Blood Pressure and Obesity Among Adolescents: A School-Based Population Study in China

Zhong-qiang Cao¹, Liping Zhu², Tao Zhang¹, Li Wu¹ and Youjie Wang¹

BACKGROUND
There is little information regarding the obesity epidemic situation and risk factors of childhood hypertension (HTN) in China. The present study aimed to determine the prevalence of HTN/prehypertension (PHTN), as well as the associated risk factors, among adolescents in Changsha city, China.

METHODS
A total of 88,974 adolescents from 49 middle schools in Changsha city between 12 and 17 years of age were examined during 2009. Body weight, height, and blood pressure (BP) were measured in all adolescents. HTN and PHTN were defined according to sex- and age-specific Chinese reference data. Overweight and obesity were also defined according to sex- and age-specific Chinese reference data.

RESULTS
It was determined that the prevalence of PHTN and HTN were 7.2 and 3.1%, respectively. Furthermore, 14.6% of male adolescents were overweight and 7.0% were obese, whereas 8.6% of female adolescents were overweight and 2.9% were obese. The risk ratio (RR) of HTN were significantly higher in overweight (RR: 2.8, 95% confidence interval (CI): 2.6–3.2) and obese (RR: 8.7, 95% CI: 8.1–9.5) adolescents adjusted for age, sex, and height.

CONCLUSIONS
Chinese reference data were used to evaluate BP and body mass index (BMI) of children and adolescents. Higher prevalence of HTN was associated with higher BMI percentiles. Being overweight or obese markedly increased the risk of both HTN and PHTN among adolescents between 12 and 17 years of age in Changsha city, China.

Keywords: adolescents; blood pressure; body mass index; hypertension; prehypertension

American Journal of Hypertension, advance online publication 16 February 2012; doi:10.1038/ajh.2012.5
All students aged between 12 and 17 years old in the selected 49 schools were eligible to participate in the study. In total, there were 89,348 eligible subjects on the official name lists of the schools involved.

Ethics approval for this research was obtained from the research ethics committee of Tongji Medical College, Huazhong University of Science and Technology.

**Anthropometric measurements.** Body weight was measured to the nearest 0.1 kg using calibrated electronic weighing scales. Participants were asked to step onto the scales and wait for 3 s while the scales determined the correct weight. Height was measured using a wall-mounted stadiometer. Students were asked to stand with their back straight, feet flat, and arms hanging loosely by their sides. Height was measured as the maximum distance from the floor to the vertex of the head, and recorded to the nearest 0.1 cm.

BP was measured using a mercury sphygmomanometer with an appropriate cuff size for children. Systolic BP (SBP) was defined as the onset of the first Korotkoff phase, and diastolic BP (DBP) was defined by the fourth Korotkoff phase. BP measurements were taken 5 min after resting and were approximated to the nearest 2 mm Hg. The measurements were taken while the children were sitting, with the arm at the level of the heart. BP was measured 3 times on the right arm, and a mean value was calculated from these three measurements.

All medical examinations were performed by a trained physician or pediatrician.

**Definition of weight class.** Body mass index (BMI) was calculated using the following formula: BMI = weight (kg)/height$^2$ (m$^2$). Subjects were defined as being overweight (BMI ≥ P$_{85}$ and < P$_{95}$) or obese (BMI ≥ P$_{95}$) by referring to the Body Mass Index Reference Norm for Screening Overweight and Obesity in Chinese Children and Adolescents. Children and adolescents with a BMI below the cut-off point for being overweight were defined as normal weight.

**BP evaluation.** Prehypertension (PHTN) and HTN were defined by either the SBP, DBP, or both values exceeding the 90th and 95th percentiles, of the Recommended Blood Pressure Reference Cut-offs for Chinese Children. The mean BMI was 20.04 and 20.60 for girls and boys, respectively. The mean BMI of boys was higher than that of girls (P < 0.001). The mean BMI both in boys and girls increased with increasing age. As presented in Figure 1, both SBP and DBP increased in parallel with BMI in all age groups, especially in older groups. Higher prevalence of both HTN and PHTN was found among adolescent subjects in the higher BMI percentiles (Figure 2).

**Statistical analysis.** All data analysis was performed using SPSS Statistics 11.0 (SPSS, Chicago, IL) and Microsoft Excel 2003 software. Descriptive statistics for age, height, weight, BMI, SBP, and DBP were calculated by sex and displayed as the mean ± s.d. Significant differences between prevalences were determined using a χ$^2$ test and a post-hoc comparison. Multivariate logistic regressions were used to evaluate the odds ratio (OR) and 95% confidence interval (CI) of PHTN and HTN in overweight or obese subjects, while controlling for sex, age, and height. A recommended formula was used to correct the adjusted OR and 95% CI, because the outcomes of PHTN and HTN in obese girls and boys had clearly exceeded 10%. The significant differences between boys and girls, and between different binary groups, were determined using an unpaired Student’s t-test. Analysis of variance was used to determine the differences between three or more groups. Significance was defined by P < 0.05.

