

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

Natália Sanchez Oliveira Jensen <sup>1</sup>  
Taís de Fátima Borges Camargo <sup>1</sup>  
Denise Pimentel Bergamaschi <sup>1</sup>

**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*

<sup>1</sup> Departamento de Epidemiologia, Faculdade de Saúde Pública, Universidade de São Paulo. Av. Dr. Arnaldo 715, Cerqueira César. 01246-904 São Paulo SP Brasil. [denisepb@usp.br](mailto:denisepb@usp.br)

## Introduction

Childhood obesity is a concerning issue in Brazil and a range of countries, given its raised prevalence<sup>1,2</sup> and the presence of excess body fatness (BF) at increasingly early ages<sup>3</sup>, raising the risk of developing type 2 diabetes and cardiovascular diseases in childhood and in later life<sup>4</sup>. 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<sup>5</sup>.

Anthropometric indicators such as body mass index (BMI) are widely used<sup>6</sup>. 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<sup>7</sup>.

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<sup>8</sup>. 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<sup>9</sup>.

For WHtR, the identification of cut-off points for screening children with excess BF has been the topic of recent studies<sup>10,11</sup>; 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"<sup>12</sup>.

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<sup>13,14</sup>.

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<sup>6</sup>.

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<sup>6</sup>.

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<sup>2</sup> (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<sup>15</sup> 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<sup>2</sup>) 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

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<sup>16-19</sup>.

In this study BMI and WC alone presented better agreement with skinfold measurements than WHtR - as has also been found by other researchers<sup>20,21</sup>. In the study by Sijtsma et al.<sup>21</sup> 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.

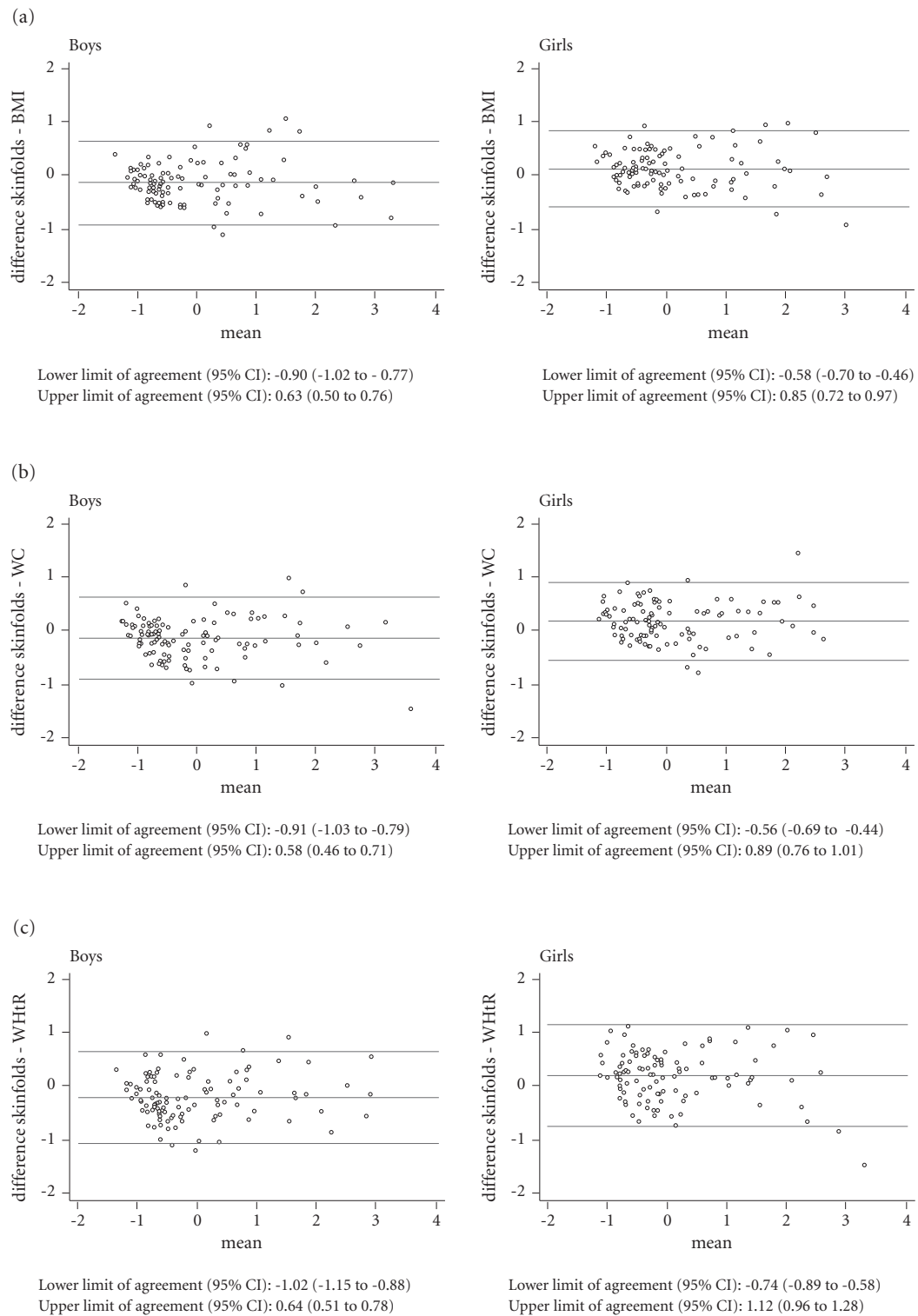
However, in another study of 9-to-11-year-old Japanese schoolchildren<sup>10</sup> as well as in a study of 7-to-10-year-old Brazilian schoolchildren<sup>11</sup>, WHtR performed well, comparably with BMI and WC in identifying excess abdominal adiposity and total BF, respectively. The disparities in 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<sup>22</sup>, 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.

