Body Mass Index and Waist Circumference as Markers of Arterial Hypertension in Adolescents

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Summary

Objective: To evaluate the sensitivity and specificity of anthropometric measurements of body fat in a sample of Brazilian adolescents for the prediction of hypertension.

Methods: The arterial blood pressure was measured on two visits in a sample of 456 students aged 12 to 17 years, from public and private schools of the Fonseca neighborhood, in Niterói, between 2003 and 2004. A subject was defined as hypertensive if he/she had systolic and diastolic pressures above the 95th percentile for sex, age and height. A questionnaire was applied and Body Mass Index (BMI) and waist circumference (WC) measurements were made.

Results: A statistically significant correlation was observed between hypertension and the cutoff points considered unfavorable, both for BMI and WC. The greatest association was with the cutoff point proposed for the Brazilian population. As to the BMI sensitivity used for American Black or White populations or for the Brazilian population, we found 52.4% to 57.1% and 52.4%, respectively. And BMI specificity was 69.3%, 70.0% and 80.88%, respectively. The sensitivity found in our sample, relative to the cutoff points for WC proposed for all American ethnic groups, was also low (45.0%) and specificity was a little higher (77.6% and 74.5%, respectively).

Conclusion: Existing American WC measurements showed low sensitivity and specificity for hypertension in our population. As to BMI, the available cutoff points also showed a low level of sensitivity. There is a need to establish body fat cutoff points that can provide a better prediction of cardiovascular risk.

Key words: Adolescents; prevalence; hypertension; obesity; abdominal circunference.

Introduction

Longitudinal studies have demonstrated that risk conditions present in childhood and adolescence tend to express in adult life (tracking). This is the case in hypertension[1], obesity[2], altered levels of HDL-C, triglycerides, and fasting glucose levels[3]. These factors tend to cluster, even in children[4,5]. Since the late 1990s, both the World Health Organization (WHO) and the National Heart, Lung, and Blood Institute (NHLBI) have proposed that abnormal body weight be classified according to the body mass index (BMI) and body fat distribution, measured by the abdominal circumference (AC) or the waist circumference (WC)[6,7]. As for these last two measurements, we observe that many authors use distinct terms in referring to the same measurement and evaluate in different locations, comparing incomparable results. The WHO recommends the use of the AC, taken at half-distance between the iliac crest and the lower rib cage rim, on the horizontal plane. The NHLBI prefers using the WC, measured at the highest portion of the right iliac crest. The guide for identification and treatment of obesity in adults, published in 1998, refers to several prospective studies showing that abdominal fat correlates with increased mortality rate and risk for diabetes, hyperlipidemia, hypertension, coronary artery disease, and cerebral and peripheral disease[8]. Some studies published at the same time demonstrated that the association between abdominal fat and hypertension[9], and intra-abdominal fat and cardiovascular risk[10], were also present in children. In spite of the need to establish cutoff points for risk prediction in children and adolescents, as to WC or AC, this was not proposed until 2004, although some articles reported percentile distributions in different populations[11]. So far, the cutoff points proposed for adults by the NHLBI[7] were used, with 88 centimeters for women and 102 centimeters for men as standards. In 2004, Katzmarzyk et al[11] compared the usefulness of the BMI and AC for predicting cardiovascular risk factor clustering. The authors concluded that the use of the BMI and AC among children and adolescents is clinically useful, and there are no differences in terms of risk predictions. The values identified for BMI were below the 85th percentile of the Center for Disease Control and Prevention (CDC) curve[12], and below other cutoff points for different populations, including Brazilian children and adolescents, as proposed by Sichieri and Allam[13]. Concurrently, Fernández et al[14] published an article presenting percentiles of WC in a representative sample of the American population, but not associating them to risk prediction. The objective of this present article was to assess the sensitivity and specificity of anthropometric body fat measurements in predicting hypertension in a sample of Brazilian adolescents. The following cutoff points were used: a) BMI proposed by

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Katzmarzyk et al[11], for the American population of Blacks and Whites, in order to discriminate cardiovascular risk clustering; b) BMI proposed for Brazilian overweight/obese adolescents by Sichieri and Allam[13]; and, c) WC, proposed by Fernandez for all ethnic groups, for the American population[14].

