Blood Pressure: Effect of Body Mass Index and of Waist Circumference on Adolescents

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Summary

Background: Increased body mass index (BMI) and waist circumference (WC) have been associated with blood pressure elevation.

Objective: To evaluate the effect of BMI and WC on blood pressure (BP) of adolescents.

Methods: Cross-sectional analytical study including 536 adolescents from public and private schools. BMI was calculated and classified as high-normal (≥ 50th p and < 85th p), overweight (≥ 85th p and < 95th p), and obesity (≥ 95th p). WC was measured and considered increased if > 75th p. BP was considered elevated if > 90th p.

Results: 319 (59.5%) adolescents were girls, the mean age was 14.0±1.99 years, high-normal weight was found in 39.6%, overweight in 37.1% and obesity in 23.3%. The percentage of high SBP and DBP followed the increase in BMI (p=0.000), reaching 46.4% among boys and 39.3% among obese girls for SBP and 42.0% and 44.6% for DBP, respectively. High SBP and DBP were 3.9 and 3.4 times more frequent among boys and 2.2 to 2.0 times more frequent among girls with WC > 75th p, respectively. Using simple linear regression analysis, each increment in BMI would increase SBP by 1.198 mmHg, and in WC by 0.622 mmHg. The prevalence ratio (PR) for elevated SBP and DBP in relation to BMI ≥ 85th p was 3.9 (95% CI 2.0-7.4[p=0.000]) and 4.3(95% CI 2.2-8.5[p=0.000]), respectively; in relation to WC > 75th p was 1.8(95% CI 1.0 to 3.0 [p=0.036]) and 1.4 (95% CI 0.8 to 2.4). BP > 90th p with WC ≤ 75th p was found in 16/181 (8.8%) of the adolescents with high-normal weight.

Conclusion: BMI and WC values have a strong influence on BP values in adolescents. (Arq Bras Cardiol 2008; 90(6): 393-399)

Key words: Adolescent, hypertension, obesity, waist circumference.

Introduction

The prevalence of overweight/obesity has increased, affecting all age ranges including the pediatric population[1]. In the United States, between the third (1994) and fourth (2002) NHANES, the number of overweight/obese children and adolescents aged from six to 19 years increased by 45%[2]. In Salvador, BA, where this study was conducted, previous data showed 13.1% of obesity in a sample of schoolchildren[3].

The relevance of the problem is even greater in view of the fact that childhood and youth obesity shows a strong association with the presence of high blood pressure (BP) and is identified as an important predictor of hypertension and obesity in adulthood[4-6]. In both age ranges, obesity is associated with the presence of cardiovascular risk factors such as hypertension, dislipidemia, insulin resistance and type-2 diabetes, in addition to leading to social and psychological problems[7]. Approximately 60% of those who present obesity in the first decades will have at least one of these metabolic alterations in adulthood[8].

Body mass index (BMI) is a parameter for weight classification as normal, overweight and obesity, whereas waist circumference (WC) is the main indicator of abdominal fat accumulation with which the same risk factors related to obesity are frequently associated[9]. Thus, these are two important methods for the diagnosis of overweight/obesity and of central obesity both in epidemiological studies and in the clinical practice[10,11], because they are precise, reproducible, and easy to perform[12].

In Brazil, studies regarding the effects of BMI and WC on BP in adolescents are still scarce. A recent study shows a low sensitivity of the cut-off points of these variables in detecting hypertension in adolescents[13]. However, studies like this, with a sample that enables the comparison of BP values according to the weight status and WC values, certainly contribute to provide data that show the gradual increase of the association of weight and increased WC with elevated BP. This should be considered by pediatricians and pediatric cardiologists as a prehypertensive state, thus deserving greater care in its

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Manuscript received July 11, 2007; revised manuscript received November 21, 2007; accepted December 20, 2007.

identification, prevention and treatment. Thus, the objective of this study was to evaluate the effect of BMI and WC on BP in a sample of adolescents in the city of Salvador, Bahia.

Methods

The target population was comprised of healthy adolescents aged between 11 and 18 years who were enrolled in public and private schools of the city of Salvador, and were participating in a study on weight status and cardiovascular risk factors, with special emphasis on the presence of insulin resistance.

