Original Article

Prevalence and Correlates of Elevated Blood Pressure in Chinese Children Aged 6-13 Years: a Nationwide School-Based Survey*

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Abstract

Objective To estimate the prevalence of elevated blood pressure (EBP) in Chinese children and identify individual and family factors associated with EBP.

Methods A nationwide cross-sectional study was conducted in 2010 using stratified cluster sampling. Participants' blood pressure was measured, and their parents completed a questionnaire on personal and family characteristics. Prevalence and correlates of EBP were assessed.

Results Among a total of 24,333 participants, 20.2% of boys and 16.3% of girls had EBP. The prevalence of EBP increased with the ascending trend of waist circumference, Waist-to-height ratio, and body mass index. The adjusted prevalence ratios (aPRs) for obese boys and girls were 2.50 and 2.97, respectively. Fewer urban boys (16.2%) had EBP than rural boys (21.7%). Boys with a family history of hypertension were 12% more likely to have EBP. Children whose mothers received a college education tended to have lower likelihood of EBP; with an aPR was 0.85 among boys and 0.78 among girls.

Conclusion EBP is common among obese students and those who have a family history of hypertension. A negative association between mothers' education levels and EBP risk in children was found.

Key words: Elevated blood pressure; Waist circumference; Waist-to-height ratio; Body mass index; Children; Cross-sectional study; China

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INTRODUCTION

Elevated blood pressure (EBP) is a leading cause of premature death in China[1]. Globally, hypertension, along with obesity, is a major risk factor for cardiovascular diseases in adults, which are major causes of premature death in both high-income as well as low-and middle-income countries[2-3]. The prevalence of these two intertwined conditions is also increasing among the pediatric population[4]. EBP in childhood predicts cardiovascular risk later in life[5]. Identifying

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childhood hypertension and its risk factors could contribute to better prevention of hypertension and cardiovascular disorders in adults[6].

Childhood obesity, an unintended consequence of rapid economic growth in the past several decades, has become widespread in China. The overall percentage of children and adolescents aged 7-17 years who were overweight and obese increased by 15.8% in one decade, from 5.7% in 1992 to 6.6% in 2002[7]. It further increased to 19.0% of boys and 10.9% of girls in 2010[8]. Obesity is closely linked to hypertension[8-10]. Earlier national data showed that the prevalence of hypertension among children aged 6-17 years increased from 7.1% in 1991 to 14.6% in 2004[11]. A study conducted in 2010 in Shandong Province in eastern China showed higher prevalence of hypertension: 26.2% of boys and 19.8% of girls[12]. The literature on EBP among Chinese children is sparse, and the factors associated with children's EBP are not well understood. We analyzed a national sample from a 2010 survey in order to, (1) estimate the prevalence of EBP in Chinese school-age children and (2) identify individual and family factors associated with EBP.

METHODS

Study Design and Subjects

This nationwide cross-sectional study was conducted in 2010. Subjects were recruited using a multi-stage cluster random sampling method in school-age children. In the first stage of sampling, eight provinces in China were selected including: Inner Mongolia, Jiangsu, Anhui, Shandong, Hunan, Guangxi, Chongqing, and Gansu. The counties in each province were sorted by average per-capita gross domestic product, and were stratified into three strata by economic level (low, middle, and high). The second stage involved randomly selecting three counties or county-level cities in each stratum. In the third stage, in each selected county, one urban and one rural elementary school were randomly selected; and in each school, two or three classes were randomly selected from each grade. Finally, all students in these selected classes (grades 1-6 and aged 6-13 years) were eligible for participation. The students who were absent on the day of the physical examination or did not complete the questionnaires were excluded. The overall participation rate was 90.0%.

The survey included two components: a physical examination of the subjects and a questionnaire interview with a parent or guardian of the participating students. The parent or guardian filled out a self-administered questionnaire under the guidance of staff from local branches of the Center for Disease Control and Prevention (CDC). The questionnaire elicited information on the subject's age and sex, mother's education level, and family history of hypertension. Mother's education level was used as a proxy for socioeconomic status, which was divided into three categories: (1) ≤6 years of schooling (elementary school or lower); (2) 7-12 years of schooling (high school); and (3) ≥13 years of schooling (junior college or higher). The family history of hypertension was defined as a history of diagnosed hypertension in any biological parent or grandparent. Ethics approval was obtained from the Ethics Committee of China CDC (IRB code: 201020). Informed consent forms were signed by the subjects' parents or guardians.

