**Original Article**

# Pubertal Hypertension is a Strong Predictor for the Risk of Adult Hypertension*

LIANG YaJun[1,2] and MI Jie[1,#]

*1. Department of Epidemiology, Capital Institute of Pediatrics, Beijing 100020, China; 2. School of Public Health, Jining Medical University, Jining 272067, Shandong, China*

**Abstract**

**Objective** To assess and compare the predictive effects of hypertension before puberty and during puberty on adult hypertension.

**Methods** A total of 412 adults from the "Beijing children and adolescents blood pressure (BP) study" cohort were followed up in a clinical examination in 2005. Systolic and diastolic BP, height, and weight in childhood were measured at a baseline survey in 1987. The participants were divided into pre-puberty and puberty sub-cohorts according to their pubertal development stage at baseline. Information on adult BP, anthropometric indices and life style were collected through questionnaire and physical examination. BP changes and the predictive effect on adult hypertension were compared between the two sub-cohorts. Correlation of BP levels between 1987 and 2005 was examined through linear regression models.

**Results** From childhood to adulthood, the regression coefficients of systolic BP were similar in the two sub-cohorts (both $\beta$=0.34, $P$<0.001), while the coefficient of diastolic BP was larger in the pubertal cohort ($\beta$=0.31, $P$<0.001) compared with the pre-pubertal cohort ($\beta$=0.12, $P$=0.017). Fifty percent of children with pubertal hypertension became hypertensive adults, while pre-pubertal hypertension resulted in 34.3%. After adjustment for sex, age, family history of hypertension, obesity in childhood, and adulthood, pubertal hypertension predicted a higher risk of adult hypertension than pre-pubertal hypertension, with odds ratios (95% confidence intervals) of 10.00 (3.03-33.07) and 2.71 (0.83-8.85), respectively.

**Conclusion** Our results suggest that hypertension during puberty is likely to result in adult hypertension.

**Key words:** Puberty; Hypertension; Adult; Follow-up

*Biomed Environ Sci, 2011; 24(5):459-466* *doi:10.3967/0895-3988.2011.05.002* *ISSN:0895-3988*

*www.besjournal.com(full text)* *CN:11-2816/Q* 

## INTRODUCTION

Hypertension is a worldwide public health problem. The prevalence of adult hypertension has increased over the last 2 decades[1]. Along with the epidemic of childhood obesity, primary hypertension has already become common in children and adolescents[2-3], while this was once considered to be rare in pediatrics[4].

The origin of hypertension in adulthood has been observed to extend back to childhood[5]. Many studies have shown that blood pressure (BP) tracks from childhood to adulthood[6], and hypertensive children are more likely to develop hypertension in

*This research was supported by grants from Beijing Municipal Science & Technology Commission (D08050700320000, D111100000611002), Beijing Medical Development Found (2007-1024), and Beijing Health System Leading Talent Grant (2009-1-08).

#Correspondence should be addressed to: MI Jie, No.2 Yabao Road, Chaoyang District, Beijing 100020, China. Tel: 86-10-8569-5591; Fax: 86-10-8563-2799; E-mail: jiemi@vip.163.com

Biographical note of the first author: LIANG YaJun, female, born in 1980, doctor of public health at Peking Union Medical College, majoring in epidemiology. E-mail: liangyajun976@163.com

Received: February 24, 2011; Accepted: July 28, 2011

adulthood[7]. An increase in childhood hypertension likely increases the prevalence of hypertension in adults in later decades, and further increases cardiovascular morbidity and mortality[8].

However, BP tracking from childhood to adulthood changes with the growth and development of children and adolescents[6]. Therefore, the predictive effect of adult hypertension might vary with the hypertension in different stages during childhood and adolescence. It is unknown which stage of hypertension predicts the strongest risk of adult hypertension?

In the present study, we aimed to assess and compare the predictive effects of hypertension before puberty and during puberty on adult hypertension. Our study was based on a longitudinal study-called the “Beijing children and adolescents BP study (BBS)”, in which 412 subjects were followed-up after18 years.

## SUBJECTS AND METHODS

### *Study Population*

All study participants came from the “BBS” cohort, which was initially conducted to evaluate high BP and related risk factors among children and adolescents of Beijing in 1987[9]. The BBS was supported by the national project of The 7th Five Year Plan, which tackled key problems in science and technology in China, and was conducted by the Capital Institute of Pediatrics who cooperated with Beijing Pediatric Hospital and Beijing Anzhen Hospital. During a baseline survey, 3 185 children and adolescents aged 6 to 18 years old (males, 53.1%) were randomly recruited from Chaoyang, Xicheng, and Haidian districts in Beijing. At baseline, children who suffered from secondary hypertension derived from chronic diseases of the heart, kidney, liver, endocrine system or vascular tissue were excluded from this study. A total of 412 adults (males, 53.2%) from the BBS cohort were followed up and invited to participate in a clinical examination in 2005. Their systolic and diastolic BP, height, and weight in childhood were measured at a baseline survey in 1987. Information on adult BP, anthropometric indices and life style were collected through questionnaire and physical examination. Loss to follow-up was mainly because of failure to trace the subjects (36.4%), being busy with work (44.5%), migration (3.3%), and other reasons of refusal.

