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ORIGINAL ARTICLE

Gender-specific prevalence and associated risk factors of prehypertension among rural children and adolescents in Northeast China: a cross-sectional study

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Abstract Little is known about the prevalence and risk profile of prehypertension among Chinese children and adolescents. The aim of the present study was to investigate the prehypertensive status and its associated risk factors among rural Chinese children and adolescents. We conducted a cross-sectional study including 5,245 children and adolescents (2,732 boys and 2,513 girls) aged 5–18 years in Northeast China. Main anthropometric data and related information were collected. The overall prevalence of prehypertension and hypertension was 15 % and 20.2 %, respectively. The prevalence of prehypertension among boys was 15.7 %, compared to that of 14.2 % among girls (P=0.256). After adjusting for age, race, weight status, waist circumference, triceps skinfold, family income, smoking and drinking status, boys aged 12–14 and 15–18 years had a 2.86- and 5.97-fold risk of prehypertension, respectively, compared to those aged 5–8 years. Overweight and obese boys had an increased risk of prehypertension in comparison to those with normal weight (overweight: odds ratio [OR]=1.837, 95 % confidence interval [CI] 1.321–2.556; obese: OR=2.941, 95 % CI 1.783–4.851). A larger triceps skinfold (≥90th percentile) was significantly related to increased odds of prehypertension (OR=2.32; 95 % CI, 1.516–3.55) among boys. For girls, only older age was found to be a risk factor for prehypertension. *Conclusion*: Pediatric prehypertension is highly prevalent in rural Northeast China. The risk factors for prehypertension differed among boys and girls. A more comprehensive risk profile of prehypertension among children and adolescents needs to be established for early prevention.

Keywords Prehypertension · Prevalence · Children · Adolescents · Risk

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Introduction

High blood pressure (BP) is a clearly established public health problem worldwide. It has been shown that hypertension may begin in childhood and adolescence, and tracks into adulthood [3, 25, 39]. Pediatric hypertension is associated with initial cardiac and renal alterations as well as target organ damages [11, 14, 17, 34]. Given the increasing prevalence of pediatric hypertension and the potential future impacts of uncontrolled high BP on this segment of the population, early detection and intervention is of key importance.

In order to call needed attention to the excess risk resulting from elevated BP, the concept of prehypertension has been brought to light for children and adolescents in accordance with what has been proposed for adults [4]. In recent years, prehypertension has been found to be highly prevalent among children and adolescents [2, 9, 27]. Detecting the risk factors associated with pediatric prehypertension would help to identify those to be targeted for early management and the reduction of cardiovascular outcomes. Weight status, such as overweight and obesity, has been found to be a risk factor for childhood and adolescent prehypertension, which is similar to reports from adult studies [12, 20]. Although numerous studies have focused on pediatric hypertension lately, epidemiological data on the prevalence and risk profile of prehypertension among rural children and adolescents are limited, especially in East Asian populations. Therefore, we performed this study to investigate the prehypertensive status and its related risk factors in a large sample of Chinese children and adolescents by gender.

Materials and methods

Study population

The procedures followed were in accordance with ethical standards of the committee on human experimentation of China Medical University. We conducted a cross-sectional study from July 2010 to January 2011 in rural areas of Shenyang, Liaoning Province, aiming to assess the gender-specific prevalence and associated risk factors of prehypertension among rural Chinese children and adolescents. A total of 7,637 students aged 5–18 years were recruited with an overall response rate of 89 %. We adopted a multistage, stratified cluster sampling scheme and included samples from the northern, southern, western, and eastern regions of rural Shenyang. Three public schools were selected randomly from each geographic region. Students from all the classes in each school were included. In total, 12 public schools from these regions and 162 classes were selected. The participants who failed to finish the process or provided incomplete data needed in the present study were excluded. Forty-four participants known to have chronic heart, renal or hepatic disease were also excluded, leading to a sample size of 5,245 students for final analysis. Figure 1 shows the recruitment process and the population derivation. Informed consent was obtained from the parents of all subjects.

