ORIGINAL ARTICLE

Role of waist circumference in predicting the risk of high blood pressure in children

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Abstract

Objective. This paper was designed to evaluate the role of waist circumference (WC) in identification of children with high blood pressure. Methods. Cross-sectional data on body mass index (BMI), WC and blood pressure (BP) were analyzed in 3 678 children (1 849 boys; 11.3 ± 2.3 years) who participated in the LEARN study. Results. Prevalence of abdominal obesity (WC ≥90th percentile) in normal weight (n = 2 982), overweight (n = 528) and obese (n = 168) children were 3.7%, 51.7% and 89.9%, respectively. Systolic BP (SBP) was higher in children with abdominal obesity compared with those with normal WC (p < 0.01) both in normal and in overweight BMI categories. Similar results were found for diastolic BP (DBP) in normal weight girls (p = 0.032) and overweight boys (p = 0.04). WC was significantly correlated with SBP and DBP in all BMI categories, even after adjustment for age and BMI. Despite these findings, no significant odds ratio (OR) of prehypertension or hypertension for abdominal obesity was found in the normal weight category. On the contrary, in overweight children, prevalence of prehypertension (OR 1.42 [1.1; 1.8]) and hypertension (OR 1.35 [1.1; 1.7]) was higher among abdominal obese children. Similarly, the prevalence of prehypertension was almost two-times higher among obese children with abdominal obesity (11.8% vs. 22.5%); however, no significant OR was found. Conclusions. The ability of WC to detect high-risk normal weight children is controversial. The additional measure of WC among overweight children seems to be relevant in identifying those at increased risk of high BP. Further research with a larger sample size is required in the obese group.

Key words: Abdominal obesity, BMI, children, hypertension, waist circumference

Introduction

Hypertension is one of the leading risk factors for premature death, stroke, cardiovascular disease and end-stage renal disease (1,2). It is estimated that within 20 years the number of adults with hypertension will increase by 24% in developed countries and by 80% in developing countries (3). Considering the potential future impact of uncontrolled hypertension in children, public health strategies to detect and treat high-risk children and adolescents are urgently required.

Obesity is the major determinant of elevated blood pressure in children (4,5). Overweight and obese children have significantly higher blood pressure values than their normal weight peers (6,7). In a recent analyses of NHANES 1988–94 and 1999–2000 surveys, obesity explained nearly 30% of the observed increase in systolic blood pressure (8).

Visceral fat is thought to be more metabolically active, than subcutaneous fat (9), and waist circumference (WC) is an index of visceral fat content (10). Thus, elevated WC is also an important risk factor for hypertension (11). Consequently, in adults, the combined measure of BMI and WC is more strongly correlated with metabolic risk, than BMI alone (12,13). Similar findings were observed in recent paediatric population studies (14,15); however, there is little evidence of the value of WC as being a useful measure in identifying children at risk of developing high blood pressure.

Therefore, the aim of the present work was to evaluate the possible role of WC as an indicator of children with high blood pressure within various BMI categories. We hypothesized that within each BMI category, the presence of abdominal obesity would be associated with an increased risk of prehypertension and/or hypertension. Consequently,
in all BMI categories, children with abdominal obesity would need to be identified and considered as high-risk individuals.

Methods
Study population
LEARN (Lifestyle, Eating, Activity and Rate of obesity in children) is an ongoing cohort study started in December 2007 and primarily aimed to evaluate trends in weight status, blood pressure, endurance capacity, eating and activity patterns of school children. Measurements are planned to be repeated yearly. Baseline sampling included first to eighth grade children from 18 primary schools in Obuda, the largest district of Budapest, the capital of Hungary. However, the study population was not representative for either the pediatric population of Hungary, or of Budapest. There were no eligibility criteria except for willingness to participate. General recruiting took place as part of the annual school health examination. Approval for this study was granted by the Medical Research Council. All parents gave their informed written consent.

Study measures
Initial data collection was performed between December 2007 and February 2008. All measures were taken in the morning by well-experienced school doctors and school nurses. Standardized training was provided prior to assessment for all staff involved in the study.