Methods

This study is part of a research project carried out in schools of the Fonseca neighborhood, in Niterói, Rio de Janeiro, from October 2003 to June 2004. This is a cross-section study in which male and female adolescents, aged 12 to 17 years, were assessed. The sample investigated was proportional to the number of students enrolled by age in all public and private schools of this neighborhood, which had 50 or more pupils enrolled in this age group as identified by the 2001 school census. Based on this census, all schools with 50 or more students enrolled from the 12-17-year age group were identified. These schools were visited, and the lists of students by age range and class served as a basis for the sample randomization of 480 students (400 plus 20% of losses), calculated for an 80% power and 5% statistical significance level. The goal was to identify the prevalence of 8%[15] of hypertension in the study population. A total of 4530 students was listed, with a variation of 14 to 20% per year of age. Of the total number enrolled in the schools, 456 pupils participated in the study. The 24 losses resulted from absences or refusals (three cases).

Data was gathered in two visits. On the first visit, a self-completed questionnaire was applied, and the first blood pressure measurement and anthropometric measurements were made; on the second visit, the second blood pressure measurement was made. Waist circumference was measured at the level of the iliac crest rim with a non-extensible tape measure with the subject in expiratory phase[16]. For height and waist dimensions, three measurements were taken for each student, using each average as an estimate. We considered as sexually mature a boy with axillary hair and a girl who had already experienced menarche[17].

For arterial hypertension determination, we used an Omrom Hem-711 model automatic blood pressure device, and the Omron 905 device, both validated according to international protocols[18]. Blood pressure measurements were taken three times on each clinical visit, with minimal intervals of one minute between one reading and another. Intervals between the two visits varied from 15 days to 3 months, according to the Fourth Arterial Hypertension Guideline, and three different cuff sizes were used[19]. The mean of the six measurements was used, three at each visit. Hypertensive adolescents were thus classified if they presented systolic arterial pressure (SAP) and diastolic arterial pressure (DAP) means greater than the 95th percentile for sex, age, and height, as proposed by the 4th Task Force[20].

Anthropometric measurements were made by a physician or a dietitian previously tested as to reliability of anthropometric measurements in a pilot study. Body Mass Index (BMI) was used, defined as the weight in kilograms divided by the height in square meters. Weight was measured using electronic scales (Filizola - model PL18 (Indústrias Filizola SA, São Paulo - SP, Brazil)). Weight was measured three consecutive times, with a scale calibration before each one. For height assessment, a plastic measuring tape was affixed to the wall and height was measured with the student in socks or barefoot, with heels together touching the wall and the subject's head on the horizontal plane, using a wooden angle ruler to locate the exact measurement on the tape measure. For both weight and height, the value used was the mean of the measurements taken. Arterial pressure measurements were taken by previously trained physicians or medical students. The unfavorable BMI conditions were as follows: a) above which, according to the study by Katzmarzyk et al[11], a greater likelihood of cardiovascular risk cluster (>3) was observed; b) above the 90th percentile, defined by Sichieri and Alam[13] as overweight/obese. For the WC, the unfavorable conditions were considered cutoff points above the 75th percentile, proposed by Fernández et al[14],for all ethnic groups. The 75th percentile was chosen for the waist measurement since the results for all ages studied were below those established for adults (102 cm for men and 88 cm for women) and because they are closest to those proposed by Katzmarzyk et al[11]. All participants aged 15 years or more signed the informed consent form, and participants aged 12 to 14 years brought consent forms signed by their parents or guardians. The study was approved by the Research Ethics Committee of the *Hospital Universitário Antônio Pedro - Universidade Federal Fluminense*.

