Relationship between Anthropometric Measures and Cardiovascular Risk Factors in Children and Adolescents

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Abstract

Background: Obesity has been identified as an important risk factor in the development of cardiovascular diseases; however, other factors, combined or not with obesity, can influence cardiovascular risk and should be considered in cardiovascular risk stratification in pediatrics.

Objective: To analyze the association between anthropometry measures and cardiovascular risk factors, to investigate the determinants to changes in blood pressure (BP), and to propose a prediction equation to waist circumference (WC) in children and adolescents.

Methods: We evaluated 1,950 children and adolescents, aged 7 to 18 years. Visceral fat was assessed by WC and waist-hip relationship, BP and body mass index (BMI). In a randomly selected subsample of these volunteers ($n = 578$), total cholesterol, glucose and triglycerides levels were evaluated.

Results: WC was positively correlated with BMI ($r = 0.85$; $p < 0.001$) and BP (SBP $r = 0.45$ and DBP $= 0.37$; $p < 0.001$). Glycaemia and triglycerides showed a weak correlation with WC ($r = 0.110$; $p = 0.008$ e $r = 0.201$; $p < 0.001$, respectively). Total cholesterol did not correlate with any of the variables. Age, BMI and WC were significant predictors on the regression models for BP ($p < 0.001$). We propose a WC prediction equation for children and adolescents: boys: $y = 17.243 + 0.316$ (height in cm); girls: $y = 25.197 + 0.256$ (height in cm).

Conclusion: WC is associated with cardiovascular risk factors and presents itself as a risk factor predictor of hypertension in children and adolescents. The WC prediction equation proposed by us should be tested in future studies. (Arq Bras Cardiol. 2013;101(4):288-296)

Keywords: Cardiovascular Diseases; Risk Factors; Obesity; Body Mass Index; Abdominal Circumference; Child; Adolescent.

Introduction

Obesity has been identified as an important risk factor for cardiovascular disease development; however, other factors, combined to obesity or not, also exert influence on this risk and must be considered in cardiovascular risk stratification in pediatrics[1]. Among these factors, we highlight waist circumference (WC) as a visceral fat indicator which has already been well explored in the adult population and has more recently been identified as a risk factor in children and adolescents[1,3]. Evidences suggest the importance of measuring abdominal obesity besides general obesity for the evaluation of health risks in the first decades of life[4].

The growing child obesity rate is associated to an increase in the diagnosis of systemic arterial hypertension (SAH) in children and adolescents[5,8]. The prevalence of primary SAH in childhood and adolescence in Brazilian epidemiologic studies varied between 0.8-8.2%[9,10], which means it is a phenomenon of great epidemiologic importance. Besides SAH, obesity is associated to other comorbidities, such as increased peripheral insulin resistance and serum cholesterol and triglyceride levels, which represent a major risk of chronic disease in adult life[11,12].

The association between body mass index (BMI) and arterial blood pressure in children has already been demonstrated in other studies[13,15]. It must be highlighted that the association between visceral fat, accessed by the waist circumference, and arterial blood pressure, has been largely reported in the adult population. However, until now, a predictive value of waist circumference related to blood pressure levels has not been suggested for children and adolescents. Besides, prediction values for WC were also not found for children and adolescents in the Brazilian population.

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Taking these perspectives into account, the present study in children and adolescents aims to: a) analyze the association among visceral obesity, arterial blood pressure, generalized obesity and biomarkers (total cholesterol, triglycerides and glucose levels); b) evaluate these variables' predictive value in relation to arterial blood pressure; and c) propose a prediction equation for WC.

Methods

In this transversal study, 1,950 children and adolescents were evaluated. Their ages ranged from 7 to 18 years old; 902 were male (46.3%) and 1,048 were female (53.7%). They were randomly selected from a sample stratified by conglomerates (center and north, south, east and west areas of the peripheral urban zone and north, south, east and west rural zone), and were enrolled in 16 schools (12 in the urban zone and 4 in the rural zone) of Santa Cruz do Sul (RS). A randomly selected sub sample ($n = 578$) was employed for total cholesterol, triglyceride and glucose assessment. Arkin and Colton formula[16] was used for calculating sample size.

Waist circumference was measured with an inelastic tape measure at the medium point between iliac crest and the external side of the last costal arch, and the hip measurement obtained at the widest part of the buttocks; both are used for calculating the waist/hip ratio– (WHR = waist circumference/ hip circumference)[17].

Blood pressure was evaluated according to the VI Brazilian Guidelines on Hypertension[6] using the auscultation method, with aneroid devices calibrated less than three months before measurement. Each device had three different sized cuffs, so the researchers could select the ones that were adequate to arm circumference, respecting the 1:2 width/length proportion. Values below the 90th percentile (if were inferior to 120/80 mmHg) were considered normotensive; values between the 90th - 95th percentiles were considered borderline; values equal or superior to the 95th percentile were considered hypertensive. It must be highlighted that any value equal or superior to 120/80 mmHg in adolescents, even if inferior to the 95th percentile, was considered borderline.

