfold thicknesses, BMI and WHtR were calculated. A Bland-Altman analysis was used in order to compare methods, with values transformed into z-scores. The analysis of limits of agreement and confidence intervals showed evidence of good agreement, above all between BMI and WC, and the sum of skinfold thicknesses, complying with strict agreement limits and differences smaller than 1 standard deviation (SD). WHtR showed moderate limits of agreement, from -1.02 to + 0.64 SD (boys) and -0.74 to + 1.12 SD (girls); its performance was not better than that of WC alone, the lower and upper limits of agreement for which were -0.91 to + 0.58 SD (boys) and -0.56 to + 0.89 SD (girls). The results support the use of anthropometric indicators to classify nutritional status, above all BMI and WC, in that both are similar when classifying children according to body fatness, and confer the advantages of being easy to obtain and affordable.*
Key words *Children, Adiposity, Anthropometry*

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Introduction

Childhood obesity is a concerning issue in Brazil and a range of countries, given its raised prevalence[1,2] and the presence of excess body fatness (BF) at increasingly early ages[3], raising the risk of developing type 2 diabetes and cardiovascular diseases in childhood and in later life[4]. World estimates show that from 1980 to 2013 the prevalence of obesity in children and adolescents has risen in developing countries from 8.1% to 12.9% in boys and from 8.4% to 13.4% in girls[5].

Anthropometric indicators such as body mass index (BMI) are widely used[6]. Despite being useful for classifying children's nutritional status, the ability of the BMI to predict BF is still a matter for debate because a high score may result both from high levels of body fatness or of lean tissue[7].

Waist circumference (WC) and waist-to-height ratio (WHtR) have also been put forward for screening for excess BF, and have shown positive associations with cardiometabolic risk factors owing to the relationship between the waist measurement and visceral adiposity[8]. However, there are no cut-off points for WC based on a representative sample of the Brazilian population for the classification of children according to body fatness[9].

For WHtR, the identification of cut-off points for screening children with excess BF has been the topic of recent studies[10,11]; a score of 0.5 has been put forward as a cut-off value to predict cardiometabolic risk both in children and adults, whatever the gender, and this has been simplified in public health advice as "keep your waist circumference below half your height"[12].

Being so easy and so affordable to obtain, the performance of these anthropometric indicators should be studied for their contribution to further epidemiological studies classifying children by BF and analyzing techniques that give valid estimates of body composition such as dual-energy X-ray absorptiometry (DEXA), isotope dilution, air-displacement plethysmography (ADP) or skinfold measurements, the latter being the most feasible in population studies[13,14].

The aim of this study was therefore to investigate the relationship between BMI, WC and WHtR and the sum of skinfold thicknesses in a 7-to-10-year-old population attending a public school in São Paulo, Brazil.

Methods

The study included all children enrolled from the 2nd to 5th years of basic education (n = 217) at a public school in the municipality of São Paulo, Brazil; data was gathered in November 2008. Anthropometric characteristics were measured by researchers trained in accordance with World Health Organization recommendations[6].

Height (cm) was measured using a SECA®stadiometer and weight (kg) using a Tanita® digital scales; the children were bare-footed and wore light clothing. Waist circumference (WC) was measured in centimeters at the mid-point between the lower border of the last rib and the iliac crest, at the end of a normal expiration, using a non-elastic tape measure[6].

Triceps, biceps, subscapula and suprailiac skinfolds (mm) were measured using a Lange®adipometer on the right-hand side of the body. All measurements were taken in duplicate, and averages were calculated later. The second measurements were recorded by the same researcher - without, however, seeing the first scores so as to avoid memory bias.

BMI (weight (kg)/height^2 (meters)), WHR (waist circumference (cm)/height (cm)) and the sum of the four skinfolds (mm) were calculated. The research project was approved by the University of São Paulo School of Public Health's Ethics Committee; the legal guardians for the children taking part in the study signed a free informed consent document.

Statistical analysis

The descriptive analysis involved calculating the mean, standard deviation and 95% confidence interval (95% CI). To analyze the agreement between each indicator and the sum of skinfold measurements, the Bland-Altman[15] approach was followed, and a scatter plot was produced to show the difference between the two variables (y axis) and their mean (x axis). To enable comparison between variables measured using different units (e.g. BMI (kg/m^2) and the sum of skinfolds (mm)), scores were standardized by taking the difference between the score and the average, divided by the standard deviation, to produce the z-score.

Agreement was assessed by analysis of the Bland-Altman plots and by calculating the limits of agreement, which amplitude was arbitrarily considered large when the differences were 1.5 standard deviations (SD) or larger, moderate

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when from 1.0 to 1.49 SD and there was considered to be agreement between the methods for differences smaller than 1.0 SD. Stat 11.0 (StataCorp LP, College Station, TX) was used for the statistical analysis.