Blood pressure measurements

According to the standardized technique described by the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents [24], BP was measured using a mercury sphygmomanometer by well-trained personnel after the subject had rested for at least 5 min. The appropriate cuff size was chosen based on the arm circumference. The participants were advised to avoid coffee, tea, and exercise for at least 30 min before the measurement and remained seated with the arm supported at the level of the heart during the measurement. The average of two measurements was used in the analysis.

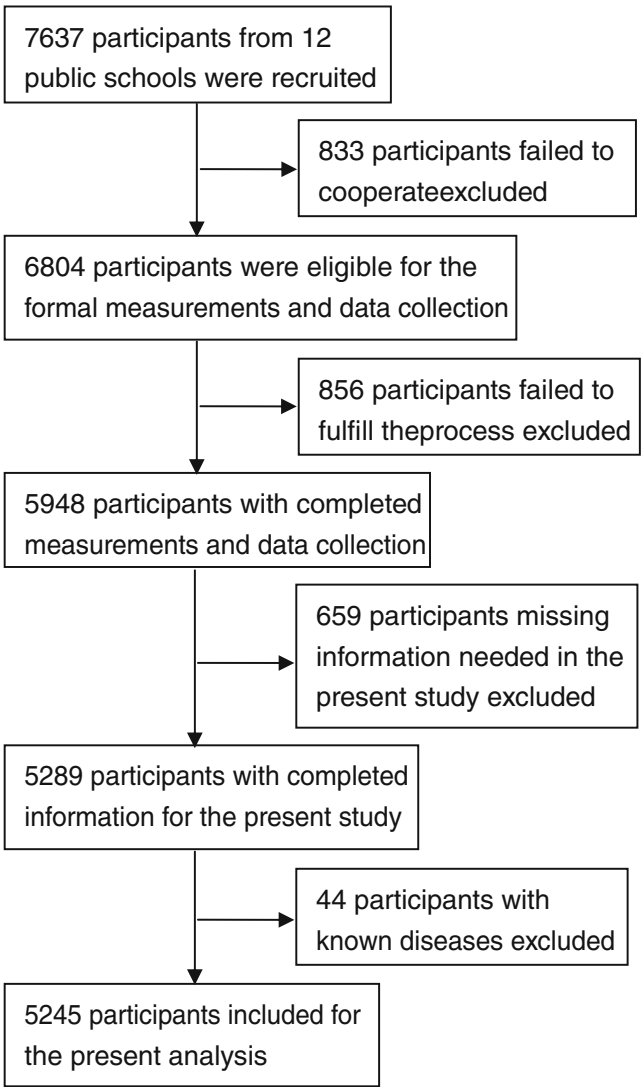

Fig. 1 Flow chart of participant recruitment and derivation

Variables

Anthropometric data including height, body weight, waist circumference (WC), and triceps skinfold of all participants were evaluated using standard protocols by trained personnel (cardiologists, doctors of internal medicine, and pediatricians). Weight and height were measured to the nearest

0.1 kg and 0.5 cm, respectively, with the participants in light clothing and on bare feet. WC was measured at the level of the umbilicus using a non-elastic tape (to the nearest 0.5 cm) with the students standing at the end of normal expiration. Triceps skinfold was measured using a fat caliper to the nearest 1 mm. Body mass index (BMI) was calculated using the formula: weight (kg)/height^2 (m^2). Information on personal characteristics, such as age, gender, and race, were collected using a questionnaire.

Definitions

According to The Fourth Report [24], prehypertension was defined as systolic BP (SBP) or diastolic BP (DBP) levels between the 90th and 95th percentile for gender, age and height, or if BP levels ≥120/80 mmHg but <95th percentile. Weight class was defined according to the tables of the International Obesity Task Force based on data from the U.S., Brazil, the Netherlands, Hong Kong, United Kingdom and Singapore [5]. We chose to use the 90th percentile to define abnormal WC and triceps skinfold due to the absence of internationally accepted percentile cut-offs to identify abnormalities in children and adolescents.