Obesity was defined according to the child growth standards of the World Health Organization[18], which is based on different populations, including a sample of Brazilian children; it recommends that children with BMI (weight in kilograms divided by the square of the height in meters) greater than the 95th percentile are classified as obese, and those with BMI between the 85th and the 95th percentile are considered overweight. Subjects with IMC ≥ 25 kg/m^2 were also excluded.

Total cholesterol, triglycerides and glucose levels were measured in a sub sample of 578 children and adolescents after 12 h fast with an Accutrend GTC monitor (Roche, Germany) and finger stick testing, according to recommendations of the I Guideline for Prevention of Atherosclerosis in Childhood and Adolescence[7].

The data were analyzed with the software Statistical Package for the Social Science 20.0 (SPSS 20.0) and Winpepi version 11.1. The non-paired Student t-test was used for comparing continuous variables between genders, chi-square was used for comparing categorical variables and multiple linear regression analysis. The data identified as asymmetrical by the Kolmogorov-Smirnov test were converted to logarithm ($\log_{10}$). The correlations were analyzed by Pearson's correlation coefficient and classified according to the correlation magnitude scale proposed by Cohen[19]. Values are expressed as mean ± standard deviation, frequency distribution analysis and 95% confidence levels, considering a 5% significance level ($p < 0.05$).

This study was approved the Institutional Research Ethics Committee of the Santa Cruz do Sul University - Unisc (process 1.189/05), according to the Helsinki Statement. Parents and responsible for the students of the schools involved authorized their participation by signing an informed consent.

Results

Table 1 presents the characteristics of the subjects and the distribution of body mass index and blood pressure, pooled by gender and considered as a single group. Among the 902 boys and 1,048 girls evaluated, no differences were found between genders regarding age ($p = 0.50$), BMI ($p = 0.77$), systolic blood pressure ($p = 0.24$) and diastolic blood pressure ($p = 0.26$). However, boys' WHR and WC measurements were larger than girls' ($p < 0.001$ for both). The prevalences of hypertension ($p = 0.12$), overweight ($p = 0.65$) and obesity ($p = 0.57$) showed no difference between genders.

Visceral fat, measured as WC, showed a positive correlation with BMI (Graph 1), systolic blood pressure (Graph 2) and diastolic pressure (Graph 3). WC was also correlated to age ($r = 0.449$; $p < 0.001$) and WHR ($r = 0.206$; $p < 0.001$). However, WHR did not show a significant correlation with BMI and was weakly related to SBP ($r = 0.192$; $p < 0.001$) and DBP ($r = 0.182$; $p < 0.001$). BMI showed a significant correlation with both SBP ($r = 0.437$; $p < 0.001$) and DBP ($r = 0.360$; $p < 0.001$).

Total cholesterol, glucose and triglyceride levels were measured in 578 volunteers (244 boys and 334 girls). No significant difference was found between boys (156.65 ± 16.75 mg/dL) and girls (156.63 ± 14.64 mg / dL; $p = 0.991$) regarding total cholesterol levels. No significant difference was found between boys (63.88 ± 15.44 mg / dL) and girls (60.77 ± 15.13 mg/dL; $p = 0.016$) regarding total cholesterol levels. However, mean triglyceride levels were higher in girls (123.62 ± 62.23 mg/dL) than boys (107.00 ± 55.86 mg/dL; $p < 0.001$).

No significant correlations were found between total cholesterol levels and the other studied variables. Glucose blood levels were weakly correlated with BMI ($r = 0.112$; $p = 0.007$), WC ($r = 0.110$; $p = 0.008$), SBP ($r = 0.153$; $p < 0.001$) and DBP ($r = 0.134$; $p = 0.001$). Triglyceride blood levels were weakly correlated with BMI ($r = 0.213$; $p = 0.001$), WC ($r = 0.201$; $p = 0.001$), SBP ($r = 0.145$; $p < 0.001$) and DBP ($r = 0.144$; $p = 0.001$).

The results involving variables that interfere in SBP, calculated by multiple regression analysis, are presented on Table 2. Age, BMI and WC were significant predictors of

Table 1 - Subject characterization and distribution regarding body mass index and arterial blood pressure

