ORIGINAL ARTICLE

Performance of body fat and body mass index cutoffs in elevated blood pressure screening among male children and adolescents

Romulo A Fernandes^{1,2}, Diego GD Christofaro^{2,3}, Camila Buonani⁴, Henrique L Monteriro¹, Jefferson R Cardoso⁵, Ismael F Freitas Jr⁴ and Dalmo RL Machado⁶

For percentage of body fat (%BF), there are no internationally accepted cutoffs. The primary function of body fat cutoffs should be to identify not only excessive body fatness, but also the increased risk of unhealthy outcomes, such as hypertension. The purpose of this study was to analyze the accuracy of different %BF and body mass index (BMI) cutoffs as screening measures for EBP in pediatric populations. It was a cross-sectional study with a sample of 358 male subjects from 8 to 18 years old. BP was measured by the oscilometric method, and body composition was measured by dual-energy X-ray absorptiometry (DXA). The accuracy of three reference tables used for body fat cutoffs was assessed. The three body fat reference tables were highly specific, but insensitive, for elevated BP screening. For elevated BP screening, all body fat cutoffs presented similar sensitivity (range=48.3–53.7%) and specificity (range=79.2–84.1%). The body fat cutoffs performed no better than BMI in screening of children and adolescents at risk of elevated BP (EBP). BMI seems a more attractive tool for this function, as it performed similarly and can be applied in large surveys and with lower costs.

Hypertension Research (2011) 34, 963–967; doi:10.1038/hr.2011.61; published online 26 May 2011

Keywords: adolescent; children; dual-energy X-ray absorptiometry; obesity; receiver operating characteristic curve

INTRODUCTION

The increase of worldwide obesity among pediatric populations in recent decades has been identified in both developed and developing countries.¹ This increase is worrisome, because it is expressly associated with a higher burden of health care costs among children and adolescents.²

Adipose tissue releases a variety of adipokines, which are strongly associated with endothelial dysfunction and, in turn, increased blood pressure (BP) values at rest. It is known that obese adolescents have increased odds of developing chronic disorders such as hypertension,³ and this physiological outcome is frequently observed among obese adolescents.^{3–7} Therefore, the primary function of body fat cutoffs should be to screen not only for excessive body fatness, but should also be to assess the increased risk of unhealthy outcomes, such as hypertension.

Williams *et al.*⁸ proposed percentage of body fat (%BF) cutoffs for white and black American children and adolescents (5–18 years old), based on values of cardiovascular risk factors (with %BF based on skinfold measurements). Taylor *et al.*⁹ went further by utilizing a reference method for the assessment of body composition (dual-

energy X-ray absorptiometry (DXA)) and proposed sex- and age-specific % BF cutoffs among white New Zealanders (3–18 years old), but these were not associated with indicators of cardiovascular risk. More recently, McCarthy *et al.*,¹⁰ in a large Caucasian British pediatric sample, proposed the 85th and 95th percentile of %BF (sex- and age-specific cutoffs (5–19 years old)) to define 'overfat' and obesity (with %BF, based on bioelectric impedance analysis), respectively.

It is possible that this large variety of cutoffs proposed for children and adolescents could exert considerable negative influence on the screening of unhealthy outcomes associated with obesity. Nevertheless, information about this question is not available in the literature. Furthermore, it is not clear if anthropometric indices (for example, body mass index (BMI) and waist circumference), which are cheaper and more routinely used in clinical and epidemiological settings, screen subjects with increased risk of elevated blood pressure (EBP) more or less adequately than %BF.

Thus, the purposes of this study were: (i) to analyze the influence of cutoff choice on the accuracy of body fat estimation as a screening tool for EBP in male pediatric populations and (ii) to verify if BMI presents similar screening characteristics to these body fat cutoffs.