In the statistical analysis, prevalence of hypertension and the respective intervals were estimated, with a 95% confidence interval. Sensitivity, specificity, and accuracy for prediction of hypertension (SAP and DAP), of the different cutoff points for BMI and WC considered unfavorable and the 95% confidence intervals were calculated according to the following formula[21]: $p \pm 1.96 \times \text{sqrt}[p(1-p)/n]$, where p = prevalence, sqrt = square root, n = total population.

Data were analyzed with the EpiInfo software, version 3.2, public domain (CDC).

Results

Of the total 456 adolescents investigated, 55.5% were girls and 44.5% were boys; 48.2% were aged between 12 and 14 years, and 51.8% were between 15 and 17 years. Of the total number studied, 83.6% were classified as sexually mature, that is, 88.1% of the girls and 78.0% of the boys. Of the total sample, 71.7% studied in public schools and 28.3% in private schools.

The mean prevalence of arterial hypertension for both sexes was 4.6; in that, 5.9 in boys and 3.6 in girls. The prevalence of systolic arterial hypertension was slightly higher than diastolic arterial hypertension among boys, and the diastolic pressure was higher among girls, although this difference was not statistically significant (Table 1).

In the sample studied, Person's correlation between BMI and the WC was 0.889, significant at 0.001 (Figure 1).

There was a statistically significant association between hypertension and the cutoff points considered unfavorable both for BMI and for WC. All prevalence ratios were greater than 1, and none of the confidence intervals included the unit. The greatest correlation seen was with the cutoff point

Table 1 - Prevalence of hypertension* by sex. Students enrolled in schools in the Fonseca neighborhood, aged 12-17 years - 2003-2004

Arterial blood pressure	Total	Male	Female
>P95 SAP 2004			
No	14	9	5
% (95% CI)	3.1 (1.8 - 5.2)	4.4 (2.0 - 8.2)	2.0 (0.6 - 4.5)
>P95 DAP 2004			
No	10	3	7
% (95% CI)	2.2 (1.1 - 4.1)	1.5 (0.3 - 4.3)	2.8 (1.1 - 5.6)
>P95 SAP or DAP 2004			
No	21	12	9
% (95% CI)	4.6 (2.9 - 7.1)	5.9 (3.1 - 10.1)	3.6 (1.6 - 6.6)

** (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004).*

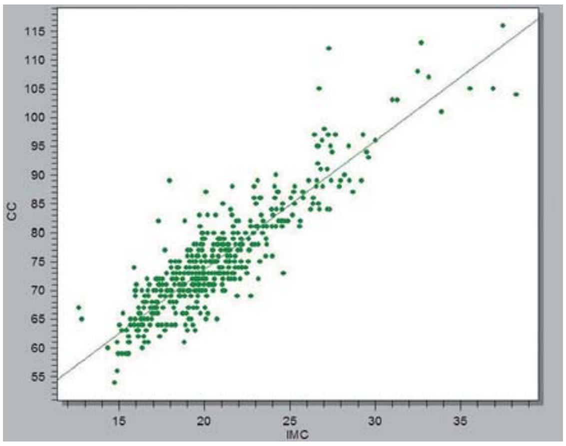

Fig. 1 - *Diagram and dispersion between WC and BMI. Adolescents aged 12-17 years enrolled in schools of the Fonseca neighborhood - 2003-2004.*

proposed for the Brazilian population (Table 2).

Sensitivity for predicting hypertension by anthropometric measurement cutoff points varied between 45.0% and 57.1%, and specificity varied between 80.9% and 69.3%. Accuracy, considering the BMI cutoff point proposed for Brazilians (66.6%), was 10% superior to that proposed for American Black or White populations (60.9%) (Table 3).