Indicators	Boys (n = 902) n (%)	Girls (n = 1048) n (%)	Total (n = 1950) n (%)
Age (years)*	11.48 ± 2.76	11.56 ± 2.55	11.52 ± 2.65
BMI (kg/m^2)	18.91 ± 3.53	18.87 ± 3.26	18.89 ± 3.38
Low weight	37 (4.1)	30 (2.9)	67 (3.4)
Low weight risk	81 (9.0)	91 (8.7)	172 (8.8)
Eutrophic	601 (66.6)	757 (72.2)	1358 (69.6)
Overweight	124 (13.7)	117 (11.2)	241 (12.4)
Obesity	59 (6.5)	53 (5.1)	112 (5.7)
Waist-−hip ratio*	0.82 ± 6.82	0.79 ± 6.88	0.81 ± 7.07
Waist circumference (cm)*	66.36 ± 9.23	64.60 ± 8.15	65.41 ± 8.71
Systolic blood pressure (mmHg)*	104.48 ± 14.81	103.70 ± 14.41	104.06 ± 14.60
Normotensive	812 (90.0)	937 (89.4)	1749 (89.7)
Borderline	39 (4.3)	43 (4.1)	82 (4.2)
Hypertensive (%)	51 (5.7)	68 (6.5)	119 (6.1)
Diastolic blood pressure (mmHg)*	61.98 ± 12.12	61.37 ± 11.83	61.65 ± 11.97
Normotensive	859 (95.2)	985 (94.0)	1844 (94.6)
Borderline	30 (3.3)	43 (4.1)	73 (3.7)
Hypertensive	13 (1.4)	20 (1.9)	33 (1.7)

**Values expresses as mean ± standard deviation, BMI: body mass index.*

SBP increase. For each 1 year increase in age, there was an 1.8 mmHg increase in blood pressure; for each 1 unit increase in BMI, blood pressure increased 0.8 mmHg and for each unit increase in WC, SBP increased 0.2 mmHg.

Table 3 presents age, BMI and WC as predictors of DBP increase. For each 1 year increase in age, there was an 1.3 mmHg increase in blood pressure; for each 1 unit increase in BMI, blood pressure increased 0.5 mmHg and for each unit increase in WC, SBP increased 0.2 mmHg.

In a better multiple linear regression model, a WC prediction equation for children and adolescents is proposed, excluding individuals with BMI > 25 kg/m^2 and including variables such as gender and height in the model:

Boys' WC: y = 17.243 + 0.316 (height in cm); estimated standard error = 5.59; R^2 = 0.478.

Girls' WC: y = 25.197 + 0.256 (height in cm); estimated standard error = 5.95; R^2 = 0.244.

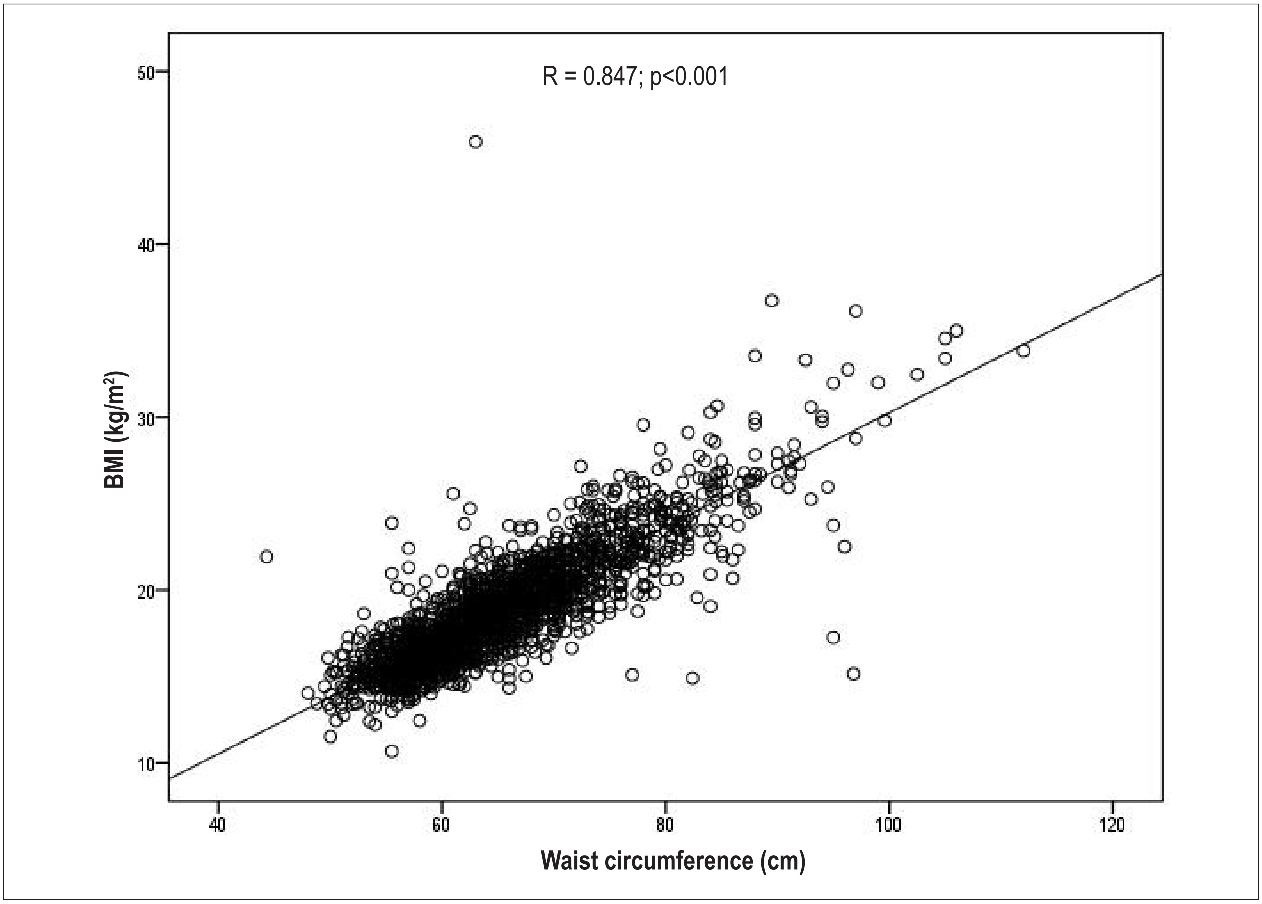
The ROC curve (Graph 4) shows that waist measurement's sensitivity was close to 100% (98.15%) for SBP; however, regarding specificity, as expected, it was inferior to 20% (19.93%). On the other side, the ROC curve (Graph 5) of waist measurement to DBP demonstrated a very similar behavior, with a 97,96% sensitivity and 21,64% specificity.