Weight status. To measure weight, weighing scales were calibrated to 0.1 kilogram (kg) and measures up to 150 kg were used. To measure standing height, height boards calibrated to 0.1 centimeter (cm) and mounted at a right angle between a level floor and against a straight, vertical surface (wall or pillar) were used. Both body weight and height were measured in light underwear and BMI was calculated (kg/m²). Non-elastic metal tape was used for the measurement of WC at the level of umbilicus at the end of gentle expiration. Overweight and obesity were defined according to the IOTF cut-off points for BMI (16) and abdominal obesity was classified according to the Hungarian reference data (17). Currently there are no WC percentile cut-off points defined to identify abdominal obesity in children or adolescents, but it has been proposed to choose a high cut-off point, such as the 90th or 95th percentile (18,19). Thus, we decided to use age- and gender-specific 90th percentiles as a cut-off point to denote abdominal obesity.

Blood pressure. Resting blood pressure (BP) was assessed in a seated position, using a sphygmomanometer after a 5-minute rest period on the right arm. After a further five minutes the measurement was repeated and an average BP was calculated. The BP measurement procedure was not further detailed by the protocol; it was implemented according to the Hungarian guideline for school medical staff (20). Hypertension was defined as average systolic BP (SBP) and/or average diastolic BP (DBP) ≥95th percentile (21). SBP and/or DBP between the 90th and 95th percentile were designated as prehypertension. While there is no existing pediatric reference data for BP in Hungary for these age groups, we used the US normative blood pressure tables (21).

Statistical analysis
Statistical analysis was performed with Statistica 7.0 statistical software (StatSoft Inc, Tulsa, OK). Unless otherwise indicated, data are presented as mean values and standard errors (SE). Statistical significance was set at \( p < 0.05 \) for all tests.

Dummy variables (e.g., normal WC \( = 0; \) abdominal obesity \( = 1 \) ) were created and subjects were divided into two groups for WC and three groups for BMI and BP.

Descriptive statistics summarized the data. Normal distribution was checked by the Kolmogorov-Smirnov normality test. Differences between groups were analyzed using Analysis of Variance (ANOVA) or Analysis of Covariance (ANCOVA) and Tukey post hoc test. Bivariate correlations between age, BMI, WC and blood pressure were determined using Pearson’s coefficient of correlation.

In order to answer the question whether overweight (estimated by BMI) or abdominal obesity (estimated by WC) independently increases the risk of developing elevated blood pressure in children, we used 2 \( \times \) 2 (absence or presence of abdominal obesity and prehypertension or hypertension) or 3 \( \times \) 2 contingency tables (BMI categories and absence or presence of prehypertension or hypertension) and chi-square test.

To determine the predictability of prehypertension or hypertension from abdominal obesity within different BMI categories, an age and gender adjusted logistic regression model was used. A normal WC was defined as the reference category (OR = 1.00).
Children were excluded from the study if data was missing for a variable included in any statistical model. We also excluded those children whose height, weight or WC was more than 3 standard deviations beyond the age and gender specific 50th percentile based on the Hungarian reference data (17).

Results

Subject characteristics

Data was collected from a total of 3 810 students, but 132 record forms (3.5%) were excluded from the analysis after data cleaning. The final sample included 3 678 children (1 849 boys and 1 829 girls), whose ages ranged from 6.5 to 15.5 (mean age: 11.3 ± 2.3 years). The characteristics of subjects, categorized according to gender, BMI and WC, are shown in Table I.

Based on the IOTF criteria, prevalences of overweight and obesity were 14.4% (n = 528) and 4.6% (n = 168), respectively. Abdominal obesity was found in 533 of the 3 678 children (14.5%). Frequency of abdominal obesity increased in parallel with weight status. Thus, the prevalences among normal weight, overweight and obese children were 3.7%, 51.7% and 89.9%, respectively.

In the normal BMI category, children with abdominal obesity were older than children with normal WC (p < 0.001).

In all three BMI categories, BMI values were higher in children with abdominal obesity compared with those with normal WC (p < 0.01). No gender difference in BMI was observed with the exception of the obese group with abdominal obesity, where boys had a higher BMI than girls (p = 0.011).

In contrast, gender differences in WC were seen both in the normal and in the overweight BMI category, where boys with normal WC had higher values than girls (p = 0.00002). Similar difference was shown among obese children with abdominal obesity (p = 0.00002).