Statistical analysis

Continuous variables were expressed as medians and ranges, and categorical variables were described as frequencies and percentages. Comparisons between continuous and categorical variables were analyzed by the non-parametric test and the chi-square test, respectively. Multivariate logistic regression analyses adjusted for age, race, weight status, WC, triceps skinfold, family income, smoking and drinking status were used to test significant determinants of prehypertension status by gender, with odds ratios (ORs) and 95 % confidence intervals (CIs) calculated. A P value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS software version 17.0.

Results

The present study consisted of 2,732 boys and 2,513 girls aged 5–18 years. Of the 5,245 participants, we found the overall prevalence of prehypertension and hypertension to be 15 % and 20.2 %, respectively. The prevalence of prehypertension among boys was 15.7 %, compared to 14.2 % among girls (P=0.256).

Table 1 presents the prevalence of prehypertension in different groups. Among boys, the prevalence increased with age from 10.1 % (5–8 years old) to 31.3 % (15–18 years old). Prehypertension was most prevalent among 15- to 18-year-olds of both genders. The prevalence among girls aged 9–11 years was slightly lower than that of 5- to 8-year-olds. Prehypertension was more common among overweight and

Table 1 Prevalence of prehypertension among children and adolescents in Liaoning Province, China

	Boys (n=2,732)	P value <0.001	Girls (n=2,513)	P value <0.001	Total (n=5,245)	P value <0.001
Age (years)						
5–8	60 (10.1)		60 (11)		120 (10.5)	
9–11	98 (10.2)		78 (9.1)		176 (9.7)	
12–14	186 (20.6)		155 (18.1)		341 (19.4)	
15–18	85 (31.1)		65 (25.5)		150 (28.4)	
Race		0.616		0.65		0.976
Han	350 (15.5)		294 (14.4)		644 (15)	
Non-Han	79 (16.5)		64 (13.6)		143 (15)	
Weight status[a]		0.015		0.184		0.166
Normal	289 (14.5)		304 (14.5)		593 (14.5)	
Overweight	90 (19)		48 (14.1)		138 (16.9)	
Obesity	50 (19.1)		6 (7.3)		56 (16.3)	
Family income (CNY/month)		0.53		0.397		0.997
<2,000	97 (14.7)		97 (15.4)		194 (15.1)	
2,000–5,000	275 (16.3)		201 (13.5)		476 (15)	
≥5,000	57 (14.7)		60 (15.3)		117 (15)	

Data are expressed as n (%)

CNY, China yuan (1CNY=US$0.157)

[a] Weight status was defined according to the International Obesity Task Force [5]

obese boys than those with normal weight, while it showed the opposite results for the girls.

Both mean SBP and DBP increased with age, irrespective of gender and BP status (Figs. 1 and 2). Prehypertensive boys had a significantly ($P<0.05$) higher mean SBP compared to their female counterparts aged 14–16 years. However, a higher mean DBP was observed among prehypertensive girls aged 13–14 years than their male counterparts ($P<0.05$).

Table 2 presents the baseline characteristics of participants with normotension and prehypertension. Prehypertensive participants were older and had higher mean levels of BMI and WC when compared with participants of both genders with normal BP (all $P<0.05$). A significantly higher mean triceps skinfold level was only observed among prehypertensive boys.

Table 3 presents the multivariable logistic regression analysis of risk factors related to prehypertension by gender. Among boys, those aged 12–14 and 15–18 years were associated with a 2.86- and 5.97-fold risk of prehypertension, respectively, compared to those aged 5–8 years. Overweight and obese boys had an increased risk of prehypertension in comparison to those with normal weight (overweight: OR=1.837, 95 % CI 1.321–2.556; obesity: OR=2.941, 95 % CI 1.783–4.851). A larger triceps skinfold (≥90th percentile) was significantly related to increased odds of prehypertension among boys (OR=2.32; 95 % CI, 1.516–3.55). For girls, older age was found to be a risk factor for prehypertension. An additional analysis using the 95th percentile to define an abnormal triceps skinfold value indicated that a larger triceps skinfold was associated with an increased risk of prehypertension among girls (OR=1.945; 95 % CI, 1.125–3.364, $P=0.017$).