Discussion

Among the main findings of our study is the association of WC with blood pressure and BMI. We found weak evidence of association between biomarkers and visceral fat (WC and WHR), BMI and blood pressure. Age, BMI and WC showed significant predictive value for blood pressure change in a better multiple linear regression model with. Our results made possible the establishment of a WC prediction equation in children and adolescents.

The hypertension prevalence and diagnosis rates in children and adolescents have been increasing noticeably[20]. Evidences suggest that childhood arterial hypertension can lead to arterial hypertension in adult life[15,20] and to the early development of coronary artery disease observed as atherosclerosis in children and young adults[12]. Our findings showed a prevalence of arterial hypertension of 5.7% of boys and 6.5% of girls, with a global prevalence of 6.1%. These values agree with other reports which showed a prevalence of arterial hypertension with 3% in Santos (SP)[21], 5% in Goiânia (GO)[22] and 7,7% in Maceió (AL)[23].

Our results showed that WC and WHR were higher in males, similarly to what was seen in other studies[24,25]. Our studies showed that a higher association of blood pressure with WC than WHR, suggesting that visceral fat, accessed by WC, can be a better predictor of hypertension in childhood and adolescence. It must be highlighted, however, that WC is secondary measurement of visceral fat. Our study demonstrated a moderate correlation of CC with SBP and DBP, while Lee et al[4], evaluating 1,254 obese children aged 6-12 years old, showed a strong correlation among these variables. Sarni et al[8] did not find correlation between WC and SBP or DBP in a sample of 65 preschoolers of low socioeconomic status. It must be highlighted that care must