Results

The 217 school children taking part in the study were almost equally distributed by gender (n = 111 boys and n = 106 girls) and an average age of 9.2 years (SD 1.0 year). Superimposing the confidence intervals, no difference was found between boys and girls as to scores for average height, weight, BMI, WC, WHtR and sum of skinfold thicknesses (Table 1).

Figure 1 presents the Bland-Altman plots. The analysis of limits of agreement and their confidence intervals showed evidence of good agreement, above all between BMI and WC with the sum of skinfold thicknesses, complying with strict agreement limits and differences smaller than 1 standard deviation (SD). WHtR showed moderate limits of agreement, from -1.02 to +0.64 SD (boys) and -0.74 to +1.12 SD (girls); the performance of WHtR was not better than that of WC alone, the lower and upper limits of agreement for which were -0.91 to +0.58 SD (boys) and -0.56 to +0.89 SD (girls).

Discussion

The results from this study support the use of BMI and WC to identify children with excess BF, bearing out findings published in the literature that describe the indicators' good performance in identifying excess BF with DEXA or skinfolds as reference[16-19].

In this study BMI and WC alone presented better agreement with skinfold measurements than WHtR - as has also been found by other researchers[20,21]. In the study by Sijtsma et al.[21] investigating the performance of BMI, WC and WHtR in predicting cardiometabolic risk in 3-to-7-year-old children, WHtR showed the worst performance in estimating BF percentage, and the lowest scores for correlation to variables indicating cardiometabolic risk.

However, in another study of 9-to-11-year-old Japanese schoolchildren[10] as well as in a study of 7-to-10-year-old Brazilian schoolchildren[11], WHtR performed well, comparably with BMI and WC in identifying excess abdominal adiposity and total BF, respectively. The disparities in the literature may be linked to the age group of the individuals assessed and to differences between populations.

Furthermore, given that WHtR was proposed in the late 1990s and that interest in its performance as a BF indicator has grown in recent years[22], the number of articles on this indicator is scarce when compared with BMI and WC. Further studies would seem to be necessary in order to enable definitive conclusions to be drawn as to its effectiveness in detecting excess BF in children.

Sample size is one limitation of the present study, as is the use of data concerning children from a single public school, hindering any generalization of the results. On the other hand one advantage was the fact that the study was carried out with all of the schoolchildren from the 2nd to 5th years of basic education (i.e. 7-to-10-year-olds).

Table 1. Mean values, standard deviation (sd), and 95% confidence interval (95% CI) of height, weight, body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and sum of skinfold thicknesses in 7-10-year-old children attending a public school in São Paulo, Brazil.

	Boys			Girls			All		
Variable	Mean	sd	95% CI	Mean	sd	95% CI	Mean	sd	95% CI
Height (cm)	134.9	8.6	133.3-136.5	136.0	9.5	134.2-137.9	135.5	9.1	134.3-136.7
Weight (kg)	34.0	10.4	32.1-36.0	34.7	9.2	32.9-36.4	34.4	9.8	33.0-35.7
BMI (kg/m^2)	18.4	3.9	17.7-19.1	18.5	3.8	17.8-19.2	18.5	3.8	18.0-19.0
WC (cm)	63.7	10.0	61.8-65.6	63.4	9.0	61.7-65.2	63.6	9.5	62.3-64.9
WHtR	0.47	0.1	0.46-0.48	0.47	0.1	0.45-0.48	0.47	0.1	0.46-0.48
∑ skinfold thicknesses (mm)	44.1	2.5	39.1-49.0	52.0	2.4	47.2-56.8	47.9	1.8	44.4-51.4