¹Department of Physical Education, UNESP Univ Estadual Paulista, Institute of Bioscience, Rio Claro, Brazil; ²Department of Physical Education, Universidade do Oeste Paulista UNOESTE, Presidente Prudente, Brazil; ³Department of Collective Health, Universidade Estadual de Londrina UEL, Londrina, Brazil; ⁴Department of Physical Education, UNESP Univ Estadual Paulista, Presidente Prudente, Brazil; ⁵Department of Physical Therapy, Universidade Estadual de Londrina UEL, Londrina, Brazil and ⁶Department of Physical Education, Universidade de São Paulo USP, Ribeirão Preto, Brazil

Correspondence: Professor RA Fernandes, Department of Physical Education. Institute of Biosciences—UNESP, Av 24^A, 1515. 13506-900 Rio Claro (SP), Brazil.

E-mail: romulo_ef@yahoo.com.br

Received 27 March 2010; revised 7 December 2010; accepted 23 March 2011; published online 26 May 2011

METHODS

Sample

This cross-sectional study was carried out in the city of Presidente Prudente (Human Development Index =0.846), Southeastern Brazil, from July to November 2008. Before the study, a minimum required sample size was estimated ($n=275$), based on an obesity prevalence of 13.9%,¹ an error of 5%, an α -error of 5% ($z=1.96$) and a design effect of 1.5. Furthermore, an additional loss rate of 10% was considered ($n=303$). After the fieldwork, the sample included 358 male children and adolescents from 8 to 18 years old ($n=92$ children (from 8 to 10 years old) and $n=266$ adolescents (from 11 to 18 years old)). The sample population was found at schools ($n=3$) and recreational associations ($n=3$), where all male students/members in each setting were invited to participate as volunteers in the study. Inclusion criteria for participants consisted of a self-declaration of health and an affirmation that they were neither taking any prescription medicine nor undergoing any current clinical treatment. In each school or club, all interested students received a written informed consent form, which was to be filled out by both the parents and the students before they could take part in the study. The study was approved by the Ethics Committee on Human Experimentation of the Universidade de São Paulo.

Anthropometric measures

Body weight (wearing shorts and a t-shirt (nearest 100 g)) and barefoot height were measured with an electronic scale and wall-mounted stadiometer, respectively. BMI was calculated with values of weight divided by height, squared (kg m^{-2}). All anthropometry was assessed using standardized techniques¹¹ by a single experienced researcher. Children and adolescents were classified as overweight or obese according to the BMI-based definition proposed by Cole *et al.*¹² (in all statistical analysis, overweight and obesity were merged).

Blood pressure (BP) values

Systolic and diastolic blood pressure (SBP and DBP) values were measured with an electronic device (MX3 Plus; Omron, Kyoto, Kansai, Japan) previously validated for pediatric populations.¹³ After 5 min of rest in a seated position, two measures were taken on the right arm, with a 2 min interval between them, and the mean value was used. For the subjects' blood pressure (BP) measurement, two types of cuffs were used according to the arm circumference (6 mm $\times$ 12 mm for children, and 9 mm $\times$ 18 mm for adolescents 14–18 years old and for those children with a larger arm size), following the recommendations of the American Heart Association.¹⁴ The National High Blood Pressure Education Program¹⁵ cutoffs adjusted for age and height percentile (P95), were applied to indicate the presence of elevated BP (EBP).

Dual-energy X-ray absorptiometry (DXA)

Whole body and regional body composition were measured with a Lunar DPX-NT scanner (Lunar DPX-NT; General Electric Healthcare, Little Chalfont, Buckinghamshire, UK). The software provides measurements of lean soft tissue, fat and bone mineral density for the entire body, as well as for specific regions, as well as %BF. All DXA measurements were made at a university laboratory with a constant controlled temperature. Each morning, before any measurements were taken, the device was calibrated by the same researcher and, according to the reference values provided by the manufacturer, the tests presented high reliability.

Body fat cutoffs

The comparison of body fat cutoffs was based on three reference tables developed for children and adolescents of different nations (no cutoff was adjusted according to ethnic groups): (i) Williams *et al.*⁸ classify subjects as either non-obese or obese (American population); (ii) Taylor *et al.*⁹ use non-obese, overweight and obese as categories, in which the categories overweight and obese were clustered (overweight+obesity; New Zealand population); whereas (iii) McCarthy *et al.*¹⁰ use the following classifications: 'normal', 'overfat' and 'obese', in which the categories overfat and obese were clustered (overfat+obesity; British population).