Discussion

In a large cross-sectional study among children and adolescents in rural China, we found a relatively high prevalence of prehypertension. Risk factors, such as older age and

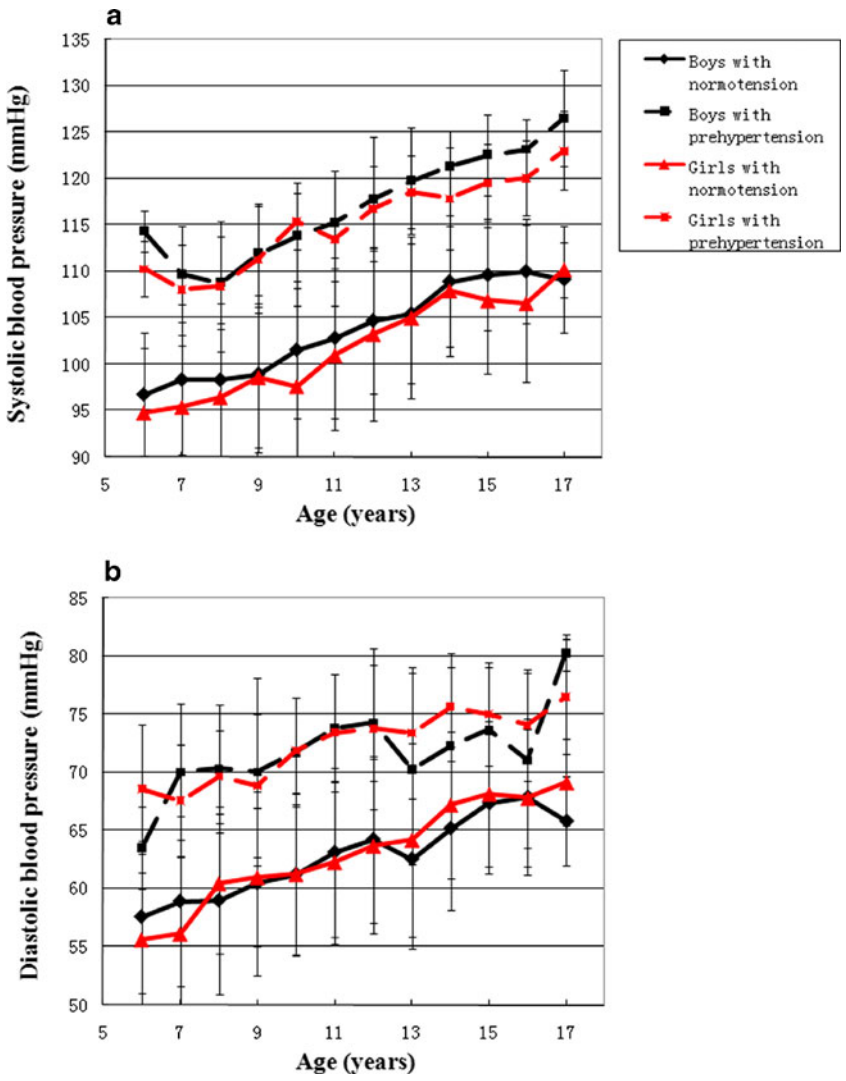

Fig. 2 Blood pressure of participants with normotension and prehypertension

Table 2 Baseline characteristics of participants with normotension and prehypertension