Variable	Boys			Girls			All		
	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 <sup>2</sup> )	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<sup>14</sup>. Using skinfold measurements necessitates the training of assessors, standardization of the procedures followed, and a reliability study, indicating the quality of the data<sup>23</sup>. We therefore opted to work with duplicate scores. The literature recommends taking at least two measurements<sup>24</sup>, although some authors argue for three measurements to be taken<sup>25</sup>.

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.<sup>26</sup>, for example, with the triceps and calf. Furthermore, studies of children and adolescents question the validity of these equations in different populations<sup>27,28</sup>.

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.

## Acknowledgments

To Brazil's National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico* - CNPq) for funding the original project and for the scholarship for Natália Sanchez Oliveira Jensen. To the University of São Paulo for the grant in Initiation in the Scientific Method (*Iniciação Científica*) for Tais de Fátima Borges Camargo (RUSP Institutional Scholarship) during the execution of the study.

## References

1. Instituto Brasileiro de Geografia e Estatística (IBGE). *Antropometria e estado nutricional de crianças, adolescentes e adultos no Brasil*. Rio de Janeiro: IBGE; 2010.
2. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA* 2014; 311(8):806-814.
3. de Onis M, Blössner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr* 2010; 92(5):1257-1264.
4. Park MH, Sovio U, Viner RM, Hardy RJ, Kinra S. Overweight in childhood, adolescence and adulthood and cardiovascular risk in later life: pooled analysis of three british birth cohorts. *PLoS One* 2013; 8(7):e70684.

5. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, Mullany EC, Biryukov S, Abbafati C, Abera SF, Abraham JP, Abu-Rmeileh NM, Achoki T, AlBuhairan FS, Alemu ZA, Alfonso R, Ali MK, Ali R, Guzman NA, Ammar W, Anwar P, Banerjee A, Barquera S, Basu S, Bennett DA, Bhutta Z, Blore J, Cabral N, Nonato IC, Chang JC, Chowdhury R, Courville KJ, Criqui MH, Cundiff DK, Dabhadkar KC, Dandona L, Davis A, Dayama A, Dharmaratne SD, Ding EL, Durrani AM, Esteghamati A, Farzadfar F, Fay DF, Feigin VL, Flaxman A, Forouzanfar MH, Goto A, Green MA, Gupta R, Hafezi-Nejad N, Hankey GJ, Harewood HC, Havmoeller R, Hay S, Hernandez L, Husseini A, Idrisov BT, Ikeda N, Islami F, Jahangir E, Jassal SK, Jee SH, Jeffreys M, Jonas JB, Kabagambe EK, Khalifa SE, Kengne AP, Khader YS, Khang YH, Kim D, Kimokoti RW, Kinge JM, Kokubo Y, Kosen S, Kwan G, Lai T, Leinsalu M, Li Y, Liang X, Liu S, Logroscino G, Lotufo PA, Lu Y, Ma J, Mainoo NK, Mensah GA, Merriman TR, Mokdad AH, Moschandreas J, Naghavi M, Naheed A, Nand D, Narayan KM, Nelson EL, Neuhouser ML, Nisar MI, Ohkubo T, Oti SO, Pedroza A, Prabhakaran D, Roy N, Sampson U, Seo H, Sepanlou SG, Shibuya K, Shiri R, Shiue I, Singh GM, Singh JA, Skirbekk V, Stapelberg NJ, Sturua L, Sykes BL, Tobias M, Tran BX, Trasande L, Toyoshima H, van de Vijver S, Vasankari TJ, Veerman JL, Velasquez-Melendez G, Vlassov VV, Vollset SE, Vos T, Wang C, Wang X, Weiderpass E, Werdecker A, Wright JL, Yang YC, Yatsuya H, Yoon J, Yoon SJ, Zhao Y, Zhou M, Zhu S, Lopez AD, Murray CJ, Gakidou E. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; 384(9945):766-781.
6. World Health Organization (WHO). *Physical Status: The use and interpretation of anthropometry*. Geneva: WHO; 1995. (WHO – Technical Report Series, 854).
7. Freedman DS, Ogden CL, Blanck HM, Borrud LG, Dietz WH. The abilities of body mass index and skinfold thicknesses to identify children with low or elevated levels of dual-energy X-ray absorptiometry-determined body fatness. *J Pediatr* 2013; 163(1):160-166.
8. Harrington DM, Staiano AE, Broyles ST, Gupta AK, Katzmarzyk PT. Waist circumference measurement site does not affect relationships with visceral adiposity and cardiometabolic risk factors in children. *Pediatr Obes* 2013; 8(3):199-206.
9. Bergmann GG, Gaya A, Halpern R, Bergmann ML, Rech RR, Constanzi CB, Alli LR. Waist circumference as screening instrument for cardiovascular disease risk factors in schoolchildren. *J Pediatr (Rio J)* 2010; 86(5):411-416.
10. Fujita Y, Kouda K, Nakamura H, Iki M. Cut-off values of body mass index, waist circumference, and waist-to-height ratio to identify excess abdominal fat: population-based screening of Japanese school children. *J Epidemiol* 2011; 21(3):191-196.
11. Ribeiro EA, Leal DB, de Assis MA. Diagnostic accuracy of anthropometric indices in predicting excess body fat among seven to ten-year-old children. *Rev Bras Epidemiol* 2014; 17(1):243-254.
12. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. *Nutr Res Rev* 2010; 23(2):247-269.
13. Weber DR, Leonard MB, Zemel BS. Body composition analysis in the pediatric population. *Pediatr Endocrinol Rev* 2012; 10(1):130-139.
14. Michels N, Huybrechts I, Bammann K, Lissner L, Moreno L, Peeters M, Sioen I, Vanaelst B, Vyncke K, De Henauw S. Caucasian children's fat mass: routine anthropometry v. air-displacement plethysmography. *Br J Nutr* 2013; 109(8):1528-1537.
15. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 1(8476):307-310.
16. Reilly JJ, Dorosty AR, Ghomizadeh NM, Sherriff A, Wells JC, Ness AR. Comparison of waist circumference percentiles versus body mass index percentiles for diagnosis of obesity in a large cohort of children. *Int J Pediatr Obes* 2010; 5(2):151-156.
17. Flegal KM, Ogden CL, Yanovski JA, Freedman DS, Shepherd JA, Graubard BI, Borrud LG. High adiposity and high body mass index-for-age in US children and adolescents overall and by race-ethnic group. *Am J Clin Nutr* 2010; 91(4):1020-1026.
18. Tuan NT, Wang Y. Adiposity assessments: agreement between dual-energy X-ray absorptiometry and anthropometric measures in U.S. children. *Obesity (Silver Spring)* 2014; 22(6):1495-1504.
19. Leal DB, de Assis MAA, Conde WL, Bellisle F. Performance of references based on body mass index for detecting excess body fatness in schoolchildren aged 7 to 10 years. *Rev Bras Epidemiol* 2014; 17(2):517-530.
20. Hubert H, Guinhouya CB, Allard L, Durocher A. Comparison of the diagnostic quality of body mass index, waist circumference and waist-to-height ratio in screening skinfold-determined obesity among children. *J Sci Med Sport* 2009; 12(4):449-451.
21. Sijtsma A, Bocca G, L'abée C, Liem ET, Sauer PJ, Corpeleijn E. Waist-to-height ratio, waist circumference and BMI as indicators of percentage fat mass and cardiometabolic risk factors in children aged 3-7 years. *Clin Nutr* 2014; 33(2):311-315.
22. Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obes Rev* 2012; 13(3):275-286.
23. Freaza SEM, Sewell CD, Adami F, Hinnig PF, Bergamaschi DP. Relação entre atividade física e peso, estatura e IMC de escolares de 7 a 10 anos. In: 10º Congresso Nacional da Sociedade Brasileira de Alimentação e Nutrição, 2009, São Paulo. *Anais do 10º Congresso Nacional da Sociedade Brasileira de Alimentação e Nutrição – SBAN – Dos Genes à Coletividade*. São Paulo: SBAN; 2009. p. 304.
24. Heyward VH, Stolarczyk LM. *Avaliação da composição corporal aplicada*. São Paulo: Manole; 2000.
25. Lohman TG, Roche AF, Martorell R, editors. *Anthropometric standardization reference manual*. Champaign: Human kinetics; 1988.
26. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stilman RJ, Van Loan MD, Bembien DA. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60(5):709-723.
27. Yeung DC, Hui SS. Validity and reliability of skinfold measurement in assessing body fatness of Chinese children. *Asia Pac J Clin Nutr* 2010; 19(3):350-357.
28. Hoffman DJ, Toro-Ramos T, Sawaya AL, Roberts SB, Rondo P. Estimating total body fat using a skinfold prediction equation in Brazilian children. *Ann Hum Biol* 2012; 39(2):156-160.

---

Article submitted 08/06/2015

Approved 06/08/2015

Final version submitted 08/08/2015