Statistical analysis

Initially, the Kolmogorov–Smirnov test rejected the normality of the numerical data, and so, non-parametric descriptive statistical methods were applied (median and interquartile range). Additionally, the Mann–Whitney *U*-test was used to compare numerical variables between two groups (subjects with normal and elevated BP values). Spearman's rank was used to analyze correlations between BP values and chronological age. The kappa (κ) statistic indicated the agreement level between categorical variables. The chi-square (χ^2) test, either with Yates' correction or linear trend analysis, was used to determine associations among categorical outcomes. Receiver operating characteristics curves with the default parameters (sensitivity (true-positive rate), specificity (true-negative rate), positive predictive value, negative predictive value and area under curve (AUC)) were compared, to determine the best %BF cutoff reference table. Significance (*P*) was set at 5% and statistical software SPSS version 13.0 (SPSS, Chicago, IL, USA) was utilized for all analyses.

RESULTS

The sample was composed of 358 male children and adolescents. The prevalence of EBP was 26% ($n=93$); chronological age was poorly correlated to BP values (SBP: $r=0.38$ with $P=0.001$; DBP: $r=0.22$ with $P=0.001$). Table 1 shows the general characteristics of the sample grouped by BP values. Subjects with EBP had higher values of body weight, BMI and %BF. Independent of %BF cutoff, obese subjects presented higher values of both SBP and DBP (all with $P=0.001$). Children and adolescents who were identified as overweight/obese by BMI also presented higher values of SBP and DBP than those with normal weight (both comparisons with $P=0.001$).

The three cutoffs for body fat presented elevated agreement in the identification of obese children and adolescents (Taylor *et al.*⁹ and McCarthy *et al.*¹⁰ ($\kappa=0.93$; $P=0.001$); Taylor *et al.*⁹ and Williams *et al.*⁸ ($\kappa=0.87$; $P=0.001$); Williams *et al.*⁸ and McCarthy *et al.*¹⁰ ($\kappa=0.89$; $P=0.001$)), whereas, BMI presented moderate agreement in the identification of obesity (Taylor *et al.*⁹ ($\kappa=0.62$; $P=0.001$); McCarthy *et al.*¹⁰ ($\kappa=0.58$; $P=0.001$); Williams *et al.*⁸ ($\kappa=0.60$; $P=0.001$)). The prevalence of obesity indicated by Williams *et al.*⁸ cutoffs was not lower in either adolescents or children ($P=0.376$). Taylor *et al.*⁹ cutoffs were associated with age groups (children=40.2% and adolescents=26.5%; $P=0.003$), whereas McCarthy *et al.*¹⁰ cutoffs were not associated with age ($P=0.126$). Figure 1 shows the prevalence of obesity identified by DXA and overweight/obesity identified by BMI. There was no significant difference between the obesity prevalence identified by Williams *et al.*⁸, Taylor *et al.*⁹ and McCarthy *et al.*¹⁰ cutoffs. Independently of %BF cutoffs, there was a positive association between EBP values and obesity ($P=0.001$, for all), because obese subjects presented a higher occurrence of EBP. The same pattern of association was observed between BMI status and prevalence of EBP. Regarding EBP rate, there were no differences among any of the

Table 1 General characteristics of the sample grouped according BP values

Variable	Normal BP ($n=265$)	EBP ($n=93$)	P-value
	Median (IR)	Median (IR)	
Age (years)	12.8 (5.2)	13.6 (5.2)	0.468
Weight (kg)	43.5 (25.9)	57.5 (26.1)	0.001
Height (cm)	154.1 (31.1)	161.7 (27.7)	0.103
BMI (kg m^{-2})	17.8 (4.1)	20.9 (5.3)	0.001
%BF	13.4 (9.1)	22.1 (19.2)	0.001

Abbreviations: BP, blood pressure; %BF, body fat percentage; BMI, body mass index; IR, interquartile range.