Health Measurements

The physical examinations were performed by health professionals from local county CDCs. Blood pressure (BP) was measured in the right arm using a mercury sphygmomanometer with appropriate cuff size (7, 9, or 12 cm) after the subject had been seated quietly for five min, making sure that the cuff covered at least two-thirds of the upper arm. Korotkoff phases 1 and 5 were used for defining systolic BP (SBP) and diastolic BP (DBP), respectively. Two readings were obtained within a 2-min interval. If the pressure readings differed by ≥6 mmHg, a third measurement was performed. The mean of the last two measurements was used in the analysis. The definition of EBP in children is based on the normative distribution of BP in healthy children. EBP was defined as SBP or DBP or both equal to or above the 95th percentile for children of the same age, gender, and height according to *The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents*[13].

Body height and weight of the participants were measured using standard protocols, without shoes and outerwear. Height was measured to the nearest 0.1 cm on a column stadiometer and weight to the nearest 0.1 kg on a digital scale. Waist circumference (WC) was measured to the nearest 0.1 cm by a nonelastic flexible tape. With the participant in a standing position, the tape was applied horizontally midway between the lowest rib margin and the iliac crest. Waist-to-height ratio (WtHR) was calculated as

waist circumference (cm)/height (cm). Both WC and WtHR were categorized into quartiles by sex. Body mass index (BMI) was calculated as weight (kg)/height squared (m^2). BMI that is less than the 5th percentile for children of the same age and gender is considered underweight, above the 95th percentile as obese, and between the 85th and 95th percentiles as overweight[14].

Statistical Analysis

Participants' personal and family characteristics were compared between boys and girls using student's *t*-test or Wilcoxon rank-sum test for continuous variables and χ^2 test for categorical variables. All *P*-values reported are two-sided. Mean and standard error (SE) of SBP and DBP were calculated by age, WC, WtHR, BMI, residence, family history of hypertension, and mother's education.

The sex-specific prevalence and 95% confidence interval (CI) of EBP were calculated by age group. The relationship between EBP and WC, WtHR, and BMI were assessed using generalized linear models adjusting for age, and the relationship between EBP and residence, family history of hypertension, and mother's education was assessed adjusting for age and BMI. The model distribution type with the 'binomial distribution', and the 'logit' link function in the model is chosen. All analyses were performed using SAS software, version 9.3 (SAS Institute Inc., Carey, NC, USA).

RESULTS

Personal and Family Characteristics

A total of 24,333 children (13,006 boys and 11,327 girls) were included in the analysis (mean age was 9.3 years (range 6-13); mean height, 133.0 cm; mean weight, 30.3 kg; mean WC, 57.8 cm; mean WtHR, 0.43; and mean BMI, 16.8 kg/m^2). About 40% of children had at least one parent or grandparent with hypertension. The majority of the children's mothers received a high school education. On average, boys were taller and heavier than girls, and had larger WC, WtHR, and BMI than girls (all *P*<0.05). There were no statistical differences between boys and girls with respect to family history of hypertension and mothers' educational level (Table 1).

Systolic and Diastolic Blood Pressure

Overall, SBP and DBP increased with age, WC, WtHR, and BMI status in both boys and girls (all *P*<0.05) (Table 2). Children residing in rural areas had higher age- and BMI-adjusted SBP and DBP than those residing in urban areas (*P*<0.05). A family history of hypertension was more likely to contribute to higher age- and BMI-adjusted DBP in boys and age- and BMI-adjusted SBP and DBP in girls (*P*<0.05). SBP and DBP in boys and SBP in girls decreased as of mother's education level decreased after adjusting for age and BMI (*P*<0.05).