Discussion

The accuracy of BMI cutoff points, proposed for predicting cardiovascular risks for American Black and White adolescents, or those proposed for defining overweight/obese Brazilian adolescents, did not prove useful in predicting hypertension in students of a multiracial Brazilian community comprised of different socioeconomic brackets. Sensitivity values for BMI for the American Black or White populations, or for the Brazilian population (52.4% to 57.1% and 52.4%, respectively), were inferior to those found for the population of Bogalusa (67% to 74%). Specificity was closer (69.3%, 70.0%, and 80.88%, respectively, *versus* 66.8% to 73.6%)[11].

The level of sensitivity found in our sample, relative to WC cutoff points proposed for American ethnic groups, was also low (45%), inferior to that found by the American study (67.5%)[14], and specificity was a little higher (77.6% and 74.5%, respectively).

Even though the association (prevalence ratio) between hypertension and overweight/obesity with the cutoff points proposed for the Brazilian population was strong (4.2), and higher than what had been observed when considering the cutoff points proposed for the American population (2.38 and 2.94), the sensitivity of the first proposal was near 50%.

The importance to establish cutoff points for anthropometric measurements of central adiposity was reinforced with the study performed by Yusuf et al[22], published in November 2005. These authors showed that, similar to the Interheart study population, measurements of central obesity (waist/hip ratio and AC) show a strong correlation with occurrence of acute myocardial infarct. This concern extends to children and adolescents since there is evidence that obesity and remaining cardiovascular risk factors tend to cluster, even in childhood, and remain until adulthood.

Brazil is the American country with the greatest population of African ancestors. Miscegenation is a part of the Brazilian history[23]. As such, the establishment of anthropometric standards for the Brazilian population needs to take into account references of the population as a whole, with no ethnic distinctions, which does not happen in population studies of other countries. Since the cutoff points proposed by Katzmarzyk et al[11] take into consideration populations of Black and White Americans separately, in the present study we opted for testing anthropometric parameters of both populations, and the WC for all ethnic groups[14] given the absence of population references for waist measurements in the Brazilian population.

We aimed to examine the correlation between BMI and WC in order to exclude the possibility of greater failures in measuring these parameters. The association observed was close to that described by Iwao et al[24] for adult women and men (0.84 and 0.88, respectively). The prevalence of hypertension estimated was similar to that found by Rosner[25] in a study of American populations from 1979 to

Table 2 - Prevalence ratio (PR) of arterial hypertension (SAP and/or DAP) for BMI and WC in cutoff points considered unfavorable*. Adolescents aged 12-17 years, enrolled in schools in the Fonseca neighborhood - 2003-2004

Variable (number)	SAP and/or DAP >95	SAP and/or DAP <=p95	Prevalence ratio (95% CI)
BMI for black			
Unfavorable	11	133	2.38 (1.03-5.47)
Favorable	10	301	
BMI for white			
Unfavorable	12	130	2.94 (1.27-2.82)
Favorable	9	304	
BMI for brazilian			
Unfavorable	11	83	4.22 (1.85-9.65)
Favorable	10	351	
WC for all ethnic groups			
Unfavorable	9	97	2.66 (1.13-6.25)
Favorable	11	334	

** According to cutoff points proposed for BMI for the American population by Katzmarzyk et al (2004) and for the Brazilian population, by Sichieri and Allam (1996). For WC, Fernández et al was used (2004).*

Table 3 - Estimated values and confidence intervals of sensibility, specificity of cutoff points considered unfavorable for BMI* and WC*, to predict hypertension. Adolescents aged 12-17 years, enrolled in schools in the Fonseca neighborhood - 2003-2004

Anthropometric measures (unfavorable cutoff points)	Estimated value (%)	95% confidence interval	
		Lower limit (%)	Upper limit (%)
BMI for black			
Sensitivity	52.38	30.34	73.61
Specificity	69.35	64.74	73.62
Accuracy	60.87	47.54	73.61
BMI for white			
Sensitivity	57.14	34.44	77.41
Specificity	70.05	65.46	74.27
Accuracy	63.59	49.95	75.84
BMI for brazilian			
Sensitivity	52.38	30.34	73.61
Specificity	80.88	76.79	84.40
Accuracy	66.63	53.56	79.01
WC for all ethnic groups			
Sensitivity	45.00	23.83	67.95
Specificity	77.49	73.20	81.29
Accuracy	61.24	48.51	74.62