In this study, follow-up participants were divided into pre-puberty and puberty sub-cohorts according to their pubertal stages at baseline. During the baseline survey, girls after menarche were classified as the pubertal sub-cohort, while other girls were considered as pre-pubertal. However, data on boys’ puberty stages were not collected during the baseline survey. Fortunately, we found data of boys’ first emission ages from the “Report on the Physical Fitness and Health Surveillance of Chinese School Students (1991)”[10]. In this report, the mean age of boys’ first emission ages was 13.84 years in Beijing in 1991, which was almost the same period as the BBS baseline study. Therefore, we classified boys according to this report. Boys aged ⩾13.84 years were classified as the pubertal sub-cohort, while the other boys were classified as the pre-pubertal sub-cohort.

This study was approved by the Institutional Review Boards and Ethics Committees of the Capital Institute of Pediatrics. Participants’ informed consents were obtained from children and their parents.

### *Measurements*

Height and weight were measured to calculate body mass index (BMI, weight in kilograms divided by the square of height in meters).

BP at baseline and follow-up was measured by auscultation with a mercury sphygmomanometer according to a standard protocol[11]. After each subject rested at least 15 minutes in the sitting position, BP was measured on the right arm, which was supported at heart level. The cuff size was determined according to the size of the subject’s arm to cover at least two-thirds of the upper arm. Subjects received three measurements of BP on one visit during each survey. The three measurements were separated by at least a 1-2 minutes’ interval, during which the right arm was raised up for 5-6 seconds. Differences in two consecutive readings of BP at the same sitting should not have been no more than 4 mmHg. The last two readings of BP one visit were averaged and reported as the BP values in this study[9]. At the baseline survey, the first and the fourth Korotkoff sounds were defined as systolic BP (SBP) and diastolic BP (DBP) of children and adolescents, respectively.

### *Definitions*

Being overweight and obesity in children and adolescents (7-18 years old) were defined according to the age- and sex-specific BMI reference values proposed by the Working Group on Obesity in China[12]. This local reference did not include BMI cut-off points for children aged 6 years old. For children aged 6 years old, we used the age- and sex-specific 85th and 95th BMI percentiles from the US Center for Disease Control and Prevention 2 000 Growth Charts to define being overweight and obesity, respectively[13]. In adults, being overweight was defined as a BMI ≥24 kg/m$^2$ and a BMI <28 kg/m$^2$, and obesity was defined as BMI ≥28 kg/m$^2$.

Among children and adolescents, we used the age- and sex-specific BP reference standard of Chinese children and adolescents to define pre-hypertension and hypertension (see Appendix)[14]. Both SBP and DBP <90th percentile was defined as normal BP; SBP and/or DBP ≥90th percentile and <95th percentile was defined as pre-hypertension; and SBP and/or DBP ≥95th percentile was defined as hypertension. In adulthood, pre-hypertension and hypertension were diagnosed according to the China Guideline for Hypertension Prevention and Control issued in 2009[15]. Adult hypertension was diagnosed as SBP ≥140 mmHg and/or DBP ≥90 mmHg or currently taking anti-hypertensive drugs, while pre-hypertension was defined as SBP ≥120 mmHg and <140 mmHg or DBP ≥80 mmHg and <90 mmHg.

**APPENDIX.** Recommended Blood Pressure Reference Cut-offs for Chinese Children and Adolescents Aged 6-17 Years (mmHg)

| Age (year) | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | SBP | | DBP | | SBP | | DBP | |
| | $P_{90}$ | $P_{95}$ | $P_{90}$ | $P_{95}$ | $P_{90}$ | $P_{95}$ | $P_{90}$ | $P_{95}$ |
| 6 | 108 | 112 | 71 | 74 | 106 | 110 | 70 | 73 |
| 7 | 111 | 115 | 73 | 77 | 108 | 112 | 72 | 75 |
| 8 | 113 | 117 | 75 | 78 | 111 | 115 | 74 | 77 |
| 9 | 114 | 119 | 76 | 79 | 112 | 117 | 75 | 78 |
| 10 | 115 | 120 | 76 | 80 | 114 | 118 | 76 | 80 |
| 11 | 117 | 122 | 77 | 81 | 116 | 121 | 77 | 80 |
| 12 | 119 | 124 | 78 | 81 | 117 | 122 | 78 | 81 |
| 13 | 120 | 125 | 78 | 82 | 118 | 123 | 78 | 81 |
| 14 | 122 | 127 | 79 | 83 | 118 | 123 | 78 | 82 |
| 15 | 124 | 129 | 80 | 84 | 118 | 123 | 78 | 82 |
| 16 | 125 | 130 | 81 | 85 | 119 | 123 | 78 | 82 |
| 17 | 127 | 132 | 82 | 85 | 119 | 124 | 79 | 82 |

***Note.*** SBP: Systolic blood pressure; DBP: Diastolic blood pressure, defined as the fourth Korotkoff sound; $P_{90}$: the 90th percentile; $P_{95}$: the 95th percentile.