Elevated Blood Pressure

The overall prevalence of EBP among children in this study was 18.4%; 20.2% for boys and 16.3% for girls with children aged 10-11 years having the highest prevalence (Table 3). The prevalence of EBP increased with the ascending trend of WC, WtHR, and BMI in both boys and girls. The prevalence of EBP increased from 17.2% in boys with normal weight to 26.1% for overweight boys and 49.3% for

Table 1. Characteristics of Chinese School-age Children, 2010

Characteristic	Total (*n*=24,333)	Boys (*n*=13,006)	Girls (*n*=11,327)	*P*-value
Age (mean±SD), y	9.3±1.8	9.3±1.8	9.2±1.8	0.16
Height (mean±SD), cm	133.0±11.4	133.2±11.1	132.8±11.8	<0.01
Weight (mean±SD), kg	30.3±8.6	30.9±8.9	29.5±8.3	<0.001
Waist circumference (mean±SD), cm	57.8±7.8	59.0±8.3	56.4±7.0	<0.001
Waist to Height Ratio (mean±SD)	0.43±0.05	0.44±0.05	0.42±0.04	<0.001
BMI (mean±SD), kg/m^2	16.8±2.6	17.1±2.8	16.5±2.4	<0.001
Family history of hypertension	9636 (39.6)	5135 (39.5)	4501 (39.7)	0.69
Mother's education level				0.43
Elementary school or lower	5908 (24.3)	3179 (24.4)	2729 (24.1)	
High school	15034 (61.8)	8031 (61.8)	7003 (61.8)	
Junior college and higher	3391 (13.9)	1796 (13.8)	1595 (14.1)	

Note. SD: standard deviation.

Table 2. Systolic Blood Pressure and Diastolic Blood Pressure in Chinese School-age Children, 2010

Characteristic	Boys (*n*=13,006)					Girls (*n*=11,327)				
	n	SBP		DBP		*n*	SBP		DBP	
		Mean (SE)	Median	Mean (SE)	Median		Mean (SE)	Median	Mean (SE)	Median
Age (years)										
6-7	3831	100.3 (1.5)	100	65.6 (1.1)	63	3329	98.9 (1.2)	98	64.7 (0.9)	62
8-9	4118	103.2 (1.3)	100	67.4 (0.8)	66	3689	101.5 (1.3)	100	66.8 (0.8)	65
10-11	4179	106.9 (1.8)	104	70.4 (1.2)	69	3625	105.9 (1.5)	103	69.7 (1.1)	69
12-13	878	107.7 (1.8)	107	70.8 (1.3)	70	684	106.8 (1.3)	108	69.6 (0.9)	70
Total (6-13)	13,006	104.6 (1.5)	101	68.6 (0.9)	67	11,327	103.4 (1.1)	100	67.8 (0.7)	66
P-value		<0.001		<0.001			<0.001		<0.001	
Waist circumference (quartile), cm [†]										
Q1	3198	99.3 (0.8)	100	65.2 (0.5)	64	2783	98.5 (0.8)	99	64.8 (0.6)	64
Q2	3218	102.0 (1.2)	100	67.0 (0.8)	65	2848	100.1 (0.7)	100	65.1 (0.7)	65
Q3	3311	104.4 (1.4)	101	68.4 (1.0)	68	2805	103.9 (1.6)	100	68.2 (1.1)	67
Q4	3279	109.4 (1.9)	107	71.2 (1.3)	70	2891	107.0 (1.5)	103	70.5 (0.9)	69
P-value		<0.001		<0.001			<0.001		<0.001	
Waist to height ratio (quartile) [†]										
Q1	3249	101.3 (1.0)	100	66.6 (0.7)	65	2821	99.7 (1.0)	100	65.6(0.7)	65
Q2	3249	101.6 (1.2)	100	66.8 (0.7)	65	2841	100.4 (0.9)	100	65.8 (0.7)	65
Q3	3253	103.3 (1.6)	100	67.4 (1.2)	66	2830	103.0 (1.8)	100	67.5 (1.2)	66
Q4	3255	108.5 (2.0)	106	70.7 (1.3)	70	2835	105.6 (1.3)	102	69.3 (0.7)	69
P-value		<0.001		<0.001			<0.001		<0.001	
BMI category [†]										
Underweight	837	98.5 (1.7)	100	66.1 (1.4)	65	885	98.4 (1.0)	99	65.1 (0.8)	64
Normal	9663	102.8 (1.3)	100	67.2 (0.9)	65	9246	101.7 (1.2)	100	66.6 (0.7)	65