** According to cutoff points proposed for BMI for the American population by Katzmarzyk et al (2004) and for the Brazilian population, by Sichieri and Allam (1996). For WC, Fernández et al was used (2004).*

1996, in non-obese individuals (between 2.9 and 4.2% for systolic hypertension and between 2.4% and 3% for diastolic hypertension). Thus, it could be expected that, in principle, the measurements proposed for the American population would be useful to compare the population we investigated, which did not happen.

Today we recognize that adipose tissue has multiple important functions in regulating the energy and metabolic balance. The greatest negative impact of visceral fat has been attributed to the distinct biological properties of this deposit in relation to the deposits in other tissues[26]. The association between obesity and blood pressure is explained by other mechanisms and its relation with the functional activity of adipocytes is not yet clear. The waist circumference measurement alone cannot discriminate between visceral and subcutaneous fat. Nevertheless, research supports the idea that individuals with large waist circumferences have a greater probability of experiencing hypertension, diabetes, dyslipidemia and metabolic syndrome, adding information to data provided by the BMI[24,27]. Investigations with more precise measurements of fat showed that the associations between intra-abdominal fat and several metabolic disorders begin in childhood[28].

The need to establish cutoff points for central adiposity, expressed by AC, WC, or the waist/hip ratio is evident. Even so, we did not find any article proposing these cutoff points for the Brazilian population. The existing American measurements for WC show low sensitivity and specificity for hypertension in our population. As to the BMI, the cutoff points available also demonstrated low sensitivity.

This study has several limitations. The sample covers a narrow age bracket (12 to 17 years), and does not include children. It only takes in one neighborhood of a medium-size Brazilian city. No biochemical tests were available for constructing a more encompassing cardiovascular risk indicator, and lastly, measurements of AC and waist/hip ratios were not available. In spite of all these restrictions, the need to conduct a study to identify more accurate cutoff points for predicting hypertension and other cardiovascular risks is patent. The waist measurement may be incorporated into life habits, and become an indicator of cardiovascular health for populations of children, adolescents, and adults. Changes in lifestyle, achieved through public policies of health promotion seeking to reach the population indiscriminately, may be accompanied by more focused actions, in order to use more specific approaches for segments of the population with greater risks.