Because of the convenient number of students, access to the study and structural facilities for the determination of the variables proposed, three private and four public schools located in a middle-class neighborhood were selected.

The project followed the standards of the National Commission (Council) on Research Ethics (CONEP, resolution 196/1996) and was approved by the Research Ethics Committee of *Maternidade Climério de Oliveira* – UFBA.

Preliminarily, awareness seminars on the importance of detecting cardiovascular risk factors in the pediatric population were held. Among the students who agreed to participate in the study and who provided the written informed consent signed by their legal representatives, those with BMI greater than or equal to the 50th percentile for age and gender were selected. The group of normal-weight individuals was in the range between the 50th and 84th percentiles, the group of overweight individuals was between the 85th and 94th percentiles, and the group of obese individuals was in the range greater than or equal to the 95th percentile. The BMI range of this normal-weight group has been considered high-normal because it has an increased risk of overweight/obesity and hypertension in young adulthood. The selection was thus made to enable a better comparison between the groups defined by weight status[6]. The final sample was comprised of 536 students, 143 (27%) of whom from private schools and 393 (73%) from public schools. The study was conducted between May 2005 and November 2006.

The clinical assessment of the students included:

The following anthropometric measurements

Height, weight, waist circumference, and body mass index (BMI). The measurements were taken by the first investigator, with the help of medical students previously tested as regards the reliability of anthropometric measurements in a pilot study, with the adolescents barefoot and wearing light clothing. Height was measured with a stadiometer (Leicester) to the nearest 0.1cm, and weight was measured on a digital scale to the nearest 0.1 Kg. BMI was calculated using the Quetelet index (kg/m^2) and was classified according to age and gender as high-normal (≥ 50th p and < 85th p), overweight (≥ 85th p and < 95th p) and obesity (≥ 95th p)[6,14]. WC was measured half way between the lower border of the last rib and the upper border of the iliac crest at the end of a normal expiration, using a non-stretchable tape measure. The arithmetic mean of two measurements was considered for the analysis. Central obesity was defined as WC > 75th p for age and gender, as proposed by Ferranti et al[15] and Fernandez et al[16].

Blood pressure was measured after a 5-minute rest, with the patient in the sitting position, in the right upper limb supported at the height of the heart, using a Missouri mercury column sphygmomanometer. Cuffs with width of 40% of the arm circumference as measured at the midpoint between the elbow and the acromion, and length of 80 to 100% of this measure were used. The mean of three consecutive readings taken at 60-second intervals was recorded.

Systolic blood pressure (SBP) was determined at Korotkoff phase I and diastolic blood pressure (SBP) at Korotkoff phase V. BP values were classified according to the Task Force on High Blood Pressure in Children and Adolescents from the National High Blood Pressure Education Program[17] as normal (< 90th p), high normal (≥ 90th p and < 95th p), and hypertension (≥ 95th p), considering age, gender and height. BP values ≥ 90th p were considered high according to age, gender and height percentile.

Statistical analysis

Continuous variables were expressed as mean and standard deviation. Normality of variable distribution was assessed using the Shapiro-Wilk test. Categorical variables were expressed as percentages.

Statistical tests

The comparison between genders of the means of the age, weight, height, BMI, WC, SBP and DBP variables was made using the Student's t test for independent samples. Comparison of percentages of the BMI, WC, SBP and DBP categorized variables was made using the Pearson's chi-square test. The comparison of the means of three or more continuous variables was made using ANOVA and between two means of the same variable using Bonferroni post-test. The analysis of the significance of the influence of the BMI and WC predictive variables on the SBP and DBP endpoint variables, respectively, was made using simple linear regression analysis, and its prevalence ratio (PR) was calculated using multiple logistic regression analysis.

P values lower than 5% ($p<0.05$) were considered significant.

Data were analyzed using the Stata 8.0 software (Stata, College Station, TX).

RESULTS

The main demographic, anthropometric and clinical characteristics of the sample of 536 adolescents are shown in Table 1. A total of 217 (40.5%) boys and 391 (59.9%) girls were studied, and this difference was significant (p=0.000). Students from public schools had a slightly but statistically significant higher mean age (14.2±1.90 *versus* 13.5±2.10, p=0.001); significant predominance of non-white individuals (79.7 *versus* 20.3; 78.6 *versus* 21.4; p=0.001, respectively); and significantly higher BMI, WC and DBP values (p=0.000). As regards weight status, the high-normal group significantly predominated in private schools (55.9%; p=0.000), whereas no significant difference was found in public schools.