Both in normal and in overweight BMI categories, SBP values were higher in children with abdominal obesity compared with those with normal WC (p < 0.01). Similarly, both normal weight girls (p = 0.032) and overweight boys (p = 0.04) with abdominal obesity had higher DBP than those with normal WC. In the obese group, both SBP and DBP values were higher in case of abdominal obesity; however, differences were not significant. No significant gender difference was found either in SBP or in DBP except for children with normal BMI and normal WC, where boys had higher SBP than girls (p = 0.013).

Prevalence of elevated blood pressure and independency analysis

Generally, the prevalences of prehypertension and hypertension were 12.8% (n = 471) and 14.6% (n = 537), respectively. Prevalence of both abnormalities increased in parallel with BMI category (for prehypertension: normal: 11.5%, overweight: 17.4%, obese: 21.4%; for hypertension: normal: 11.2%, overweight: 26.7%, obese: 36.3%). All of these increases were significant except for the difference in the prevalence of prehypertension between the overweight and obese group. Compared with children with normal WC, both prehypertension and hypertension were more frequently recognized among abdominal obese children (prehypertension: 11.5% vs. 20.3%, p < 0.0001; hypertension: 12.2% vs. 29.1%, p < 0.0001).

In line with these findings, results from chi-square statistics supported the view that both increases in BMI category and the presence of abdominal obesity independently raised the risk of developing prehypertension or hypertension.

The prevalence of prehypertension and hypertension within the different BMI categories at normal and elevated WC values are shown in Figure 1a and 1b. Within each BMI category, prevalence of prehypertension was higher among abdominal obese children; however, the difference was significant only in the overweight group. Similarly, a higher rate of hypertension was found among abdominal obese overweight and obese children, but the difference was not significant in the obese group.

Correlation coefficients and explained variance in blood pressure by BMI and WC

Overall, both BMI (r_{SBP} = 0.44; r_{DBP} = 0.38) and WC (r_{SBP} = 0.47; r_{DBP} = 0.39) correlated significantly with SBP and with DBP (p < 0.05). Table II presents the bivariate correlation coefficients between age, BMI, WC, SBP and DBP in different BMI categories. Age, BMI and WC correlated significantly with BP values. BMI showed the same correlations to SBP and DBP as to WC. For both SBP and DBP, the strongest correlations with BMI and WC were found in obese children, although the differences between correlation coefficients were not significant.

After adjustment for age, correlation coefficients for BMI and WC were reduced, but were still significantly correlated with SBP and DBP. In contrast, when the results were adjusted for age and WC, correlations between blood pressure values and BMI in overweight and obese children were no more significant. On the contrary, when WC was
### Table I. Comparison of anthropometric and blood pressure values in 7–15-year-old children with versus without abdominal obesity within different BMI categories (n = 3 678). Data are mean values, with standard errors.

<table>
<thead>
<tr>
<th></th>
<th>Normal weight (n = 2 982)</th>
<th>Overweight (n = 528)</th>
<th>Obese (n = 168)</th>
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<tbody>
<tr>
<td></td>
<td>WC &lt;90th</td>
<td>WC ≥90th</td>
<td>WC &lt;90th</td>
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<td></td>
<td>M (n = 1 428) F (n = 1 445)</td>
<td>M (n = 50) F (n = 59)</td>
<td>M (n = 114) F (n = 141)</td>
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<td>M (n = 50) F (n = 59)</td>
<td>M (n = 114) F (n = 141)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>11.1 ±0.1a</td>
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<td></td>
<td>11.1 ±0.1a</td>
<td>12.6 ±0.3</td>
<td>12.1 ±0.2</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>16.9 ±0.1b</td>
<td>19.9 ±0.3</td>
<td>23.2 ±0.2</td>
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<td></td>
<td>16.9 ±0.1b</td>
<td>19.9 ±0.3</td>
<td>23.2 ±0.2</td>
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<tr>
<td>WC (cm)</td>
<td>61.4 ±0.2bc</td>
<td>81.2 ±0.8</td>
<td>81.8 ±0.5</td>
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<tr>
<td></td>
<td>61.4 ±0.2bc</td>
<td>81.2 ±0.8</td>
<td>81.8 ±0.5</td>
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<tr>
<td>SBP (mmHg)</td>
<td>108.2 ±0.3</td>
<td>114.5 ±1.5</td>
<td>117.7 ±0.9</td>
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<tr>
<td></td>
<td>108.2 ±0.3</td>
<td>114.5 ±1.5</td>
<td>117.7 ±0.9</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>64.2 ±0.2</td>
<td>65.8 ±1.1</td>
<td>69.3 ±0.7</td>
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<td></td>
<td>64.2 ±0.2</td>
<td>65.8 ±1.1</td>
<td>69.3 ±0.7</td>
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</tbody>
</table>