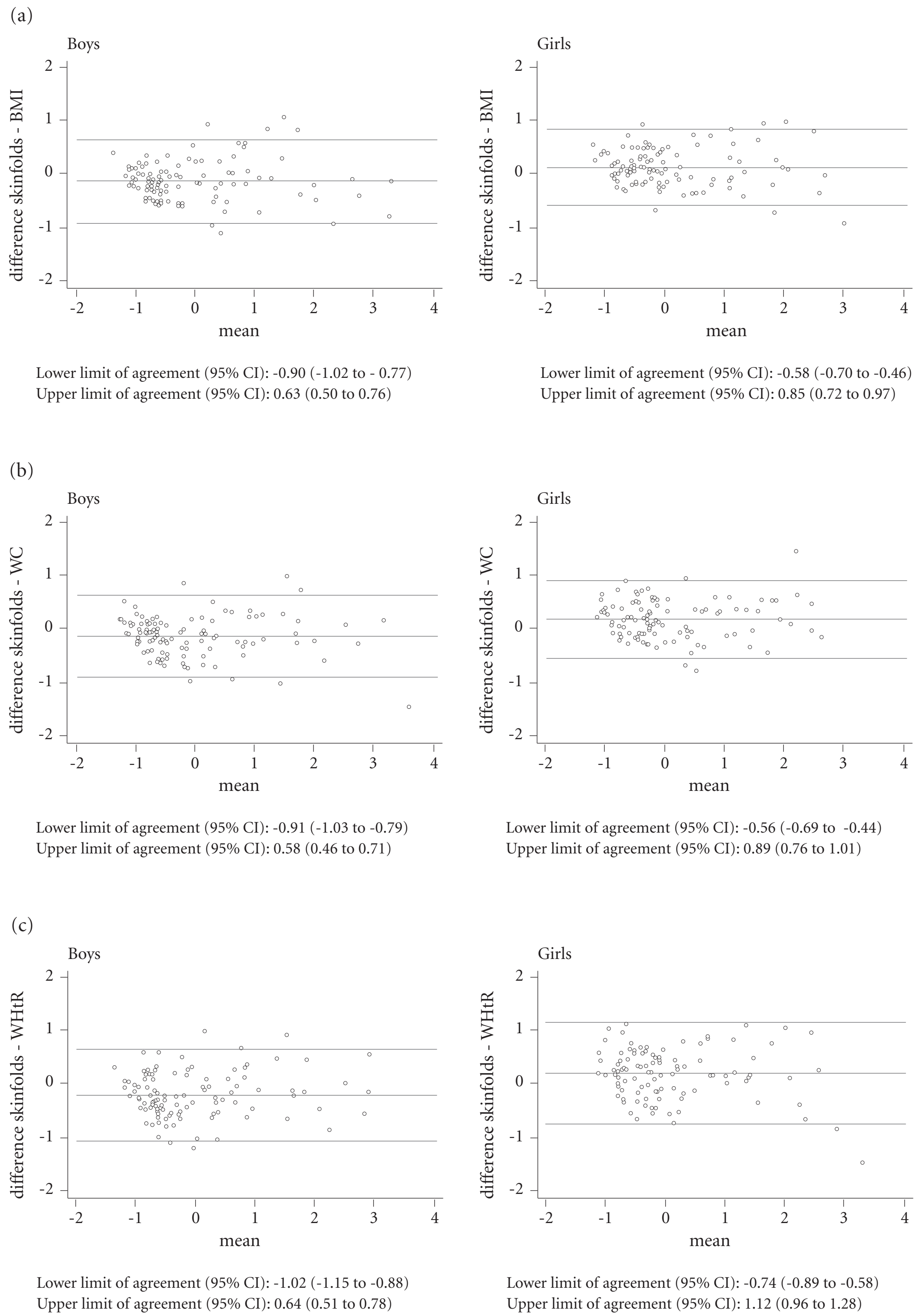

Figure 1. Bland and Altman plots. Distribution of 7-10-year-old children attending a public school in São Paulo, Brazil, according to mean values and differences (transformed into z-scores) between anthropometric indicators (a) body mass index (BMI), (b) waist circumference (WC), and (c) waist-to-height ratio (WHtR) and the sum of skinfold thicknesses, by gender.

* Values converted to z.

The choice of skinfolds as the method of comparison, rather than such techniques as DEXA or ADP, enabled measurements to be taken in the school itself, facilitating the field work. The literature indicates this method as the best choice when DEXA or ADP equipment - for example - is not available for financial or operational reasons[14]. Using skinfold measurements necessitates the training of assessors, standardization of the procedures followed, and a reliability study, indicating the quality of the data[23]. We therefore opted to work with duplicate scores. The literature recommends taking at least two measurements[24], although some authors argue for three measurements to be taken[25].

We opted to sum the scores rather than use predictive equations since we had access to measurements for four skinfolds - biceps, triceps, subscapular and suprailiac - that reflect both central and peripheral fatness. The equations normally consider one or two skinfolds - as in Slaughter et al.[26], for example, with the triceps and calf. Furthermore, studies of children and adolescents question the validity of these equations in different populations[27,28].

To conclude, the results show agreement between BMI and WC and the skinfolds, reinforcing favorable evidence in the literature of the use of these measurements in classifying schoolchildren as to BF. Division of the waist score by the height (WHtR) showed worst agreement compared with waist circumference alone. We therefore particularly suggest the use of BMI and WC in epidemiological studies as methods for classifying nutritional status, because both perform similarly and have the advantage of being harmless, affordable and easy to obtain and interpret.

Collaborations

NOS Jensen, TFB Camargo and DP Bergamaschi helped in the conception of the article, in the statistical analysis and in the interpretation of the data, the drafting and the proof reading of the manuscript.

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