Continued

Characteristic	Boys (*n*=13,006)					Girls (*n*=11,327)				
	n	SBP		DBP		*n*	SBP		DBP	
		Mean (SE)	Median	Mean (SE)	Median		Mean (SE)	Median	Mean (SE)	Median
Overweight	1448	106.9 (1.8)	105	70.0 (1.3)	70	875	107.8 (1.5)	106	71.6 (1.2)	70
Obese	1058	114.5 (2.1)	110	75.1 (1.5)	71	321	113.3 (2.0)	110	75.1 (1.5)	71
P-value		<0.001		<0.001			<0.001		<0.001	
Residence [‡]										
Urban	7126	103.3 (1.3)	101	67.1 (0.9)	66	6177	101.4 (1.1)	100	66.4 (0.8)	66
Rural	5880	104.1 (1.7)	101	68.4 (1.1)	67	5150	102.5 (1.4)	100	67.3 (0.8)	66
P-value		<0.001		<0.001			<0.001		<0.001	
Family history of hypertension [‡]										
Yes	5135	104.1 (1.2)	102	68.5 (0.7)	68	4501	103.0 (1.0)	101	67.4 (0.7)	67
No	7871	103.8 (1.5)	100	67.9 (1.0)	66	6826	101.9 (1.2)	100	66.9 (0.7)	65
P-value		0.12		<0.001			<0.001		<0.01	
Mother's education level [‡]										
Elementary school or lower (1)	3179	104.9 (1.9)	100	68.7 (1.2)	67	2729	102.7 (1.6)	100	66.9 (0.9)	66
High school (2)	8031	103.6 (1.1)	101	67.8 (0.8)	67	7003	102.1 (0.9)	100	67.2 (0.6)	66
Junior college and higher (3)	1796	102.3 (0.8)	102	67.0 (0.7)	67	1595	101.4 (1.0)	100	67.1 (0.8)	66
P-value (1) *vs.* (2)		<0.001		<0.001			<0.01		0.14	
P-value (1) *vs.* (3)		<0.001		<0.001			<0.01		0.66	

Note. SE: standard error; BMI: body mass index. [†]Adjusted for age; [‡]Adjusted for age and BMI.

Table 3. Correlates of Elevated Blood Pressure in Chinese School-age Children, 2010