Table 1 - Demographic, anthropometric and clinical characteristics of a sample of adolescents according to the school attended

Variables	Total	Private	Public
N	536	143 (27%)	393 (73%)
Age, mean± sd	14.0 ± 1.99	13.5±2.1	14.2±1.9§
Gender, N(%)			
Male	217 (40.5)	77 (53.8)†	140 (35.6)
Female	319 (59.5)*	66 (46.2)	253 (64.4)‡
Skin color, N(%)			
White	198 (36.9)	114 (79.7)†	84 (21.4)
Non-white	338 (73.1)*	26 (20.3)	309 (78.6)‡
Anthropometric data, N(%)			
WC > P75th	277 (51.7)	64 (44.8)	213 (54.2)
BMI			
High-normal	212 (39.6)	80 (55.9)†	132 (33.6)
Overweight	198 (36.9)	38 (26.6)	160 (40.7)
Obese	126 (23.5)	25 (17.6)	101 (25.7)
SBP > 90th p	109 (20.4)	23 (16.1)	86 (21.9)
DBP > 90th p	94 (17.6)	15 (10.5)	79 (20.1)
Anthropometric data, mean± sd			
BMI	24.7±4.7	23.3±3.8	25.3±4.9§
WC	80.6±10.2	78.1±11.0	81.5±9.8**
SBP	111.1±12.9	109.8±11.4	111.5±13.4
DBP	70.3±9.3	66.4±9.6	71.6±8.8§

**Total: male x female, white x non-white, p= 0.000; †Private school: male x female, white x non-white, high-normal x overweight x obese, p= 0.000; ‡ Public school: male x female, white x non-white, p= 0.000. P value along the line – Private School x Public School: §Age, BMI, DBP, p= 0.000; WC, **p=0.001; BMI – body mass index; WC – waist circumference; SBP - systolic blood pressure; DBP - diastolic blood pressure.*

SBP changes according to weight status and gender are shown in Table 2. A total of 212 (39.6%) high-normal weight, 199 (37.1%) overweight and 125 (23.3%) obese adolescents were compared. A significant (p=0.000) increasing positive gradient of the elevated BP percentage was observed among high-normal weight and overweight adolescents, as well as between overweight and obese adolescents. SBP was elevated in 46.4% of the obese boys and in 39.3% of the obese girls, and DBP was elevated in 42.0% and 44.0%, respectively. The result of the simple linear regression analysis of SBP values in relation to BMI values (Figure 1) shows the strength of the influence of BMI on SBP, r=0.436 (p=0.000), with a beta coefficient of 1.198, thus indicating that for each one-unit increase in BMI, SBP would increase by 1.198 mmHg.

SBP changes according to WC and gender are shown in Table 3. The percentage of adolescents with high SBP and

Table 2 - Percentage distribution of normal and abnormal values of blood pressure according to weight status and gender

N=536	Hight normal (212[39.6])*		Overweight (199[37.1])*		Obese (125[23.3])*	
SBP	**Normal**	**Alterada**	**Normal**	**Alterada**	**Normal**	**Alterada**
Total	196 (92.4)	16 (7.6)	153 (76.9)	46§ (23.1)	71 (56.8)	54 (43.2)‡
Male	73 (89.0)	09 (11.0)	48 (72.7)	18 (27.3)	37 (53.6)	32 (46.4)‡
Fem	123 (94.6)	07 (5.4)	105 (79.0)	28 (21.0)	34 (60.7)	22 (39.3)‡
DBP	**Normal**	**Abnormal**	**Normal**	**Abnormal**	**Normal**	**Abnormal**
Total	198 (93.4)	14(6.6)	165 (82.9)	34§(17.1)	71 (56.8)	54 (43.2)‡
Male	72.(87.8)	10 (12.2)	57 (86.4)	09 (13.6)	40 (58.0)	29 (42.0)‡
Fem	126 (96.9)	04 (3.1)	108 (81.2)	25 (18.8)	31 (55.4)	25 (44.6)‡