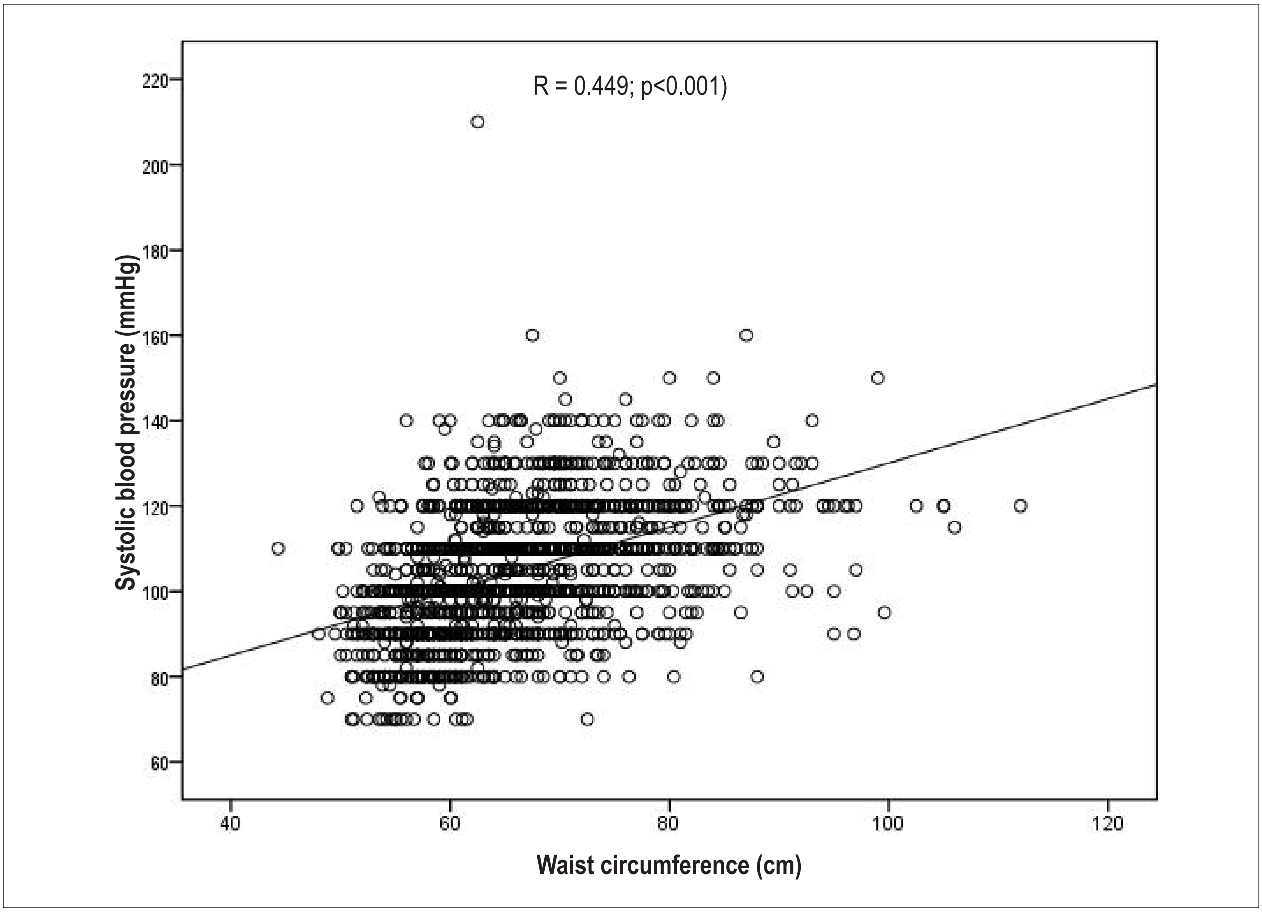


Graph 1 - *BMI to waist circumference ratio.*

be taken when comparing studies, since differences can be seen regarding age, socioeconomic status and body mass. We observed a stronger association of WC with SBP ($r = 0.449$) than with DBP ($r = 0.374$), suggesting that visceral fat exerts greater influence in SBP levels.

Various mechanisms may explain the association between visceral obesity and arterial blood pressure[26,28]. Visceral fat can be distinguished from fat localized in other anatomic regions by its functional and metabolic characteristics, inducing hepatic insulin resistance due to lipotoxicity[26], releasing more free fatty acids in hepatic portal vein and increasing substrate levels for atherogenic lipoprotein production[27]. The greater quantity of visceral fat may favor an increase in sympathetic activity mediated by the associated insulin resistance, besides potentializing the activity of the renin-angiotensin-aldosterone system due to the increased angiotensinogen secretion by visceral adipocytes, when compared to the subcutaneous fat[28]. The visceral fat accumulation could also exert a mechanical effect, inducing renal compression and promoting arterial blood pressure exacerbation[29]. As recently demonstrated in young individuals, WC correlates with insulin resistance markers, independent from BMI[30], predicting individual components of metabolic syndrome, such as high blood pressure and dyslipidemia[31]. Other studies have demonstrated that WC is associated with inflammatory biomarkers, such as C-reactive protein and adiponectin in young individuals[32,33].

The best association found in our study was found in BMI and WC ($r = 0.847$). This correlation's magnitude is similar to the one that was found by Soar et al[24] ($r = 0.87$) and Beauloye et al[34] ($r = 0.74$). The literature documents fairly well the greater importance of visceral obesity to the detriment of overweight in the risk assessment for the development of cardiovascular and metabolic dysfunction[35,36]. However, the combination of WC and BMI measurements have become more efficient for cardiovascular dysfunction prediction than the isolated utilization of only one of the anthropometric indicators[37]. In light of this, we evidenced a better multiple regression model both for SBP and DBP, with both models involving age combined to BMI and WC. As expected, age was a stronger predictor than SBP and DBP, followed by BMI and WC. BMI, representing generalized obesity, was a stronger predictor of blood pressure change than WC measurement in the studied sample. On the other hand, our data demonstrate an absence of significant correlation between BMI and WHR, as referred previously in preliminary studies in Dutch children[38]. Thus, we suggest that WHR may not be the better