**RESULTS**

Of the 89,348 adolescents enrolled into the study, 88,974 (99.6%) subjects, comprising 44,211 boys and 44,763 girls, took the medical examination.

Mean SBP and DBP by age and sex are presented in Table 1. Both SBP and DBP increased significantly with age throughout all age groups, and SBP increased significantly more than DBP. Boys had a significantly higher SBP and DBP than girls in all age groups (P < 0.01).

Using the criteria of Recommended Blood Pressure Reference Cut-offs for Chinese Children, the prevalences of HTN and PHTN were, respectively, 1.5% (n = 671) and 6.7% (n = 2,990) in girls, and 4.7% (n = 2,069) and 7.6% (n = 3,374) in boys. There was a significant difference in the prevalence of both HTN and PHTN between boys and girls in each age group (P < 0.001) (Table 2).

The mean BMI was 20.04 and 20.60 for girls and boys, respectively. The mean BMI of boys was higher than that of girls (P < 0.001). The mean BMI both in boys and girls increased with increasing age. As presented in Figure 1, both SBP and DBP increased in parallel with BMI in all age groups, especially in older groups. Higher prevalence of both HTN and PHTN was found among adolescent subjects in the higher BMI percentiles (Figure 2).

Table 3 presents the relationship between the prevalence of HTN or PHTN and BMI. In each age group, the prevalence of HTN and PHTN was markedly higher among overweight and obese adolescents. The proportions of adolescents with HTN across the BMI categories were, respectively, 1.0%, 3.3%, and 11.5% in normal weight, overweight, and obese girls, and 2.6%, 7.5%, and 21.7% in normal weight, overweight, and obese boys. The proportions of adolescents with PHTN across the BMI categories were, respectively, 5.6%, 13.3%, and 21.1% in normal weight, overweight, and obese boys, and 5.9%, 11.4%, and 19.6% in normal weight, overweight, and obese boys. Approximately 53.4% of the HTN cases in this study were attributed to excess body weight, and the prevalence of HTN in obese females and males was more than 11- and eightfold greater, respectively, than in normal weight subjects. The average increment of SBP was greater than that of DBP in obese boys (i.e., 11.6 mm Hg vs. 6.2 mm Hg greater than normal weight boys). Similarly, the average increment of SBP was greater than that of DBP in obese girls (i.e., 10.0 mm Hg vs. 5.6 mm Hg greater than normal weight girls).

Table 4 presents the adjusted OR and 95% CI for elevated BP risk among overweight and obese adolescents determined by logistic regression. However, the use of OR in this study was less justified where outcomes of PHTN or HTN in obese girls and boys exceeded 10%. Therefore, we estimated the risk ratio (RR) and 95% CI using a formula to correct the adjusted OR obtained from logistic regression. The results showed that...
HTN and PHTN were both associated with being overweight or obese. The RR for HTN was significantly higher in overweight (RR: 2.8, 95% CI: 2.6–3.2) and obese (RR: 8.7, 95% CI: 8.1–9.5) adolescents adjusted for age, sex, and height compared with the normal weight adolescents. The associations were observed for both SBP and DBP. Furthermore, the association between obesity and elevated BP (i.e., PHTN and HTN) was much stronger for SBP than for DBP among all adolescents in each age group.

### DISCUSSION

We present here a cross-sectional, school-based population study with a relatively large sample size. Our study determined that 3.1 and 7.2% of adolescents in Changsha city of China were hypertensive or prehypertensive, respectively, based on the criteria of Chinese reference data. Both SBP and DBP were strongly associated with BMI in both girls and boys among all age groups. Most importantly, being overweight or obese were both markedly associated with increased risk of HTN and PHTN after adjusting for age, gender, and height.