	Boys (*n*=2,732)			Girls (*n*=2,513)		
	Normotension	Prehypertension	*P* value	Normotension	Prehypertension	*P* value
Age (years)	10 (6–17)	13 (6–17)	<0.001	10 (5–17)	13 (5–18)	<0.001
Race (Han)	1,481 (83.4)	350 (81.6)	0.371	1,330 (82)	294 (82.1)	0.955
Weight (kg)	34 (17–92.5)	49 (20–98)	<0.001	34 (17–87)	44 (20–75)	<0.001
Height (cm)	140 (107–185)	156 (104–187)	<0.001	141 (105–173)	152.5(115–172)	<0.001
BMI (kg/m^2)	17.4 (10.7–41.6)	19.7 (11–40.5)	<0.001	17.3 (11.6–45.7)	18.4 (13.7–28.7)	<0.001
Weight status			<0.001			0.315
Normal	1,446 (81.4)	289 (67.4)		1,403 (86.5)	304 (84.9)	
Overweight	245 (13.8)	90 (21)		179 (11)	48 (13.4)	
Obesity	85 (4.8)	50 (11.7)		40 (2.5)	6 (1.7)	
WC (cm)	59 (42–102)	67 (46–104)	<0.001	58 (41–96)	62 (42–90)	<0.001
Triceps skinfold (mm)	7.5 (2–35)	10 (3–40)	<0.001	9 (2–40)	9.3 (2–28)	0.206
SBP (mmHg)	102.5 (65–119.5)	120 (90–132.5)	<0.001	100 (65–119.5)	117.5 (90–127.5)	<0.001
DBP (mmHg)	62.5 (30–77.5)	73 (46–82.5)	<0.001	62 (40–79)	73 (55–82)	<0.001

Data are expressed as medians (ranges) or as *n* (%)

BMI body mass index, *WC* waist circumference, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

overweight or obesity, were identified and found to be different among boys and girls.

The high prevalence of pediatric prehypertension was not unexpected. According to the National Health and Nutrition

Table 3 Associations between prehypertension and related factors in multivariate logistic regression models

	Boys (*n*=2,732)			Girls (*n*=2,513)		
	OR	95 % CI	*P* value	OR	95 % CI	*P* value
Age (years)						
5–8	1.000 (ref)			1.000 (ref)		
9–11	1.199	0.843–1.706	0.313	0.789	0.549–1.134	0.2
12–14	2.862	2.033–4.03	<0.001	2.029	1.447–2.845	<0.001
15–18	5.966	3.916–9.09	<0.001	3.466	2.279–5.27	<0.001
Race						
Han	1.000(ref)			1.000(ref)		
Non-Han	1.098	0.824–1.464	0.523	0.965	0.71–1.313	0.823
Weight status						
Normal	1.000(ref)			1.000 (ref)		
Overweight	1.837	1.321–2.556	<0.001	1.12	0.752–1.668	0.578
Obesity	2.941	1.783–4.851	<0.001	0.744	0.288–1.921	0.541
WC (cm)						
<90th	1.000 (ref)			1.000 (ref)		
≥90th	0.859	0.563–1.312	0.483	1.318	0.709–2.45	0.383
Triceps skinfold (mm)						
<90th	1.000(ref)			1.000 (ref)		
≥90th	2.32	1.516–3.55	<0.001	1.405	0.945–2.089	0.093
Family income (CNY/month)						
<2,000	1.000(ref)			1.000 (ref)		
2,000–5,000	1.007	0.768–1.321	0.957	0.83	0.629–1.094	0.185
≥5,000	0.985	0.674–1.438	0.936	0.875	0.603–1.268	0.479

Adjusted for age, race, weight status, waist circumference, triceps skinfold, family income, smoking and drinking status

OR odds ratio, *95% CI* 95 % confidence interval, *WC* waist circumference, *CNY* China yuan (1 CNY=US$0.157)

Examination Surveys (NHANES), the mean SBP and DBP raised by 1.4/3.3 mmHg from 1988–1994 to 1999–2000 [23]. The prevalence of prehypertension among children and adolescents in China increased dramatically from 1991 to 2004, with an average relative increase of 6.38 % [18]. In a study of 1,829 American students aged 5–17 years, the prevalence of prehypertension was found to be 16.7 % [22]. In addition, pediatric prehypertension was also highly prevalent in urban Nigeria and Northern Greece [6, 26]. The high prevalence we observed in this acknowledged high salt-intake area was not surprising.

