ABSTRACT

Background: Hypertension is correlated to increased body fat, particularly visceral fat, which can be assessed using anthropometric parameters. Objective: Association blood pressure with anthropometric indicators in school students from São Luís, Maranhão, Northeastern Brazil. Methods: Cross-sectional study with a sample of 304 female adolescents aged 12-19 years. The following anthropometric parameters were assessed: body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR) and conicity index (C Index). Additionally, hemodynamic parameters – systolic blood pressure (SBP) and diastolic blood pressure (DBP) were also assessed. Descriptive analyses, Student’s t test for independent samples, Mann-Whitney U test, Chi-square test and Person correlation coefficient were used for data analysis. Results: In the study sample, 12.5% of participants were obese and 13.5% had borderline high blood pressure. Only the variables BMI, WC and WHtR were statistically significantly correlated to SBP and DBP. Conclusion: Anthropometric indicators BMI, WC and WHtR are correlated to SBP and DBP and can be a low-cost, non-invasive and easy-to-use alternative for screening high blood pressure in adolescents.

KEYWORDS: Anthropometry, Blood Pressure, Obesity, Adolescent.

INTRODUCTION

Obesity is characterized by the excessive accumulation of fat in the body that harms the health of the individual and is associated with comorbidities such as metabolic disorders, dyslipidemias, cardiovascular diseases, type 2 diabetes, hypertension and some cancers. Among adolescents, the diagnosis of obesity itself already implies an increased risk for the development of cardiometabolic diseases, primary morbidity and the development of certain types of cancer in their lifetime.

Since 1998, the World Health Organization (WHO) recognizes obesity as a global epidemic that affects both developed and developing countries. According to the report of WHO's Commission on Ending Childhood Obesity (2016), the number of children who are overweight or obese in low- and middle-income countries more than doubled between the years 1990 and 2014 – from 7.5 to 15.5 million. In Brazil, the prevalence of overweight and obesity in children and adolescents has tripled in the last decades, according to the Consumer Expenditure Survey (Pesquisa de Orçamento Familiar – POF 2008-2009), the prevalence of overweight and obesity among adolescents was 20.5.

Overweight and obesity are associated with high blood pressure, which even with moderate elevations is already considered a health risk. Studies show a prevalence of hypertension (HT) in adolescents and a concomitant increase in obesity rates. Thus, anthropometric indices emerge as an important screening method as they can be used to investigate the association between adiposity and high blood pressure in adults and in children and adolescents.
Considering that the anthropometric indices are low-cost, easy-to-use, reproducible and non-invasive methods that can be used for screening adolescents with high blood pressure, the present study aims association blood pressure with anthropometric indicators in school students from the city of São Luís, located in the state of Maranhão, Northeastern Brazil.

METHODS

Subjects

This cross-sectional research was conducted from 2011 to 2014. Sample size was determined for estimating proportion based on a 4.0% prevalence of obesity in female adolescents, a suggested outcome prevalence of 10%, tolerable error of 5% and power of 95%, with an additional 20% for possible losses or refusals. Thus, the sample size was determined to be 256.8 adolescents. The sample was obtained from the school population of 16 schools of the municipal, state and federal education systems of the city of São Luís, located in the state of Maranhão, Northeastern Brazil. The schools were randomly chosen and the final sample consisted of 304 female adolescents aged 12-19 years. The following exclusion criteria were used: pregnant or nursing adolescents, those using contraceptive pills or who had not reached menarche, and those with physical disability that prevented or hindered measurements.

The study was approved by the Human Research Ethics Committee of the University Hospital of the Federal University of Maranhão (Hospital Universitário da Universidade Federal do Maranhão – HUUFMA) the protocol number 251/11.

Evaluation

The measurement of all variables was performed by trained staff using calibrated equipment. Anthropometric measurements including weight, height and waist measurements were obtained using standardized techniques by well-trained researchers. All measurements were performed in duplicate, with the mean being considered for data analysis.

Weight was measured using a digital scale (Seca® 803, Hamburg, Germany) with a 0.1 kg resolution. Height was measured using a portable vertical stadiometer (Seca® 213, Hamburg, Germany) with a 1 mm resolution. Waist circumference was measured using inextensible anthropometric tape with 0.1 cm resolution. (Seca® 201, Hamburg, Germany) at the smallest horizontal girth between the costal margins and the iliac crest at minimal respiration. The analysis of abdominal adiposity was performed considering the cutoff point proposed by Taylor et al. (2000) for gender and age.