References

1. Lauer RM, Clarke WR. Childhood risk factors for high adult blood pressure: the Muscatine Study. Pediatrics. 2004; 84: 633-41.
2. Freedman DS, Khan LK, Serdula MK, Dietz WH, Srivasan SR, Berenson GS. The relation of childhood BMI to adult adiposity: the Bogalusa Heart Study. Pediatrics. 2005; 115: 22-7.
3. Goran MI, Gower BA. Abdominal obesity and cardiovascular risk in children. Coron Artery Dis. 1998; 9: 483-7.
4. Katzmarzyk PT, Pérusse L, Malina RM, Bergeron J, Després JP, Bouchard C. Stability of indicators of the metabolic syndrome from childhood and adolescence to young adulthood: the Québec family study. J Clin Epidemiol. 2001; 54: 190-5.
5. Power C, Lake JK, Cole TJ. Measurement and long-term health risks of child and adolescent fatness. Int J Obes. 1997; 21: 507-26.
6. Katzmarzyk PT, Tremblay A, Pérusse L, Després JP, Bouchard C. The utility of the international child and adolescent overweight guidelines for predicting coronary heart disease risk factors. J Clin Epidemiol. 2003; 56: 456-62.
7. World Health Organization Consultation on Obesity. Obesity: Preventing and Managing the Global Epidemic. Geneva, Switzerland: Division of Non Communicable Diseases, Program of Nutrition, Family and Reproductive Health, World Health Organization; 1998.
8. National Institutes of Health (NIH). National Heart, Lung, and Blood Institute. Obesity Education Initiative Expert Panel. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults – The Evidence Report. Obes Res. 1998; 6: 51S-209S.
9. Lurbe E, Alvarez V, Liao Y, Tacons J, Cooper R, Cremades B, et al. The impact of obesity and body fat distribution on ambulatory blood pressure in children and adolescents. Am J Hypertens. 1998; 11 (4Pt1): 418-24.
10. Owens S, Gutin B, Ferguson M, Allison J, Karp W, Le NA. Visceral adipose tissue and cardiovascular risk factors in obese children. J Pediatr. 1998; 133: 41-5.
11. Katzmarzyk PT, Sathanur R, Srinivasan WC, Malina RM, Bouchar C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. Pediatrics. 2004; 114: 198-205.
12. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat. 2002; 246: 1-190.
13. Sichieri R, Allam VC. Avaliação do estado nutricional de adolescentes brasileiros através do índice de massa corporal. J Pediatr (Rio J.). 1996; 72 (2): 80-4.
14. Fernández JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. J Pediatr. 2004;145 (4): 439-44.
15. Brandão AP, Ferreira JO, Brandão AA, Pozzan R, Cerqueira RO. Avaliação da pressão arterial em crianças e adolescentes: estudo do Rio de Janeiro. HiperAtivo. 1996; 2: 86-92.
16. NHLBI Obesity Education Initiative. The practical guide. Identification, evaluation, and treatment of overweight and obesity in adults. NIH publication 2000. Number 00-4084. [acesso em 2005 jul 05]. Disponível em: <http://www.nhlbi.nih.gov/guidelines/obesity/prctgd_b.pdf.
17. Fonseca VM, Sichieri R, da Veiga GV. Fatores associados à obesidade em adolescentes. Rev Saude Publica. 1998; 32 (6): 541-9.
18. O'Brien E, Beevers G, Lip GY. ABC of hypertension: blood pressure measurement. Part IV: automated sphygmomanometry: self blood pressure measurement. BMJ. 2001;322(7295):1167-70.
19. IV Diretrizes Brasileiras de Hipertensão Arterial. Arq Bras Cardiol. 2002; 78 (supl. 1): 1-40.
20. 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 (2): 555-76.
21. Newcombe RG. Two-sided confidence intervals for the single proportion: comparison of seven methods. Stat Med. 1998; 17: 857-72.
22. Yusuf S, Hawken S, Ounpuu S, Bautista L, Franzosi MG, Commerford P, et al., and the INTERHEART Study Investigators. Obesity and the risk of myocardial infarction in 27,000 participants from 52 countries: a case-control study. Lancet. 2005; 366 (9497): 1640-9.
23. Travassos C, Williams DR. The concept and measurement of race and their relationship to public health: a review focused on Brazil and the United States. Cad Saude Publica. 2004; 20 (3): 660-78.
24. Iwao S, Iwao N, Muller D, Elahi D, Shimokata H, Andrés R. Does waist circumference add to the predictive power of the body mass index of coronary disease? Obes Res. 2001; 9: 685-95.

25. Rosner B, Prineas R, Daniels SR, Loggie J. Blood pressure differences between blacks and whites in relation to body size among US children and adolescents. Am J Epidemiol. 2000; 151 (10): 1007-19.

26. Giorgino F, Laviola L, Eriksson JW. Regional differences of insulin action in adipose tissue: insights from in vivo and in vitro studies. Acta Physiol Scand. 2005; 183 (1): 13-30.

27. Gus M, Fuchs SC, Moreira LB, Moraes RS, Wiehe M, Silva AF, et al. Association between different measurements of obesity and the incidence of hypertension. Am J Hypertens. 2004; 17: 50-3.

28. Okosun IS, Liao Y, Rotimi CN, Prewitt TE, Cooper RS. Abdominal adiposity and clustering of multiple metabolic syndrome in White, Black and Hispanic Americans. Ann Epidemiol. 2000; 10: 263-70.