The criteria for determining normal and abnormal BP in children and adolescents are arbitrary, and to a certain extent, artificial. Most BP cut-offs for children and adolescents are based on percentile tables that establish the normal BP range, and define BP deviations from normal growth curves for specific age groups. The normative data for BP in children and adolescents is the United States-based 2004 Task Force Report Update, which has been widely used in recent US-based or European-based studies. However, whether these data are applicable to children and adolescent populations in other parts of the world, or from different ethnic backgrounds, is unknown. One study conducted on the Hungarian adolescent population demonstrated that this may not be the case, because the SBP of boys across different subgroups was 6–11 mm Hg greater in Hungarian adolescent than that in the United States. Other studies also demonstrated that there are geographical and ethnic variations in BP. Xu et al. reported that the prevalence of HTN in 5,762 Chinese children aged 7–14 years varied greatly using different diagnostic criteria. Thus, in the present study, we used Chinese reference data to evaluate BP in children and adolescents. A comparison of the 90th and 95th percentiles of SBP and DBP between the Chinese and US reference data revealed that the Chinese reference standards are similar to those of the United States in the 5–15 years of age group. However, the Chinese reference data for children younger than 5 years or older than 15 years of age were lower than the United States reference data.

The reference data were established based on the composite data of nine large Chinese epidemiological studies involving 112,227 children aged 3–18 years old. Only the 50th age-specific height percentile of each age group was considered in the Chinese BP reference, which made this BP reference table much simpler than the United States BP table. Nonetheless, these BP reference data proved to be applicable to Chinese adolescents aged between 3 and 18 years. However, there is strong possibility of under- or over-diagnosing HTN in extremely tall and short children of the same age when BP (particularly SBP) values are

### Table 1 | Comparison of mean value of systolic and diastolic BP according to sex and age

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>SBP (mean ± s.d.)</td>
</tr>
<tr>
<td>12</td>
<td>5,397</td>
<td>100.40 ± 9.29</td>
</tr>
<tr>
<td>13</td>
<td>5,143</td>
<td>102.94 ± 9.91</td>
</tr>
<tr>
<td>14</td>
<td>6,742</td>
<td>105.97 ± 10.08</td>
</tr>
<tr>
<td>15</td>
<td>9,454</td>
<td>108.50 ± 10.17</td>
</tr>
<tr>
<td>16</td>
<td>9,675</td>
<td>110.44 ± 10.36</td>
</tr>
<tr>
<td>17</td>
<td>7,800</td>
<td>111.75 ± 10.28</td>
</tr>
</tbody>
</table>

### Table 2 | The prevalence of hypertension and prehypertension by sex and age

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>PHTN, n (%)</td>
<td>HTN, n (%)</td>
</tr>
<tr>
<td>12</td>
<td>5,397</td>
<td>394 (7.3)</td>
<td>95 (1.8)</td>
</tr>
<tr>
<td>13</td>
<td>5,143</td>
<td>550 (10.7)</td>
<td>155 (3.0)</td>
</tr>
<tr>
<td>14</td>
<td>6,742</td>
<td>576 (8.5)</td>
<td>247 (3.7)</td>
</tr>
<tr>
<td>15</td>
<td>9,454</td>
<td>1,110 (11.7)</td>
<td>528 (5.6)</td>
</tr>
<tr>
<td>16</td>
<td>9,675</td>
<td>343 (3.5)</td>
<td>706 (7.3)</td>
</tr>
<tr>
<td>17</td>
<td>7,800</td>
<td>401 (5.1)</td>
<td>338 (4.3)</td>
</tr>
<tr>
<td>Total</td>
<td>44,211</td>
<td>3,374 (7.6)</td>
<td>2,069 (4.7)</td>
</tr>
</tbody>
</table>

HTN, Hypertension; PHTN, Prehypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure.
Blood pressure and Obesity Among Adolescents

not adjusted for height percentiles.\textsuperscript{16} We adjusted for height when calculating the odds of HTN and PHTN by logistic regression analysis, and found the odds for HTN were reduced after adjustment for height.

Numerous studies reported on the relationship between BP and BMI in children of Western countries.\textsuperscript{17–21} Few population-based studies on the association between BP and BMI in children in China are available. In the present study, it was found that being overweight or obese significantly influenced not only the level of BP, but also the prevalence of HTN or PHTN. The influence of BMI was stronger on SBP than DBP in both girls and boys. We demonstrated that SBP and DBP increased across the entire range of BMI, and were not defined by a threshold (Figure 1).

Figure 1 | Body mass index (BMI) categories and mean SBP and DBP by sex for six age groups. DBP, diastolic blood pressure; SBP, systolic blood pressure.