Figure 1 Obesity prevalence in male children and adolescents according to various body fat cutoffs.

Figure 2 Elevated blood pressure (EBP) prevalence in male children and adolescents according to various body fat cutoffs and body mass index (BMI).

body fat references (Figure 2) or between body fat cutoffs and BMI cutoffs (data not shown).

BMI and %BF are presented as screening tests for EBP (Table 2). Sensitivity and specificity were similar for all body fat and BMI cutoffs in the studied samples. Independently of cutoff, the proportion of true-positive cases was low and ranged from 52 to 70% and from 34 to 48.5% in children and adolescents, respectively. Compared with the true-positive cases, true-negative cases were much higher (ranging from 79.2 to 87.5%). Regarding EBP screening, there were no differences among any of the body fat references or between body fat cutoffs and BMI cutoffs (χ^2 -test with $P > 5\%$ for all comparisons).

The rate of misclassification was around of 30% in all body fat and BMI cutoffs (Williams *et al.*⁸=25.1% ($n=90$), Taylor *et al.*⁹=27.3% ($n=98$), McCarthy *et al.*¹⁰=27.9% ($n=100$) and Cole *et al.*¹²=25.1% ($n=90$)). BMI presented the lowest proportion of false-positive cases (36.6% ($n=33$)) followed by Williams *et al.*⁸ (46.6% ($n=42$)), McCarthy *et al.*¹⁰ (54% ($n=54$)) and Taylor *et al.*⁹ (56.1% ($n=55$)).

However, Taylor *et al.*⁹ presented the lowest proportion of false-negative cases (43.9% ($n=43$)), followed by McCarthy *et al.*¹⁰ (46% ($n=46$)), Williams *et al.*⁸ (53.4% ($n=48$)) and Cole *et al.*¹² (63.3% ($n=57$)). The proportion of efficiency also was similar for all reference tables ($P > 5\%$ for all comparisons). Figure 3 shows the global measure of screening accuracy of the analyzed cutoffs.

DISCUSSION

This cross-sectional study analyzed the accuracy of three %BF cutoffs in EBP screening among male children/adolescents, and presented data which suggests that the choice of %BF cutoffs does not have a significant influence on such screening. When compared with these cutoffs, BMI produces similar screening characteristics.

The EBP rate found in this study ($\sim 26\%$) was higher than the 10% observed among the general Brazilian pediatric population.¹⁶ This may have been partially due to the obesity observed in a large percentage of the overall sample. Increased white adipose tissue releases a variety of adipokines that are related to a decrease in the production and utilization of nitric oxide, which has important functions in the control of vascular tone and suppression of vascular smooth muscle cell proliferation. This decreased effect of nitric oxide is associated with endothelial dysfunction and, thus, arterial hypertension.¹⁷ In pediatric populations, previous studies have found that high SBP is frequently related to higher adiposity,^{3,16} indicating that the above-mentioned mechanisms could occur not only in adults, but also in children and adolescents.

Obesity identified by DXA (independent of cutoff) and BMI were markedly associated with EBP. However, the results seem to indicate that the magnitude of this association is slightly cutoff dependent (Williams *et al.*⁸ cutoffs, odds ratio=4.7 (95% confidence intervals=2.9; 8.4); McCarthy *et al.*¹⁰ cutoffs, odds ratio=4.4 (95% confidence intervals=2.6; 7.3); Taylor *et al.*⁹ cutoffs, odds ratio=4.0 (95% confidence intervals=2.4; 6.6)). This data indicate that %BF cutoff choice has no significant effect when testing the association between obesity and EBP.