BMI was calculated for each participant as a ratio of weight divided by height squared (kg/m²). Based on the WHO 2006/2007 percentiles for gender and age, the adolescents were classified according to their nutritional status into: normal weight if ≥ percentile (p) 3 and < percentile (p) 85, overweight ≥ p 85 and < p 97 and obese ≥ p 97. The waist-to-height ratio (WHtR) was calculated by the formula [WC (cm)/ height (cm)] and the cutoff point used was 0.50. The conicity index (CI) was determined by measuring weight, height and WC and applying the equation:

\[
CI = \frac{WC (cm)}{Body	ext{ weight (kg)}} \times \frac{1}{Height (m)}
\]

Measurement and classification of blood pressure were performed based on the protocol of the VI Brazilian Guidelines on Hypertension. BP was measured trough the indirect method using the auscultatory technique with a properly calibrated BIC® aneroid sphygmomanometer. The patient received information on the procedure and was allowed to rest for at least five minutes in a quiet environment. The patient was told not to talk during the measurement and remained in a sitting position with legs uncrossed, feet flat on the floor, leaning back on the chair and relaxed. The arm should be supported and positioned at the level of the heart (the midpoint level of the sternum or fourth intercostal space), bared and unrestricted by clothing with the palm of the hand turned upward and the elbow slightly flexed. After measurement, systolic and diastolic blood pressure values were stratified: SBP (80, 90, 100, 110, 120, 130 and 140) and DBP (40, 50, 60, 70, 80, 90 and 100). Mean BMI, WtHR, WC and CI values were calculated for each stratum for further analysis of correlation between these parameters.

Statistical Analysis

Statistical analysis was performed using SPSS® version 19. The Kolmogorov-Smirnov test was used to verify the normality of the variables: age, weight, height, BMI, WC, CI, WtHR, SBP and DBP. After that, the sample was divided into groups classified according to the blood pressure diagnosis and body mass index. Groups were compared using Student’s t-test for independent variables with normal distribution and Mann-Whitney U test for variables without normal distribution. Pearson correlation coefficient was used to check for associations between anthropometric indices (BMI, WC, WtHR and CI Index) and SBP and DBP. Chi-squared test was used to verify differences in excess weight prevalence and altered WC and WtHR between the groups with and without high BP. Results were considered statistically significant if p < 0.05.

RESULTS

Participants were 304 female adolescents with a mean age of 14.72 years ± 2.13 years. Regarding nutritional status, 61.5% (n=187), 26% (n=79) and 12.5% (n=38) were at normal weight, overweight and obese, respectively – the prevalence of excess weight was 38.5% (n=117). In the study sample, 26% (n=79) of participants had central adiposity. As for blood pressure, 82.9% (n=252) of participants had normal blood pressure, 13.5% (n=41) presented borderline high BP and 3.6% (n=11) had stage I and II hypertension.
The sample was stratified by BMI into two groups: eutrophic (normal weight) and excess weight (overweight+obese). Table 1 shows that all variables presented a statistically significant difference (p <0.05) between groups.

Table 1. Characteristics of participants stratified by BMI.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Eutrophic (n=187)</th>
<th>Excess weight (n=117)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>19.47 ± 2.18</td>
<td>25.39 ± 3.11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>65.74 ± 6.59</td>
<td>79.88 ± 10.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>C Index</td>
<td>1.09 ± 0.08</td>
<td>1.15 ± 0.11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.41 ± 0.04</td>
<td>0.51 ± 0.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>100.00 ± 11.15</td>
<td>110.00 ± 11.88</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>60.00 ± 9.74</td>
<td>70.00 ± 11.37</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Abbreviations: BMI- body mass index; WC- waist circumference, C Index- conicity index; WHtR- waist-to-height ratio; SBP- systolic blood pressure; DBP- diastolic blood pressure. Student’s t test for independent variables; * Mann-Whitney U test; † values described as mean ± SD (standard deviation); ‡ values described as median ± SD (standard deviation).

Table 2. Pearson Correlation Coefficients between anthropometric parameters and systolic and diastolic blood pressure.