Figure 2 | Prevalence of HTN, PHTN according to BMI percentiles among adolescent girls and boys. BMI, body mass index; HTN, hypertension; PHTN, prehypertension.
Blood pressure and Obesity Among Adolescents

The prevalence of HTN (3.1%) obtained in our study is lower than that of a study conducted in Beijing (9.0%),22 which used the same reference data as our study. The difference may be explained by the greater obesity rate reported in the Beijing study (10.1% vs. 4.9%) and/or the different BP measuring techniques used. Previous estimates of the prevalence of HTN among Chinese children and adolescents range from 3.2–7.2%; however, these studies used various sampling techniques and HTN criteria.22–24 A study of 8,555 Chinese students aged 7–18 years in Shandong province showed that the overall prevalence of relatively high BP (>95th percentile recommended by the Task Force on Blood Pressure Control in Children (1987)) was 24.14% in boys and 22.39% in girls.25 These data were 5–15 times higher than in our study, partly because of the difference in HTN criteria used. It is also impossible for us to compare the prevalence of children with HTN worldwide due to the various definitions of childhood HTN. However, the sex- and age-specific (i.e., 12–17 years old) mean SBP and DBP in the present study are lower than in US children and adolescents.26 Thus, it could be postulated that the prevalence of HTN in the present study is lower than in US children.

It is noteworthy that the prevalences of HTN and PHTN in our study were lower than most studies performed in Western countries. However, the RRs for both systolic and diastolic HTN in overweight and obese adolescents (see Table 4) were much higher than in US or European children.21,27–29 Therefore, we may speculate that overweight and obese adolescents in China may be more susceptible to HTN than the adolescents enrolled in Western studies.

Our study demonstrated that a higher BMI was associated with elevated BP, which was consistent with most previous studies. Our data, however, were cross-sectional, and therefore no conclusions regarding causality can be drawn. The association between obesity and childhood HTN is controversial.
Chiolero et al. reported that BP level has not increased during the past few decades to parallel the concomitant epidemic of pediatric obesity. Willig et al. reported that total fat mass and body weight are not associated with HTN risk in healthy children after removing the association with height. A study conducted in Anhui of China also showed no relationship between measures of adiposity and DBP among 12–18 years old rural Chinese children. The variations in adiposity measures, socioeconomic status, dietary intake, and physical activity levels may influence the difference in results of these studies.

A significant sex difference in BP was found among subjects in this study. The age-specific BP values (SBP and DBP) were higher among boys than girls, and boys had a higher prevalence of HTN than girls in the same age and BMI percentiles. Male children typically have higher BP than female children, and elevated BP was more prevalent among boys than girls. Although the exact mechanisms responsible for the sex differences in BP are not clear, there is significant evidence that the sex steroids, such as testosterone, secreted during puberty play an important role. Shankar et al. found that the rates of increase in SBP among boys during pubertal growth were 3–6 times greater compared with those in pre-puberty while it was 2–4 times greater among pubertal girls.

Studies using ambulatory BP monitoring techniques in children have shown that with increasing age, BP increased in both boys and girls. However, after the onset of puberty, boys exhibit a higher BP increment than do age-matched girls. We also observed the same phenomenon in our study: at ages 12–14 years, boys had higher SBP than girls by 2.6–5.8 mm Hg; and at ages 15–17 years, boys had higher SBP than girls by 7.9–10.0 mm Hg.

The present study was a large, population-based study with a fair participation rate, ensuring that the results were representative of the general population. Physicians and pediatricians were trained to perform standardized BP measurements, which had a good level of accuracy and validity. However, our study did have some limitations that need to be considered. BP was determined on only a single occasion. It has been reported that measuring BP on two or three different visits decreased the prevalence of elevated BP. Thus, the prevalence of HTN or PHTN was likely overestimated in the present study. However, most other epidemiological studies on BP in children and adolescents also relied on single-visit readings. DBP was defined by the K-4 Korotkoff sound in our study, while The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents 2004 favors the K-5 Korotkoff sound (i.e., disappearance of Korotkoff sound) for DBP. We adopted the K-4 Korotkoff sound in this study because it is more reliable and reproducible than K-5, and it was easy for us to control the measurement error in our large sample size. A study by Liang et al. showed that the prevalence rates of HTN were 5.0% when DBP was measured using K4, and 2.4% when DBP was measured using K-5, in school-aged Chinese children. Therefore, the HTN rate might be overestimated in our study.

In conclusion, Chinese reference data were used to evaluate BP and BMI of children and adolescents. Higher prevalence of HTN was associated with higher BMI percentiles. Being overweight or obese markedly increased the risk of both HTN and PHTN among adolescents between 12 and 17 years of age in Changhai city, China.

Acknowledgments: The study was funded by NECT Program 07-0333 and National Natural Science Foundation of China, Project No: 30671733. We thank Bureau of Education of Changhai city for organizing the medical examination for the children and adolescents in junior and senior high school. Grant support: NECT Program 07-0333, National Natural Science Foundation of China, Project No: 30671733.

Disclosure: The authors declared no conflict of interest.