Abbreviations: M, male; F, female; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC <90th, normal waist; WC ≥90th, abdominal obesity; a, Different (p < 0.05) from abdominal obese subgroup within the same BMI and gender category; b, Different (p < 0.05) from abdominal obese subgroup within the same BMI and gender category (adjusted for age); c, Different (p < 0.05) from female subgroup with the same BMI and WC category (adjusted for age); d, Different (p < 0.05) from abdominal obese subgroup within the same BMI and gender category (adjusted for age and BMI).

### Discussion

In total, 3% of the normal weight children had abdominal obesity. Children with high WC values had, on average, 6 mmHg higher systolic and 2.6 mmHg higher diastolic blood pressure values than those with normal WC. These findings were in line with our baseline hypothesis, that normal weight adolescents (13–16-year-olds), the normal weight or in the obese categories. In contrast, in overweight children abdominal obesity was associated with prehypertension and hypertension due to abdominal obesity within the three BMI categories as presented in Table III.

Overall, the Odds Ratios (OR) for developing prehypertension and hypertension in children with abdominal obesity were 1.96 (95% CI = 1.5–2.5) and 2.74 (95% CI = 2.2–3.4), respectively. ORs for prehypertension and hypertension due to abdominal obesity within the three BMI categories are presented in Table III. No significantly increased OR was found either in the normal weight or the obese categories. In the overweight category, only a few studies investigated the effect of abdominal obesity on CVD risk factors. Similarly, results from the KOPS Study confirmed that an added use of a second obesity measurement (i.e., WC, triceps or percentage of body fat) could improve the identification of CVD risk factors in children with abdominal obesity. In normal weight children, WC was a good predictor of insulin resistance, as measured by the HOMA-IR, only a few studies investigated the effect of abdominal obesity in normal weight children, and the results of these were controversial (14,15,25–27).

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Role of WC in normal weight children

In general, WC, which provided reliable information about visceral abdominal fat in children (23,24), was a good predictor for abdominal obesity. Children with high WC values had a similar rate of variance in systolic (15–26%) and diastolic (18–22%) blood pressure. According to the R²-values, BMI and WC explained a similar rate of variance in systolic (15–26%) and diastolic (18–22%) blood pressure.
BMI (14). Also, Genovesi et al. (15) found that WC did not improve the ability of BMI to identify hypertension in normal weight children. Our data did not clearly confirm our hypothesis that the additional measuring of WC could extend the usefulness of BMI for the identification of high BP in normal weight children. Thus, the prognostic importance of abdominal obesity in normal weight children needs to be defined in prospective studies.

The high prevalence of elevated blood pressure in the normal weight group was an interesting and unexpected finding of our study. Studies investigating the prevalence of high blood pressure in a normal weight pediatric population have shown mixed results. Some showed lower rates (28,29), whereas others reported similar data to ours (30,31). Those authors, however, who had the possibility to perform measurements on different days, found a significantly lower rate of high blood pressure at the second or third measurement occasion, than at the first (32). Confirming these results, Florianczyk et al. (33) found that only 2/3 of the high blood pressure cases identified as ambulatory could be reinforced with ABPM. Unfortunately we did not have the possibility either to assess blood pressure on different days or to use ABPM in the LEARN Study, but we were able to compare the results of the first and second measurements. Although the systolic BP was significantly smaller for the second time (p < 0.00001), in practice the difference was very small (109.9 ± 14.2 vs. 108.4 ± 12.5 mmHg). Confirming this finding, the difference in prevalence of prehypertension or hypertension based on the first and second measurement was not more than 1.5%. First and second measures of diastolic blood pressure did not differ significantly. In summary, we concluded that based on the results of previous authors (32,33), the real prevalence of elevated blood pressure among the normal weight LEARN children could be somewhat lower than we presented.

Table II. Bivariate correlations (r) between age, BMI, WC and blood pressure within different BMI categories in 7–15-year-old children (n = 3 678).