Graph 2 - *Systolic blood pressure to waist circumference ratio.*

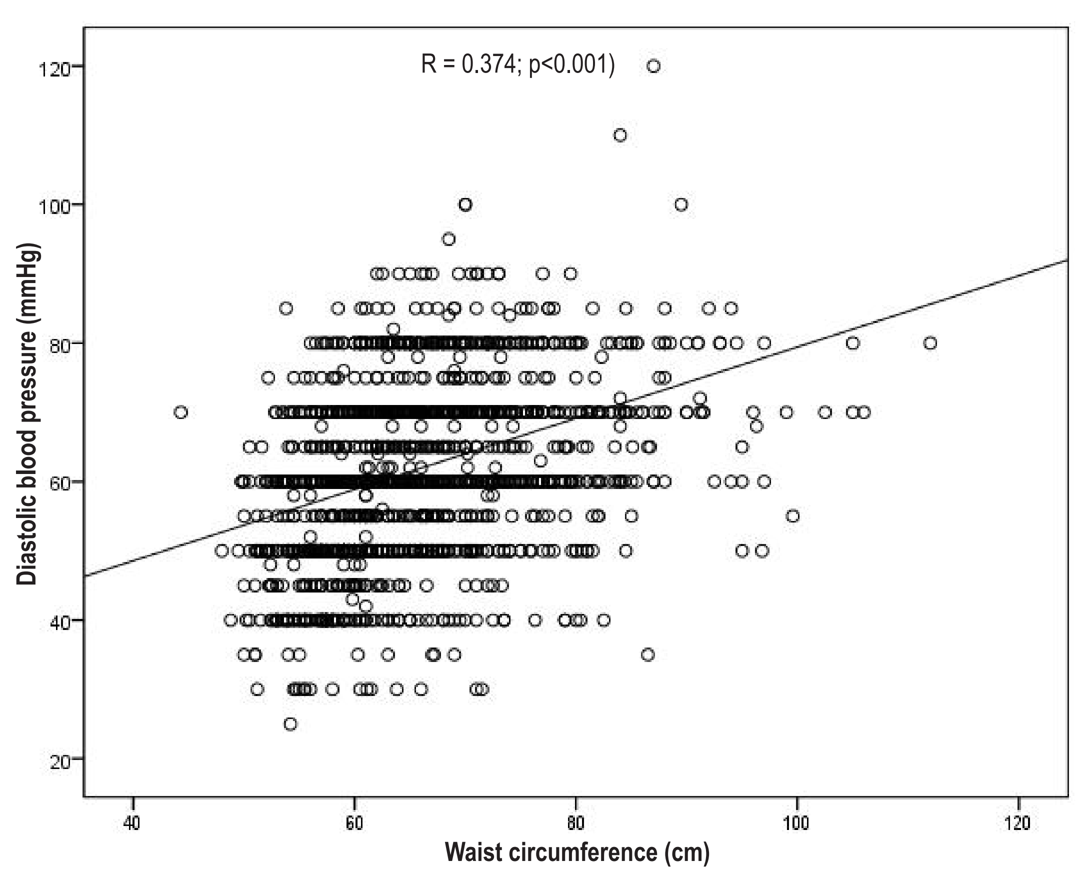
indicator of childhood obesity. Besides that, in a previous study in adults, WHR was reported as a weak predictor of visceral fat change evaluated by magnetic resonance[39].

It is not clear why age seems to be a better predictor of arterial blood pressure than anthropometric measurements. Freedman et al[2] indicate that arterial blood pressure changes in a certain population do not necessarily correlate to obesity changes. Besides that, Li et al[13] indicated that the intensity of the association between BMI and arterial blood pressure increases with age. These evidences suggest that anthropometric's influence on hypertension is quite complex and needs to be better investigated.

Some reports demonstrate and association between arterial blood pressure and BMI, suggesting that obesity is a strong risk factors for high blood pressure development in childhood and adult life[13,15]. Our findings suggest that body mass increase exerts greater influence in SBP than DBP, as seen with the stronger correlation found between BMI and SBP. This observation corroborates other studies' findings that have also demonstrated that SBP is more affected by BMI than DBP[13,20]. According to this, the data presented by the Bogalusa Heart Study (Louisiana, USA), which evaluated pressure measurements in 11,478 children and adolescents aged 5 to 17 years old, from 1974 to 1993, showed SBP reductions throughout this period[2].

Our study identified a smaller number of associations between biomarkers (total cholesterol, glucose and triglyceride levels) and WC, SBP, DBP and BMI. Even when considered significant, the correlations involving these variables were classified as weak. This tendency was also identified in preliminary studies, which demonstrated the absence of a correlation between BMI and WC and total cholesterol and glucose levels, and the weak correlation of BMI and triglycerides in obese children between 8 and 18 years old[34]. Sarni et al[8] reported that WC is not related to total cholesterol and triglyceride levels in preschoolers. Our findings suggest an absent or weak association between obesity, visceral obesity and arterial pressure and the accessed biomarkers, possibly due to the younger age group of the volunteers or to the fact that the biomarkers' mean levels are within the normal range for the studied sample. It must be highlighted that the limited sub sample size used for biochemical evaluation may have limited study power for detecting the association between biochemical variables and the other variables.