**Data: (N [%]); ‡ P= 0.000 (high-normal versus overweight versus obese); SBP – systolic blood pressure; DBP – diastolic blood pressure.*

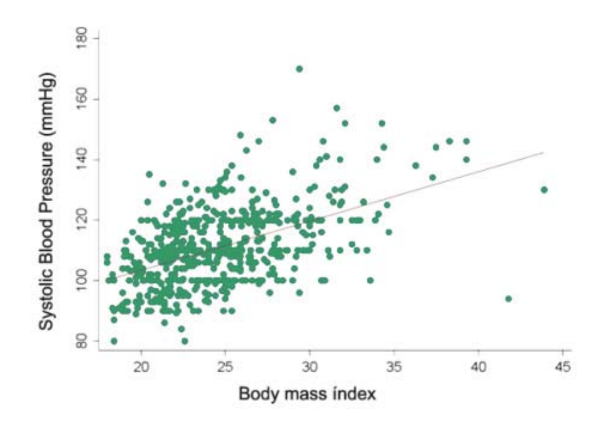

Figure. 1 - Simple linear regression of systolic blood pressure (SBP) in relation to body mass index (BMI) in a sample of 536 adolescents (r = 0.436; p=0.000; Beta coef. = 1.198).

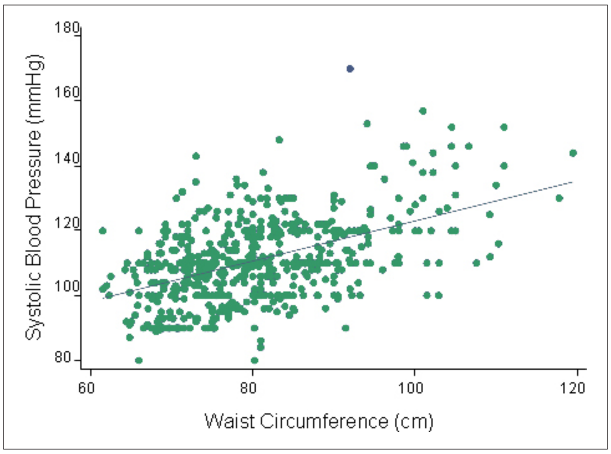

Figure 2 - Simple linear regression of systolic blood pressure (SBP) in relation to waist circumference (WC) in a sample of 536 adolescents (r= 0.493; p=0.000; Beta coef. = 0.622).

Table 3 - **Percentage distribution of normal and abnormal values of blood pressure according to waist circumference and gender**

	WC ≤ 75th p†		WC > 75th p	
SBP	**Normal**	**Abnormal**	**Normal**	**Abnormal**
Total	230 (88.5)	30 (11.5)	190 (68.8)	86 (31.2)
Male	75 (86.2)	12 (13.8)*	83 (63.8)	47 (36.2)*
Female	155 (89.6)	18 (10.4)*	107 (73.3)	39 (26.7)*
DBP				
Total	231 (88.8)	29 (11.2)	203 (73.6)	73 (26.2)
Male	76 (87.4)	11 (12.6)**	93 (71.5)	37 (28.5)**
Female	155 (89.6)	18 (10.4)**	110 (75.3)	36 (24.7)**

*Data - N (%) *SBP (WC ≤75 versus WC>75) - M, p=0.0002; F, p=0.0001; **DBP (WC ≤75 versus WC>75) - M, p=0.0059; F, p=0.0007; † Total of adolescents with high-normal weight status with BP > 90th p and WC ≤ 75th p - 16/181 (8.8%) (high SBP in 6, high DBP in 2 and both high SBP and DBP in 8); total of overweight individuals with BP > 90th p and WC ≤ 75th p - 24/78 (30.8%) (high SBP in 5, high DBP in 8 and both high SBP and DBP in 11); WC - waist circumference; SBP - systolic blood pressure; DBP - diastolic blood pressure.*

DBP was significantly higher among those with increased WC (> 75th p) in both genders. In the male gender, however, BP elevation in the presence of central obesity was 3.9 (SBP) to 3.4 (DBP) times more frequent than in those with WC ≤ 75th p, in contrast with frequencies 2.2 (SBP) to 2.0 (DBP) times higher in the female gender. The beta coefficient of 0.622 of the simple linear regression analysis (r=0.493; p=0.000) showed that for each 1-cm increase in WC, SBP would increase by 0.622mmHg (Figure 2). Along the regression line, it is worth pointing out the finding of 8.8% (16/181) high-normal weight adolescents and 30.8% (24/78) overweight adolescents who presented elevated SBP (> 90th p) associated with normal WC values (≤ 75th p).