<table>
<thead>
<tr>
<th>Variables</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>0.97**</td>
<td>0.94**</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.90*</td>
<td>0.95*</td>
</tr>
<tr>
<td>C Index</td>
<td>0.44</td>
<td>0.03</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.90</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Abbreviations: BMI- body mass index; WC- waist circumference, C Index- conicity index; WHtR- waist-to-height ratio; SBP- systolic blood pressure; DBP- diastolic blood pressure. ** p<0.01  * p<0.05.

In Table 3, the sample was also stratified into two groups: one with participants with normal BP and the other with those with high BP (borderline + stage I and II hypertension). It should be noted that weight, BMI, WC, WHtR, SBP and DBP presented statistically significant difference (p<0.05) per group.

Table 3. Characteristics of participants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal BP (n=252)</th>
<th>High BP (n=52)</th>
<th>All (n=304)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>14.77 ± 2.18</td>
<td>14.48 ± 1.87</td>
<td>14.72 ± 2.13</td>
<td>0.380</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.56 ± 0.06</td>
<td>1.56 ± 0.06</td>
<td>1.56 ± 0.06</td>
<td>0.571</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>51.00 ±11.26</td>
<td>56.85 ± 10.82</td>
<td>51.40 ± 11.30</td>
<td>0.005</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>20.93 ± 4.05</td>
<td>23.28 ± 3.56</td>
<td>21.38 ± 4.01</td>
<td>0.002</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>70.35 ± 10.69</td>
<td>75.20 ± 10.09</td>
<td>71.18 ± 10.73</td>
<td>0.003</td>
</tr>
<tr>
<td>C Index</td>
<td>1.11 ± 0.10</td>
<td>1.14 ± 0.10</td>
<td>1.11 ± 0.10</td>
<td>0.058</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.44 ± 0.06</td>
<td>0.47 ± 0.06</td>
<td>0.44 ± 0.06</td>
<td>0.001</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>100.00 ± 9.91</td>
<td>120.00 ± 10.23</td>
<td>100.00 ± 11.75</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>60.00 ± 8.37</td>
<td>80.00 ± 11.77</td>
<td>63.00 ± 10.51</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Abbreviations: BMI- body mass index; WC- waist circumference, C Index- conicity index; WHtR- waist-to-height ratio; SBP- systolic blood pressure; DBP- diastolic blood pressure. Student’s t test for independent variables; * Mann-Whitney U test; † values described as mean ± SD (standard deviation); ‡ values described as median ± SD (standard deviation).

Table 4 shows the blood pressure diagnosis of school students. The prevalence of high blood pressure was higher among participants with excess weight and altered WC and WHtR.
Table 4. Prevalence of normal and high blood pressure according to BMI, WC and WHtR.

<table>
<thead>
<tr>
<th>Variables (n=304)</th>
<th>Normal BP [n (%)]</th>
<th>High BP [n (%)]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>163 (87.2%)</td>
<td>24 (12.8%)</td>
<td>0.012</td>
</tr>
<tr>
<td>Excess weight</td>
<td>89 (76.1%)</td>
<td>28 (23.9%)</td>
<td></td>
</tr>
<tr>
<td>WC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>193 (85.8%)</td>
<td>32 (14.2%)</td>
<td>0.024</td>
</tr>
<tr>
<td>Altered</td>
<td>59 (74.7%)</td>
<td>20 (25.3%)</td>
<td></td>
</tr>
<tr>
<td>WHtR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>203 (86.0%)</td>
<td>33 (14.0%)</td>
<td>0.007</td>
</tr>
<tr>
<td>Altered</td>
<td>49 (72.1%)</td>
<td>19 (27.9%)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI- body mass index; WC-waist circumference; WHtR- waist-to-height ratio; BP- blood pressure *
Chi-square.