In the McCarthy *et al.*¹⁰ table (85th percentile), the body fat range was from 20.1 to 23%, which was similar to the range observed among adolescents in New Zealand, from 18 to 23% (overweight in the Taylor *et al.*⁹ cutoffs). In contrast to the observations of Williams *et al.*⁸ (fixed at 25% for all ages), the McCarthy *et al.*¹⁰ %BF cutoffs showed a different pattern across age groups. Maturation and growth-related changes have great importance in this period of human development. Fernandes *et al.*¹⁸ proposed %BF cutoffs based on EBP, which varied across age groups, indicating that growth represents an important confounding factor and must be taken into consideration. Thus, the absence of similarity for these cutoffs would seem to discourage the establishment of a single %BF cutoff across different ages.

For EBP screening in pediatric populations, the utilization of internationally accepted standard reference tables for %BF, adjusted by age groups, should receive wider acceptance, as has happened with the BMI.¹² However, as is true for the BMI, the adoption of international reference tables seems to increase the proportion of false-negative cases.^{19–21} This is the case with the non age-adjusted cutoffs proposed by Williams *et al.*⁸ where the higher cutoffs generated lower prevalence of obesity and, hence, higher specificity (true-negative cases). As mentioned above, outcome underestimation generates lower sensitivity (true-positive cases), that is, the capacity to correctly identify the outcome presence; therefore, both Taylor *et al.*⁹ and McCarthy *et al.*¹⁰ cutoffs, which presented higher outcome prevalence, also demonstrated slightly better accuracy in identifying the

Table 2 Accuracy of BMI and body fat cutoffs in screening of EBP in male children and adolescents

Age groups	Cutoffs	Parameters of the ROC curves					Comparison with BMI (P-value) ^a		
		SENS	SPEC	PPV (%)	NPV (%)	Efficiency ^b	SENS	SPEC	Efficiency
Children (n=92)	Williams <i>et al.</i> ⁸	12 (52.1%)	55 (79.7%)	46.1	83.3	67 (72.8%)	1.000	0.881	0.869
	Taylor <i>et al.</i> ⁹	16 (69.5%)	48 (69.5%)	43.2	87.2	64 (69.5%)	0.413	0.374	0.749
	McCarthy <i>et al.</i> ¹⁰	13 (56.5%)	52 (75.3%)	43.3	83.8	65 (70.6%)	0.830	0.765	0.871
	Cole <i>et al.</i> ¹²	12 (52.1%)	54 (78.2%)	44.4	83.1	66 (71.7%)	—	—	—
Adolescents (n=266)	Williams <i>et al.</i> ⁸	33 (47.1%)	168 (85.7%)	54.1	81.9	201 (75.5%)	0.209	0.363	0.919
	Taylor <i>et al.</i> ⁹	34 (48.5%)	162 (82.6%)	50	81.8	196 (73.6%)	0.166	0.149	0.549
	McCarthy <i>et al.</i> ¹⁰	34 (48.5%)	159 (81.1%)	47.8	81.5	193 (72.5%)	0.166	0.088	0.372
	Cole <i>et al.</i> ¹²	24 (34.2%)	178 (90.8%)	57.1	79.4	202 (75.9%)	—	—	—
Overall (n=358)	Williams <i>et al.</i> ⁸	45 (48.3%)	265 (84.1%)	51.7	82.2	268 (74.8%)	0.289	0.485	1.000
	Taylor <i>et al.</i> ⁹	50 (53.7%)	210 (79.2%)	47.6	83	260 (72.6%)	0.109	0.091	0.497
	McCarthy <i>et al.</i> ¹⁰	47 (50.5%)	211 (79.6%)	46.5%	82.1%	258 (72.1%)	0.200	0.106	0.397
	Cole <i>et al.</i> ¹²	36 (38.7%)	232 (87.5%)	52.1	80.2	268 (74.8%)	—	—	—

Abbreviations: BMI, body mass index; NPV, negative predictive value; PPV, positive predictive value; ROC, receiver operating characteristics; SENS, sensitivity; SPEC, specificity.

^a χ^2 -test.

^bRate of subjects correctly classified.

Figure 3 Graphical plots of the sensitivity and specificity in overall sample. ROC, receiver operating characteristic.

presence of EBP. However, this higher accuracy did not achieve statistical significance.