Characteristic	Boys (*n*=13,006)			Girls (*n*=11,327)		
	N	Prevalence (95% CI)	Prevalence Ratio (95% CI)	*N*	Prevalence (95% CI)	Prevalence Ratio (95% CI)
Age (y)						
6-7	572	18.4 (8.8-28.0)	1.00	431	15.0 (7.4-22.6)	1.00
8-9	667	19.3 (13.5-25.1)	1.08 (0.98-1.20)	533	17.6 (11.8-23.4)	1.12 (0.99-1.26)
10-11	714	23.8 (12.4-35.3)	1.14 (1.03-1.27)	548	19.0 (10.7-27.3)	1.17 (1.04-1.31)
12-13	100	19.1 (8.4-29.8)	0.76 (0.62-0.93)	103	13.8 (6.0-21.7)	1.16 (0.95-1.41)
Waist circumference (quartile)†						
Q1	373	9.9 (7.1-12.6)	1.00	305	8.9 (6.2-11.5)	1.00
Q2	414	16.7 (11.1-22.3)	1.10 (0.97-1.26)	335	10.7 (7.4-13.9)	1.07 (0.93-1.24)
Q3	521	20.4 (10.2-30.5)	1.35 (1.19-1.53)	398	20.0 (8.6-31.5)	1.29 (1.12-1.49)
Q4	745	33.3 (22.0-44.7)	1.95 (1.74-2.19)	577	26.9 (18.7-35.2)	1.82 (1.60-2.07)
Waist to height ratio (quartile)†						
Q1	430	13.7 (9.7-17.6)	1.00	343	10.2 (7.1-13.3)	1.00
Q2	415	15.2 (8.7-21.7)	0.97 (0.85-1.09)	315	10.1 (6.8-13.4)	0.91 (0.79-1.05)
Q3	451	18.8 (8.2-29.4)	1.05 (0.93-1.18)	393	19.1 (8.9-29.3)	1.14 (1.00-1.31)
Q4	757	33.0 (21.6-44.5)	1.76 (1.58-1.96)	564	25.7 (17.0-34.4)	1.64 (1.45-1.85)
BMI category†						
Underweight	90	10.9 (2.2-19.6)	0.80 (0.65-0.97)	114	12.9 (7.1-18.6)	1.01 (0.84-1.20)
Normal	1290	17.2 (9.2-25.3)	1.00	1171	14.6 (7.8-21.3)	1.00
Overweight	320	26.1 (15.3-36.8)	1.66 (1.48-1.85)	212	29.6 (20.6-38.5)	1.94 (1.70-2.20)
Obese	353	49.3 (39.4-59.3)	2.50 (2.26-2.76)	118	45.9 (33.7-58.1)	2.97 (2.53-3.45)
Residence‡						
Rural	974	21.7 (12.0-31.3)	1.00	734	17.4 (9.9-25.0)	1.00
Urban	1079	16.2 (8.6-23.9)	0.89 (0.83-0.97)	881	13.2 (8.1-18.4)	0.95 (0.94-1.02)
Family history of hypertension‡						
No	1170	20.7 (11.9-29.5)	1.00	936	16.6 (9.5-23.7)	1.00
Yes	883	19.9 (13.7-26.2)	1.12 (1.04-1.20)	679	16.2 (11.8-20.5)	1.03 (0.97-1.04)
Mother's education level‡						
Elementary school or lower	507	23.0 (11.5-34.6)	1.00	425	18.5 (8.8-28.4)	1.00
High school	1275	19.8 (13.5-26.1)	0.93 (0.86-1.02)	990	15.6 (11.2-19.9)	0.89 (0.89-0.90)
Junior college and higher	271	13.2 (9.0-17.5)	0.85 (0.75-0.97)	200	14.2 (10.0-18.3)	0.78 (0.78-0.79)

Note. CI: confidence interval; BMI: body mass index. †Adjusted for age; ‡Adjusted for age and BMI.

obese boys; the adjusted prevalence ratios (aPRs) for overweight and obese boys were 1.66 (95% CI, 1.48-1.85) and 2.50 (95% CI, 2.26-2.76), respectively. Among girls, the prevalence of EBP increased from 14.6% for normal weight to 29.6% for overweight and 45.9% for obese, and the aPRs were 1.94 (95% CI, 1.70-2.20) and 2.97 (95% CI, 2.53-3.45), respectively. Compared with the participants at the 1st quartile of WtHR, the prevalence of EBP increased significantly from 13.7% to 33.0% for boys and from 10.2% to 25.7% for girls, and the aPRs were 1.76 (95% CI, 1.58-1.96) and 1.64 (95% CI, 1.45-1.85), respectively.

There was a significantly lower prevalence of EBP among boys living in urban (16.2%) compared with rural (21.7%) areas, and the aPR was 0.89 (95% CI, 0.83-0.97). Boys with a family history of hypertension were 12% more likely to have EBP (aPR, 1.12; 95% CI, 1.04-1.20) than those without it. Children whose mothers received college education tended to have a lower likelihood of EBP, and aPR was 0.85 (95% CI, 0.75-0.97) among boys and 0.78 (95% CI, 0.78-0.79) among girls.