A linear progression in the risk of adulthood hypertension with increasing BP values in children and adolescents has been observed [35], and pediatric prehypertension has been associated with risks of cardiovascular diseases such as left ventricular hypertrophy [34]. It is important to investigate the prevalence of prehypertension in children and adolescents, since it varies from area to area and it facilitates the implementation of public strategies for early management. However, it has been reported that almost 90 % of the prehypertensive cases in children and adolescents are undiagnosed [13].

Consistent with other studies [1, 7, 15, 22], we found that BP generally increased with age in both genders. Moore et al. reported that the risk of being prehypertensive was increased 2.56-fold in 12- to 17-year-old girls compared to 5- to 11-year-old girls, while it was 6.84-fold greater among boys after adjusting for BMI and race [22]. We also observed a stronger association between age and prehypertension among males. This gender-related result might be related to hormonal changes at different developing stages in the two genders.

The strong association between BMI and BP has been demonstrated in many previous studies both in children and adults [6, 7, 12, 19–22, 33, 40]. Weight loss in overweight children and adolescents has been shown to be related to a reduction of BP [10, 36]. The present study indicated that obese and overweight boys were at 3- and 2-fold increased risk of prehypertension, respectively, compared to their normal weight counterparts, which was similar to the results from the USA [22]. However, we failed to detect this association among girls. The gender-specific relationship between weight status and BP among the pediatric population has been reported in limited studies. Being overweight was not associated with prehypertension among rural Canadian girls aged 4–17 years [32], and a higher risk of being hypertensive among overweight boys than girls was found among a Portuguese population [30]. While in a prospective study, a significant effect of change in BMI on future DBP z scores was only observed in girls [8]. Since the mechanisms of obesity-associated hypertension include many aspects, such as upper body fat distribution and stimulation of the sympathetic nervous system [16], which might differ between the two genders due to diverse life habits and different gonadal hormones [37], the gender-related differences are quite possible. Wang et al. found that there were important differences in measurements of insulin resistance between males and females with the onset of puberty [38]. This explanation might be a reason for the gender-specific results. However, due to complicated interactional factors and various results, the definite mechanism of the gender-specific difference is still not fully understood. The gender differences in obesity-associated high BP needs attention and should be fully considered when exploring the mechanism or implementing treatment strategies.

In addition, we also found a positive association between triceps skinfold and prehypertension among boys, and also girls (using 95th percentile as cut-off point), indicating the potential value of skinfold for predicting elevated BP. Although a few studies have confirmed the relationship between skinfold and BP among children and adolescents [28, 29, 31], a lack of uniformed international reference values and the inconvenience involved during the measurement might compromise its clinical utilization.

There are several limitations in the present study. First, the result we report is the prevalence of "point-prehypertension." High BP should only be established reliably based on multiple measurements on at least three different occasions with participants fully relaxed. Thus, the reproducibility might not be ideal and there might be an overestimation of the prevalence in our study. Second, our data were obtained from a cross-sectional study in Northeast China and are not representative of children and adolescents throughout the whole country. Extrapolating the conclusions to the general population should be done cautiously. Third, there might be important confounders, such as pubertal maturation, food choices, and salt intake, which were not taken into account in our analysis due to limited and incomplete data.

In summary, prehypertension is highly prevalent among rural children and adolescents in Northeast China. Older age was found to be a risk factor for prehypertension among both genders. Being overweight or obese and having a larger triceps skinfold were associated with an increased risk of prehypertension in boys. Establishment of a more comprehensive risk profile of prehypertension including diet, lifestyle, and environment among children and adolescents for early prevention is an area for future studies.

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Conflict of interest None

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