Using multiple logistic regression, PR values for high SBP and DBP associated with values of BMI ≥ 85th p were 3.9 (95% CI 2.0-7.4 [p=0.000]) and 4.3 (95% CI 2.2-8.5 [p=0.000]), respectively, after age and skin color adjustment. When associated with WC > 75th p, these values were 1.8(95% CI 1.0-3.0 [p=0.036]) and 1.4 (95% CI 0.8-2.4 [NS]), respectively (Table 4).

Discussion

The present study showed a significant association of weight gain and abdominal fat concentration with blood pressure elevation in adolescents of both genders (Tables 2 and 3), thus corroborating data from other studies that showed that increased BMI and WC are good predictors of the risk of development of hypertension in adolescents[8,9,18,19]. The data also confirm the importance of excess abdominal fat in the pathogenesis of hypertension, whether directly associated with the metabolic characteristics of adipocytes located in this region and their relationships with RAAS stimulation, or indirectly via the hyperinsulinemia resulting from insulin resistance due to alterations in the cell mechanism of glucose metabolization[7,8].

These findings also show the importance of determining these two variables in the cardiometabolic risk assessment, and reinforce two important points in risk stratification of hypertension in adolescents. The first is the presence of central obesity as an indicator of a higher probability of

Table 4 - **Multiple logistic regression with systolic and diastolic blood pressures as dependent variables**

	SBP		DBP	
	PR	**95% CI**	**PR**	**95% CI**
BMI (non-adjusted)	4.0*	2.1-7.8	4.2*	2.1-8.4
BMI §(adjusted)	3.9*	2.0-7.4	4.3*	2.2-8.5
WC (non- adjusted)	1.6	1.0-2.8	1.4	0.8-2.3
WC §(adjusted)	1.8**	1.0-3.0	1.4	0.8-2.4

*§ Gender and skin color-adjusted; *p=0.000; **p=0.036; BMI – body mass index; WC – waist circumference; PR - prevalence ratio.*

elevated BP in the presence of a weight status ≥ 85th p. The second is the finding of 8.8% of adolescents with elevated BP and normal WC (WC ≤ 75th p) within the range of high-normal weight status. In the second case, it is evident that BMI between the 50th and 85th percentiles results in risk of elevated BP even in the absence of increased WC, thus indicating the need for closer surveillance as regards the BP of these adolescents. This observation is in accordance with the behavior of other biological parameters such as blood glucose and cholesterol, whose epidemiological risk is distributed along an ascending curve, thus showing that more important than the categorized classification is the distribution of values in relation to the possible risk that they may cause. In these adolescents, the relation of weight and abdominal fat accumulation with blood pressure levels is positive and continuous, as shown in the regression line of SBP in relation to BMI and WC (Figures 1 and 2); also, the risk of alteration is expected to increase as the values get closer to the cut-off point considered. These findings are similar to those of Berkey et al's[20] in adults and of Wilson et al's[21] and Moussa et al's[22] in children and adolescents.

This biologic paradigm underscores the importance of the classification of the BMI range between the 50th and 85th percentiles as a high-normal range – intermediate risk range, in which a cohort study showed that adolescents present a high risk of obesity and systolic hypertension in young adulthood[6]. This BMI range in adolescents would be similar to the grey zone of prehypertension proposed by the VII Joint National Committee for adults with pressure levels between 120/80 and 139/89 mmHg[23].