Area under curve has been used as a global measure of the performance of %BF and BMI cutoffs. In our study, the area under curve values were low (data not shown), indicating the limited performance of both. The %BF and BMI tables were highly specific, but insensitive for EBP screening, which agrees with Christofaro *et al.*,²² who analyzed a large sample of adolescents of both genders and found decreased positive predictive value (male=22% and female=18%). To adopt a more sensitive or specific %BF cutoff is the researcher's choice, and depends on the desired function for these cutoffs. In population groups with a higher prevalence of the determined outcome, higher specificity seems more adequate, because it better excludes false-positive cases and prevents overtaxing the health system. On the other hand, an outcome of low prevalence requires a more sensitive tool, which increases the true-positive cases and, in turn, improves the probability of finding subjects in need of treatment.

In the case of EBP, an outcome of moderate/high prevalence with an increasing trend, higher specificity seems more appropriate. The three

%BF cutoffs do not perform better than BMI in EBP screening, where true-positive, true-negative and efficiency of BMI were similar to the %BF measured by DXA, independently of cutoffs.

In children and adolescents, early hypertension detection is important because it tracks into adulthood. Regarding hypertension screening, BMI was performed, as well as %BF measured by DXA. BMI is determined by cheap anthropometric measurements, which can be carried out annually in schools and can be used as a simple screening tool, inserted into comprehensive public health strategies, focused on preventive actions.²³ Another interesting finding is that, although obesity presents a great burden in the hypertension genesis,¹⁷ all analyzed cutoffs presented poor screening characteristics, indicating that without adequate cutoffs, %BF monitoring may not allow for complete hypertension screening.

The strengths of our study include the use of DXA, a previously validated measure of %BF in pediatric populations,²⁴ with a relatively large sample size. However, its limitations must be clarified. The sample was composed only of boys, and it is unclear whether the results can be generalized to girls. The use of a single syndrome metabolic indicator (EBP values) and the measurement of BP values on a single day constitute the main limitations of the study. Additionally, when assessing adiposity in childhood and adolescence, even considering age adjustments, maturational stage should also be considered as a determinant or confounding variable and, therefore, the absence of this data constitutes a limitation of the study.

In summary, the results indicated that body fat estimated by DXA is strongly associated with EBP in pediatric populations, but the three analyzed body fat cutoffs have limited screening characteristics. Moreover, the BMI reference values proposed by Cole *et al.*¹² are a more attractive tool for this function, as they show similar performance in EBP screening and are more suitable for large epidemiological studies because of their lower cost.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

RAF received a postgraduate scholarship from CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior).