DISCUSSION

Our study estimated the prevalence of EBP among Chinese children aged 6-13 years to be 20.2% in boys and 16.3% in girls. The prevalence of EBP estimated for China was higher in our study compared to studies conducted for other countries. The prevalence of hypertension among urban school children aged 5-14 years in southern India was 7.2 % (6.6% in boys and 7.9% in girls)[15]. A cross-sectional study involving 794 Brazilian children aged 6-13 years from public elementary schools found 7% prevalence of high blood pressure (hypertension or prehypertension)[16]. In Japan, the prevalence of high blood pressure was 15.9% in 4th-grade boys and 15.8% in 4th-grade girls, and 11.1% in 7th-grade boys and 10.8% in 7th-grade girls[17]. In the United States, 13.6% of boys and 5.7% of girls aged 8-17 years were classified as having pre-EBP, and 2.6% of boys and 3.4% of girls as having EBP during 2003-2006[18]. However, caution should be taken when making cross-country comparisons. First, our study represented one of the most recent studies. Increasing trends of childhood EBP have been observed around the world[11,19]. Second, the method of measuring blood pressure may also contribute to the variety of study outcomes across studies; for example, repeated measurements could result in lower estimates of EBP. The estimated prevalence of EBP on the first, second, and third screens among 6193 students in Hong Kong, China were 9.54%, 2.77%, and 1.44%, respectively[20]. However, the high prevalence of EBP among Chinese children suggested an emerging health issue among children in the countries where people are becoming wealthy and adopting new and often sedentary lifestyles.

Our study also showed personal and family factors associated with EBP. Boys and girls who were overweight, obese, or had high WC, WtHR or lower mother's education levels were more likely to have EBP. Our data were in agreement with other studies that suggest high BMI and large WC are associated with EBP[21-24]. Obesity and central adiposity may impair microvascular function, and therefore result in the development of hypertension[25-26]. Among boys, EBP was higher for those having a family history of hypertension or residing in rural areas. Family history of hypertension is an important factor associated with children's EBP; our study finding is consistent with previous studies[27-28]. Place of residence is a key indicator of socioeconomic position. C Lazarou et al.[29] found that 70% of children with EBP lived in rural areas, and 58.8% had low socioeconomic status. Socioeconomic inequalities have been linked to childhood obesity in developed countries[30-31], and children with lower socioeconomic status were at a higher risk for hypertension in adulthood[32-33]. Systematic reviews also found that lower SES during childhood was related to greater risk of cardiovascular diseases during adulthood[34-35]. In this study, we also used mothers' education levels as a proxy for children's socioeconomic status, and found that mother's high education level lowered the risk of EBP among children.

This study has several strengths. First, the study participants consisted of a nationwide sample of children in grades 1-6 from both urban and rural areas. Participants were selected using a multistage sampling strategy, and the sampling weights, including design weight, post-stratification weight, and non-response weight, were used in the data analysis. The study findings can be extrapolated to all children aged 6-13 years because over 98% of Chinese children in this age group are enrolled in elementary schools due to the nine-year compulsory education policy implemented in 1986. Second, we calculated prevalence ratio instead of odds ratios. Prevalence ratio offers conservative, consistent, and

interpretable relationships of EBP among different categories in this cross-sectional study. Third, we evaluated both personal and family factors associated with EBP.

The study also has limitations. Adult residents in northern China have a higher prevalence of hypertension than those in southern China[36]. However, we did not consider the northern and southern areas as a stratum in the sampling stage of this study, and hence the understanding of the difference of EBP among children in the two stata within China is not possible.

Blood pressure was only measured on one visit in this study. Other studies have suggested that initial readings may inflate the estimate of EBP, and multiple readings measured on different occasions are needed[37-38].

CONCLUSIONS

The prevalence of EBP is high among Chinese school-age children, particularly among those who are overweight or obese. Screening of blood pressure among obese children is useful for early identification of at-risk children and provides a good opportunity for health education. Children with a family history of hypertension should also be screened. The negative association between mothers' education level and EBP risk in children may be due to mothers' roles as primary caregivers who greatly influence children's dietary and lifestyle behaviors; providing mothers with health information may be an effective strategy in preventing childhood EBP. Prevention intervention programs should also target rural schools, as children in rural areas also have high prevalence of EBP.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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