DISCUSSION

The prevalence of excess weight has increased worldwide regardless of gender or age. In a study conducted with students – including 53.4% (n= 1,671) girls – aged 7-18 years in Campinas, São Paulo, Brazil, Castilho et al.[24] found a 32.7% (n=547) prevalence of excess weight among female adolescents, corroborating the value found in the present study. However, it should be noted that overweight and obesity are related to the development of various comorbidities such as cardiovascular disease and metabolic disorders (hypertension, insulinemia, dyslipidemia, among others). There is evidence that 20% of obese children under the age of five tend to become obese adults and when obesity reaches the group of adolescents, the proportion may rise to 80%.[25,26] In the present study, participants with excess weight had a higher prevalence of high BP (23.9%) than those with normal weight. According to the literature, more than 75% of HT cases can be directly linked to obesity.[27] Moreira et al. (2013) highlight studies that support the hypothesis that obesity during adolescence is a risk factor for the development of systolic hypertension (SHT) and that such association can cause several adverse health effects in the short and long term, including the development of cardiovascular disease.[27]

BMI presented a strong and statistically significant correlation to SBP and DBP in a study conducted with 1,221 adolescents, including 603 female adolescents. Goel et al. (2016) also found a significant correlation between BMI, SBP and DBP (Pearson correlation coefficient - \( r = 0.701, P <0.01 \)) and \( r = 0.664, P <0.01 \) for SBP and DBP, respectively.[3]

Childhood obesity and its consequences have been attracting more attention in the medical field because of the increasing prevalence worldwide and long-term effects of childhood obesity in later years of life.[2] He et al.[28] in their case-control study have observed that an increase of 1 BMI unit was associated with 0.56 and 0.54 mmHg increase in SBP and DBP, respectively, for obese children. In no obese children, the increase in SBP and DBP was 1.22 and 1.20 mmHg, respectively. Furthermore, an increase in the adjusted BMI was associated with an increase in SBP and DBP in both obese and no obese children.[2]

The prevalence of high BP was also higher in the group with altered WC and WHtR; additionally, WC and WHtR were also significantly correlated to SBP and DBP. Central adiposity or obesity is a stage of excessive abdominal and visceral fat and is an important predictor of metabolic disorders and cardiovascular diseases, with WHtR and WC standing out as simple measures to assess central adiposity[29] in adolescents. In a study conducted with 1,642 adolescents aged 14-19 years, Beck et al. (2011) found that WC, BMI and WHtR were the best predictors of high blood pressure in both women and men.[15]

One of the possible mechanisms that could explain the influence of central fat on blood pressure in adolescents is the altered insulin sensitivity.[30] The molecular mechanisms for the development of obesity-related insulin resistance have been studied intensely and evidence reports that excess adipose tissue and high fat intake are capable of synthesizing and activating proteins with inflammatory actions that influence the intracellular insulin storage causing losses in GLUT4 translocation to the plasma membrane[31,32] and hence reducing glucose uptake in skeletal muscle and other tissues leading to a hyperglycemic state.[32, 33]

Obese adolescents have shown an increased insulin secretion that may be more directly associated with those with a greater accumulation of intra-abdominal fat. This increased insulin secretion may favor a higher retention of sodium – and hence water – stimulating the sympathetic activity, which may lead to high blood pressure through different physiological pathways.[30] Many factors act together to promote vasoconstriction and sodium retention. The main hypothesis suggests that leptin, free fatty acids and insulin, whose levels are increased in obesity, may act synergistically to stimulate sympathetic activity and vasoconstriction. In addition, insulin resistance and endothelial dysfunction act as amplifiers of the vasoconstrictor response. Finally, increased renal reabsorption of sodium may also occur, caused by an increased renal sympathetic activity, a
direct effect of insulin, hyperactivity of the renin-angiotensin system and possibly by an alteration of intrarenal physical forces.\[34\]

In the present study, the C Index presented a low correlation to SBP and DBP. Beck et al. (2011) found that the CI had a lower discriminatory power for predicting high BP compared to the other indices analyzed (WC, BMI and WHR) in adolescents of both genders.\[15\] Pereira & Serrano et al. (2015), in a study conducted with girls aged 14-19 years, found that the CI was not a good indicator of body mass and total body fat, probably because the relationships between its measures (weight, height and waist circumference) are not good indicators of obesity.\[35\] These findings may partially explain the fact that the C Index was not statistically significantly correlated to SBP and DBP in the present study, as visceral fat is strongly associated with metabolic disorders including dyslipidemia, hypertension, insulin resistance and type 2 diabetes.\[30\]

CONCLUSION
The present study found a high prevalence of excess weight and high blood pressure. The anthropometric indicators BMI, WC and WHR are correlated to SBP and DBP and can be a low-cost, non-invasive and easy-to-use alternative for screening high blood pressure in adolescents.

ACKNOWLEDGMENTS
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Conflict of interest
The authors declare no conflict of interest.

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