In relation to the WC cut-off point, it is also necessary to consider that the value currently used in this study may underestimate the degree of central obesity, since it is based on values obtained from American adolescents, whose anthropometric data are different from ours[24]. In this age range, there is still no value established for waist circumference from which the presence of increased visceral fat could be diagnosed. Taylor et al[25] proposed the use of the 80th p, since this cut-off point showed better sensitivity and specificity in relation to the assessment of central adiposity, using dual energy X-ray absorptiometry (DEXA) as the gold standard. On the other hand, in NHANES III, the values estimated using the 90th p as the cut-off point as already used in other studies[4-9] exceeded the values recommended for adults[26] in adolescents as from 14 years of age, thus suggesting that lower cut-off points should be used. Ferranti et al[15] studied the presence of metabolic syndrome among adolescents and suggested the use of the 75th p as the cut-off point, as we did in the present study, by identifying the values corresponding to those used in adults[16,26]. Thus, the optimal cut-off point values for BMI and WC would be those less associated with abnormal values of the metabolic syndrome components. These considerations show the need for the determination of WC cut-off points in Brazilian pediatric populations. However, we should also consider that a "normal" WC does not rule out the existence of excess intraabdominal fat in these adolescents, not yet detected by abdominal perimeter measurement, and that this fat has a more intense metabolic activity in terms of production of adipocytokines, and also that an insulin resistance state already exists, thus leading to increased BP, especially if inherited factors for hypertension coexist. Adolescents with this profile should undergo more sophisticated metabolic studies and be followed up. Meanwhile, the message to be conveyed is that in the high-normal BMI range, 50th p ≥ BMI < 85th p, it is necessary to evaluate adolescents both clinically and metabolically, even if their WC is considered normal.

Finally, with the purpose of better validating the current findings in terms of representativeness, some considerations on the sample studied are necessary. In this sample, there was a predominance of non-white (78.6 *versus* 20.3%, p=0.000) students from public schools (3.7 for each student from private school), thus making it more representative of the ethnical and social characteristics of Salvador, although it is a stratified sample due to the location of the public schools in middle and upper-class neighborhoods, therefore with a better qualified student population from the socioeconomic point of view than those from public schools on the outskirts of Salvador. The predominance of girls (59.5% *versus* 40.5%, p=0.000) in this population stands out, as well as the more homogeneous distribution according to weight status, unlike that observed among students from private schools, in whom there was a predominance of high-normal weight individuals (55.9%; p=0.000). Additionally, we should point out that the mean BMI, WC and DBP values were significantly higher among students from public schools. Based on these findings, we can assume that overweight/obese adolescents from public schools were more responsive to the study recruitment, and were more homogeneously interested in being evaluated. This being the case, this latter aspect may be useful for the implementation of treatment and prevention strategies.

Another point to consider is that the classification of BP above or under the 90th p was based on one single occasion. If repeated on a second occasion, some of these abnormal measurements could possibly have shifted to the normal range, as observed in other studies[27]. However, these considerations do not invalidate the findings of a strong influence of BMI and WC on the pressure levels of these adolescents. These two indexes are thus characterized as important predictors, whose screening may help prevent the consequences in adulthood, such as the higher risk of obesity and hypertension[28-30].

Conclusions

This study provides data on the association of increased weight status and WC with BP elevation in adolescents from private and public schools in Salvador, thus contributing to two important public health aspects: the first, by extending and consolidating the evidence that the control of excess weight should be a priority in educational and preventive strategies for health maintenance in children and adolescents. The second aspect refers more specifically to adolescents with BMI close to the 85th p, in the high-normal range considered here (IMC ≥ 50th p and < 85th p) or in the overweight range, close to this limit, where tolerance and lack of concern with weight may impede the identification of increased BP, which may already be a sign of the possible presence of dislipidemia and/or insulin resistance. The efficacy of excess weight control and prevention strategies is important so as to minimize the risk of type-2 diabetes and early cardiovascular diseases in adulthood. Despite the broader knowledge on the problem, several questions regarding pathophysiology, epidemiology, therapy and prevention still remain unanswered. Among them, the knowledge on the etiology and pathogenesis of excess weight, risk screening until adulthood, and the efficacy of interventions regarding lifestyle. All these key issues point to new research paths targeting at the control of degenerative cardiovascular diseases in adulthood.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

This study was partially funded by FAPESB.

Study Association

This article is part of the thesis of doctoral submitted by Isabel Cristina Britto Guimarães, from *Universidade Federal da Bahia*.

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