- 1 Wang Y, Monteiro C, Popkin BM. Trends of obesity and underweight in older children and adolescents in the United States, Brazil, China, and Russia. *Am J Clin Nutr* 2002; **75**: 971–977.
- 2 Wang G, Dietz WH. Economic burden of obesity in youths aged 6–17 years: 1979–1999. *Pediatrics* 2002; **109**: 1195–1200.
- 3 Chiolerio A, Madeleine G, Gabriel A, Burnier M, Paccaud F, Bovet P. Prevalence of elevated blood pressure and association with overweight in children of a rapidly developing country. *J Hum Hypertens* 2007; **21**: 121–127.
- 4 Salvadori M, Sontrop JM, Garg AX, Truong J, Suri RS, Mahmud FH, Macnab JJ, Clark WF. Elevated blood pressure in relation to overweight and obesity among children in a rural Canadian community. *Pediatrics* 2008; **122**: 821–827.
- 5 McGavock JM, Torrance B, McGuire KA, Wozny P, Lewanczuk RZ. The relationship between weight gain and blood pressure in children and adolescents. *Am J Hypertens* 2007; **20**: 1038–1044.
- 6 Fernandes RA, Freitas Júnior IF, Codogno JS, Christofaro DG, Monteiro HL, Roberto Lopes DM. Resting heart rate is associated with blood pressure in male children and adolescents. *J Pediatr* 2011; **158**: 634–637.
- 7 Jafar TH, Islam M, Poulter N, Hatcher J, Schmid CH, Levey AS, Chaturvedi N. Children in South Asia have higher body mass-adjusted blood pressure levels than white children in the United States: a comparative study. *Circulation* 2005; **111**: 1291–1297.
- 8 Williams DP, Going SB, Lohman TG, Harsha DW, Srinivasan SR, Webber LS, Berenson GS. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. *Am J Public Health* 1992; **82**: 358–363.
- 9 Taylor RW, Jones IE, Williams SM, Goulding A. Body fat percentages measured by dual-energy X-ray absorptiometry corresponding to recently recommended body mass index cutoffs for overweight and obesity in children and adolescents aged 3–18 y. *Am J Clin Nutr* 2002; **76**: 1416–1421.
- 10 McCarthy HD, Cole TJ, Fry T, Jebb SA, Prentice AM. Body fat reference curves for children. *Int J Obes (Lond)* 2006; **30**: 598–602.
- 11 Norton K, Olds T. *Anthropometrica: A Textbook of body measurement for sports and health courses*. UNSW Press: New South Wales, 1996.
- 12 Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; **320**: 1–6.
- 13 Christofaro DG, Casonatto J, Polito MD, Cardoso JR, Fernandes R, Gerage AM, Guariglia DA, Oliveira AR. Evaluation of the Omron MX3 Plus monitor for blood pressure measurement in adolescents. *Eur J Pediatr* 2009; **168**: 1349–1354.
- 14 Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves JW, Hill MN, Jones DH, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Hypertension* 2005; **45**: 142–161.
- 15 National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* 2004; **114**: 555–576.
- 16 Moura AA, Silva MA, Ferraz MR, Rivera IR. Prevalence of high blood pressure in children and adolescents from the city of Maceió, Brazil. *J Pediatr (Rio J)* 2004; **80**: 35–40.
- 17 Kotsis V, Staboulis S, Papakatsika S, Rizos Z, Parati G. Mechanisms of obesity-induced hypertension. *Hypertens Res* 2010; **33**: 386–393.
- 18 Fernandes RA, Christofaro DG, Buonani C, Araujo LR, Kassab YK, Cardoso JR, Freitas Junior IF, Machado DR. The accuracy of national body fat cutoff levels in the prediction of elevated blood pressure among Brazilian male adolescents. *J Trop Pediatr* 2010; **56**: 208–209.
- 19 Fernandes RA, Rosa CS, Silva CB, Bueno DR, Oliveira AR, Freitas Junior IF. Accuracy of different body mass index cutoffs to predict excessive body fat and abdominal obesity in adolescents. *Rev Assoc Med Bras* 2007; **53**: 515–519.
- 20 Vitolo MR, Campagnolo PD, Barros ME, Gama CM, Ancona Lopez F. Evaluation of two classifications for overweight among Brazilian adolescents. *Rev Saude Publica* 2007; **41**: 653–656.
- 21 Neovius M, Rasmussen F. Evaluation of BMI-based classification of adolescent overweight and obesity: choice of percentage body fat cutoffs exerts a large influence. The COMPASS study. *Eur J Clin Nutr* 2008; **62**: 1201–1207.
- 22 Christofaro DG, Fernandes RA, Polito MD, Romanzini M, Ronque ER, Gobbo LA, Oliveira AR. A comparison between overweight cutoff points for detection of high blood pressure in adolescents. *J Pediatr (Rio J)* 2009; **85**: 353–358.
- 23 Okuda M, Sugiyama S, Kunitsugu I, Hinoda Y, Okuda Y, Shirabe K, Yoshitake N, Hobara T. Use of body mass index and percentage overweight cutoffs to screen Japanese children and adolescents for obesity-related risk factors. *J Epidemiol* 2010; **20**: 46–53.
- 24 Wells JC, Fuller NJ, Dewit O, Fewtrell MS, Elia M, Cole TJ. 4-component model of body composition in children: density and hydration of fat-free mass and comparison with simpler models. *Am J Clin Nutr* 1999; **69**: 904–912.