We also highlight that we chose to exclude the individuals with BMI ≥ 25 kg/m^2 due to the simple fact that these individuals are already considered overweight and obese, and do not need a predictor factor for WC. We currently



Graph 3 - *Diastolic blood pressure to waist circumference ratio.*

Table 2 - Multiple linear regression model of SBP as a dependent variable

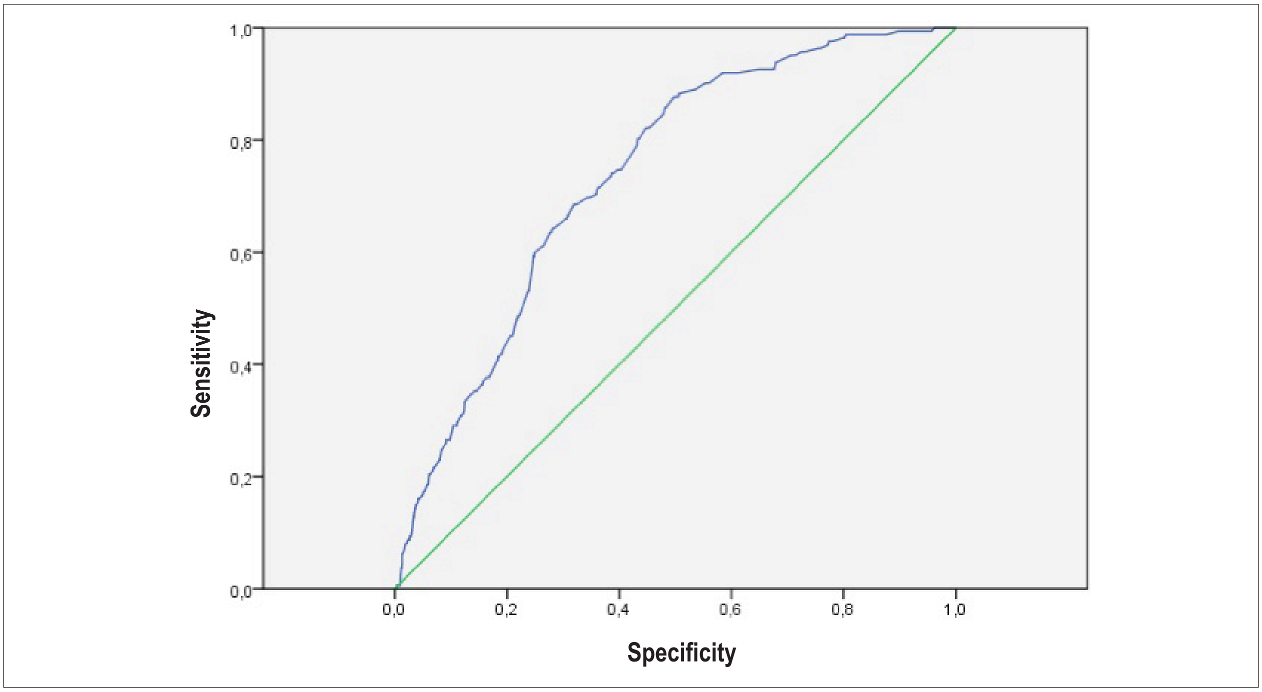
Independent variables	Non-standardized coefficients		95% confidence interval for B	Statistical analysis
	B	SD		
(Constant)	52.382	2.159	48.148 - 56.615	< 0.001
Age	1.826	0.117	1.596 - 2.055	< 0.001
BMI	0.841	0.154	0.539 - 1.143	< 0.001
WC	0.226	0.062	0.105 - 0.347	< 0.001

BMI: body mass index; WC: waist circumference.

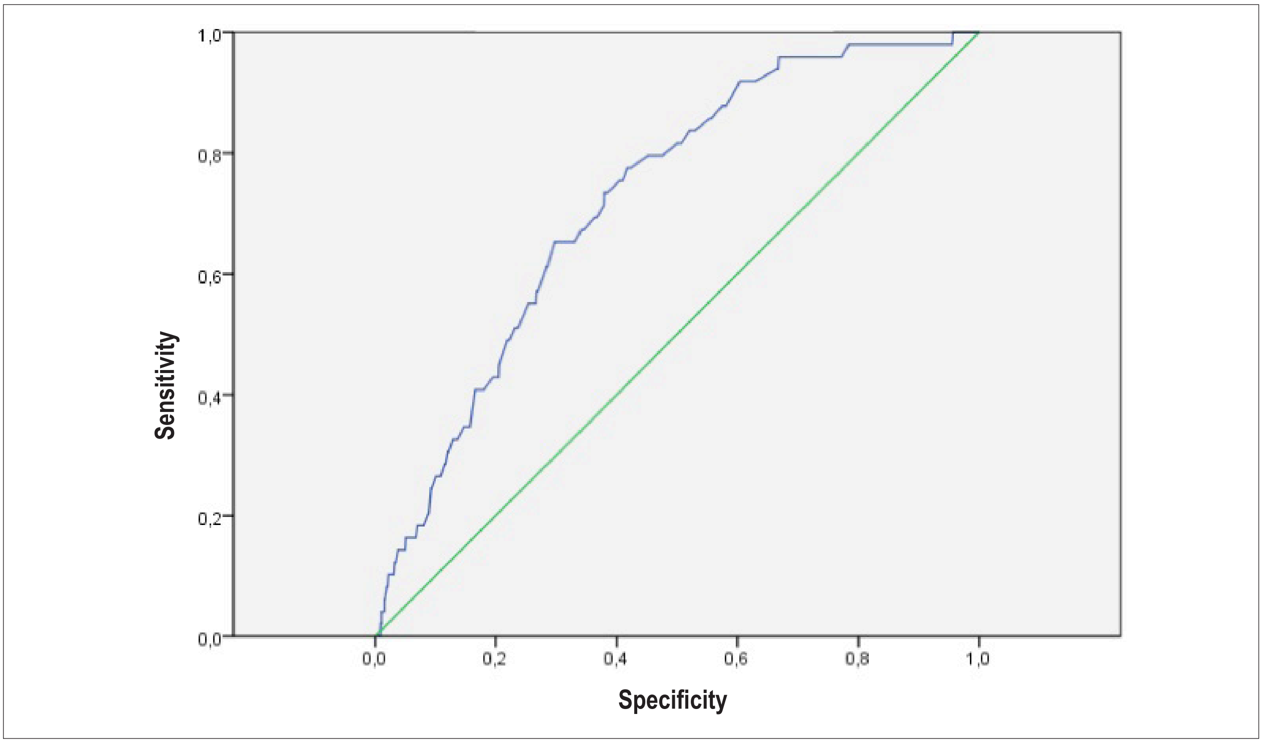
Table 3 - Multiple linear regression model of DBP as a dependent variable