<table>
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<th>Obese (n = 168)</th>
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<tbody>
<tr>
<td></td>
<td>SBP</td>
<td>DBP</td>
<td>SBP</td>
</tr>
<tr>
<td>Age</td>
<td>0.47**</td>
<td>0.38**</td>
<td>0.41**</td>
</tr>
<tr>
<td>BMI</td>
<td>0.39**</td>
<td>0.31**</td>
<td>0.39**</td>
</tr>
<tr>
<td>WC</td>
<td>0.42**</td>
<td>0.32**</td>
<td>0.39**</td>
</tr>
<tr>
<td>BMI adjusted for age</td>
<td>0.15**</td>
<td>0.11**</td>
<td>0.11**</td>
</tr>
<tr>
<td>WC adjusted for age</td>
<td>0.16**</td>
<td>0.09**</td>
<td>0.16**</td>
</tr>
<tr>
<td>BMI adjusted for age and WC</td>
<td>0.08**</td>
<td>0.07**</td>
<td>0.06</td>
</tr>
<tr>
<td>WC adjusted for age and BMI</td>
<td>0.09**</td>
<td>0.05**</td>
<td>0.13**</td>
</tr>
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</table>

Abbreviations: BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; *p<0.05 significant correlation coefficient; **p<0.01 significant correlation coefficient.
Overweight and obese children with abdominal obesity

More than 50% of overweight and almost 90% of obese children had abdominal obesity. In our recent study, results indicated that the risk of high BP was greater in overweight children with high WC values than in overweight children with normal WC. Similarly, the prevalence of prehypertension was almost two-times higher among obese children with abdominal obesity; however, the difference was not significant. These findings highlight the importance of WC evaluation in pediatric obesity practice, while measurement of WC in addition to BMI could give more information on health risk.

Considering the limited time available in clinical practice, WC should only be measured if it can provide information that could influence patient management. Our findings support the idea that measurement of WC could be an effective tool for identifying “metabolically normal, obese” patients, who do not require aggressive obesity therapy (9,34).

The findings that overweight or obese children with WC ≥90th percentile had greater risk of elevated BP compared with those with normal WC do not provide appropriate evidence that the 90th percentile is the ideal cut-off point. In this study we did not aim to determine the best WC threshold for identifying high-risk children within BMI categories. The recently published Expert Committee Recommendation regarding the Prevention, Assessment, and Treatment of Child and Adolescent Overweight and Obesity (35) did not clearly recommend WC measurement for routine clinical use due to the lack of proper information and specific guidelines for clinical application. However, the Expert Committee proposed that if clinicians measure WC, they should use a high percentile cut-off point. Waist circumference reference values are available for the Hungarian pediatric population (17) and also for other European countries (19,36–39). However, additional studies are required to establish WC cut-off points that are appropriate for identifying children with the greatest risk of metabolic disorders.

Strengths and limitations

One of the main strengths of this study was the large sample of 7 to 15-year-old girls and boys. However, the study population was non-representative. An additional strength is that the study aimed to repeat the data collection yearly, thus we would be able to follow the trends providing some prospective data regarding abdominal obesity and the development of high blood pressure. However, due to its cross-sectional nature, the current evaluation could not provide causal explanations about the associations between abdominal obesity and hypertension at this stage. It should be mentioned that BP reference data for the Hungarian pediatric population is only available for the 11–16-year-old age group (40), so we used US percentiles. Using country-specific reference data could lead to different prevalences in hypertension. The relatively small number of obese subjects may also slightly bias the results, while this obviously affected the statistical power. Using larger sample size in the obese BMI group might lead to significant results.

In conclusion, we have shown that the risk of elevated blood pressure is greater in overweight children with high WC than those with normal WC. Additional studies are required; however, to determine the prognostic importance of abdominal obesity in normal weight and in obese children and to identify the best WC cut-off points for clinical practice.

Acknowledgements

This study was sponsored by National Institute of Food and Nutrition Sciences, Hungary. We thank the research workers, school nurses, school doctors, PE teachers and the participants of the LEARN Study. We are grateful to the community of Obuda and especially for Balazs Orosz for continuous support of this project. We also wish to acknowledge Eva
Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

20. “Fodor József” School Health Association. [Guideline for completing the report about the annual school health examination]; 2001. [In Hungarian.]