Independent variables	Non-standardized coefficients		95% confidence interval for B	Statistical significance
	B	SD		
(Constant)	25.947	1.875	22.270 - 29.625	< 0.001
Age	1.319	0.102	1.120 - 1.519	< 0.001
BMI	0.512	0.134	0.249 - 0.774	< 0.001
WC	0.166	0.054	0.061 - 0.271	0.002

BMI: body mass index; WC: waist circumference.



Graph 4 - *ROC curve - waist: systolic blood pressure.*



Graph 5 - *ROC curve - waist: diastolic blood pressure.*

already have excellent references that properly discuss obesity and health risk issues to children and adolescents[2,3,11]. Some studies suggest that obesity duration is directly associated to cardiovascular morbimortality[1,5,27]. This was not our first objective. The other variables (gender and height) were chosen due to our belief that they would better represent the study sample population (children and adolescents).

WC normal values were proposed due to the importance of this measurement, which has already been described in the literature as a better cardiovascular risk predictor than BMI[40], and also aiming to facilitate the early diagnosis of visceral fat in the first decades of life. In the equation for WC prediction proposed by our study, the determination coefficient was different for boys ($R^2 = 0.478$) and girls ($R^2 = 0.244$), suggesting that the applicability of the proposed model can be better in the male population. Besides that, it is necessary that this equation is tested in additional studies; local waist measurement standards determination must be considered in studies conducted in other regions with different ethnicity, socioeconomic status and lifestyle, which can influence the measurement and make the predicted values inaccurate or not applicable in different populations. In view of this, it must be highlighted that the city of Santa Cruz do Sul (RS), at the Rio Pardo Valley, is a region of German colonization. Its economy is based in services and tobacco cultivation and is located 150 km from Porto Alegre. The ethnic diet in the city is marked by a great quantity of sweets, breads and cakes, whose role in cardiovascular risk must be better studied in future studies.

Conclusion

The present studied showed an important association between WC, BMI and arterial blood pressure. Our results made possible, for the first time, that a WC prediction equation, more robust in boys, was proposed for Brazilian children and adolescents. This study generated a WC prediction equation, based in Brazilian children and adolescent data. Of note, the studies available up to now in the literature dealed with the North American population. A weak association was also observed between biochemical and anthropometric variables, indicating little biochemistry change in the studied age range. Blood pressure and WC assessment should be part of family health programs even in the first two decades of life, and should also be part of interventions directed at health and quality of life maintenance in childhood.

Author contributions

Conception and design of the research: Burgos MS, Reuter CP, Burgos LT, Franke SIR, Prá D, Silva AMV, Reckziegel MB; Acquisition of data: Burgos MS, Reuter CP, Burgos LT, Franke SIR, Prá D, Silva AMV, Borges TS, Todendi PF, Reckziegel MB; Analysis and interpretation of the data: Burgos MS, Reuter CP, Camargo MD, Silva AMV, Reckziegel MB; Statistical analysis: Reuter CP, Camargo MD, Silva AMV; Writing of the manuscript: Burgos MS, Reuter CP, Camargo MD, Franke SIR, Prá D, Silva AMV, Borges TS, Todendi PF, Reckziegel MB; Critical revision of the manuscript for intellectual content: Burgos MS, Reuter CP, Burgos LT, Camargo MD, Franke SIR, Prá D, Silva AMV, Borges TS, Todendi PF, Reckziegel MB.

Potential Conflict of Interest

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

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Study Association

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