### *Statistical Analysis*

Statistical analysis was performed using SPSS 13.0 (SPSS Inc., Chicago, Illinois, USA). We used *t*-test to compare mean age, and the chi-square test to compare differences in the proportion of males, prevalence of being overweight, obesity, pre-hypertension, and hypertension between the pre-pubertal and pubertal sub-cohorts. Covariance analysis was used to compare the differences in height, weight, BMI, SBP, and DBP between the two sub-cohorts, with age and sex as concomitant variables. Regression coefficients were calculated through linear regression analysis to assess the correlations of BP from childhood to adulthood, after adjustment for age, sex, and BMI in childhood and adulthood. Multivariate logistic regression analysis was conducted to assess the predictive effects of adult hypertension based on pre-pubertal hypertension and pubertal hypertension. Odds ratios (*ORs*) and 95% confidence intervals (*CIs*) of hypertension in adulthood were evaluated after adjustment for age, sex, family history of hypertension, and obesity in childhood and adulthood. Statistical significance was set at *P*<0.05.

## RESULTS

### *Characteristics of Subjects*

Table 1 shows the characteristics and measurements at baseline in follow-up subjects and the entire BBS cohort. In follow-up subjects, the mean age was older (11.9±3.8 years *vs.* 11.3±3.7 years, *P*=0.001), the prevalence of pre-hypertension was lower (7.5% *vs.* 10.9%, *P*=0.034), and the proportion of family history of hypertension was higher (19.6% *vs.* 15.1%, *P*=0.021) compared with those in the entire BBS cohort. The proportion of males, height, weight, BMI, SBP, DBP, prevalence of being overweight, obesity, and hypertension were similar between follow-up subjects and the entire BBS cohort (all *P*>0.05). There were no significant differences in age, sex and all the other indices between follow-up and the entire BBS cohort with hypertension in childhood (all *P*>0.05).

### *Comparison between two Sub-cohorts*

Table 2 shows the comparison of measurements between pre-pubertal and pubertal participants at the baseline and follow-up surveys. Pubertal participants were older than their pre-pubertal counterparts (*P*<0.001), with similar male proportions in the two sub-cohorts (*P*=0.764).

**Table 1.** Characteristics and Measurements at Baseline in Follow-up Subjects and the Entire BBS Cohort [$\overline{X}$±*s* / *n*(%)]

| Characteristics | Total Subjects | | | Hypertensive Patients | | |
|---|---|---|---|---|---|---|
| | Follow-up (*n*=412) | Whole (*n*=3 185) | *P*-value | Follow-up (*n*=63) | Whole (*n*=381) | *P*-value |
| Age (year) | 11.9±3.8 | 11.3±3.7 | 0.001 | 12.0±3.9 | 12.0±3.8 | 0.874 |
| Male | 219(53.2) | 1691(53.1) | 0.981 | 25(39.7) | 172(45.1) | 0.419 |
| Height (cm)[a] | 142.8±0.4 | 142.8±0.1 | 0.840 | 148.2±0.9 | 148.0±0.4 | 0.822 |
| Weight (kg)[a] | 36.1±0.4 | 36.3±0.1 | 0.567 | 43.3±1.2 | 43.7±0.5 | 0.726 |
| BMI (kg/m$^2$)[a] | 16.9±0.1 | 17.0±0.1 | 0.497 | 18.9±0.5 | 19.2±0.2 | 0.594 |
| Overweight | 21(5.1) | 178(5.8) | 0.588 | 8(12.7) | 41(12.0) | 0.867 |
| Obesity | 17(4.1) | 123(4.0) | 0.884 | 9(14.3) | 55(16.0) | 0.726 |
| SBP (mmHg)[a] | 105.2±0.5 | 105.0±0.2 | 0.744 | 122.5±1.1 | 121.8±0.5 | 0.573 |
| DBP (mmHg)[a] | 66.2±0.4 | 66.3±0.1 | 0.764 | 79.3±1.0 | 77.5±0.4 | 0.092 |
| Pre-hypertension | 31(7.5) | 348(10.9) | 0.034 | - | - | - |
| Hypertension | 63(15.3) | 381(12.0) | 0.053 | - | - | - |
| Family History of Hypertension | 80(19.6) | 481(15.1) | 0.021 | 19(30.2) | 82(21.6) | 0.133 |

***Note.*** BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure. [a]Mean and standard error were listed through covariance analysis, with age and sex as concomitant variables.

**Table 2.** Comparison of Characteristics between Pre-pubertal and Pubertal Participants [$\overline{X}$±*s* /*n*(%)]

| Characteristics | Baseline (1987) | | | Follow-up (2005) | | |
|---|---|---|---|---|---|---|
| | Pre-puberty (*n*=253) | Puberty (*n*=159) | *P*-value | Pre-puberty (*n*=253) | Puberty (*n*=159) | *P*-value |
| Age (year) | 9.3±2.1 | 16.0±1.7 | <0.001 | 27.3±2.1 | 34.0±1.7 | <0.001 |
| Male | 133(52.6) | 86(54.1) | 0.764 | 133(52.6) | 86(54.1) | 0.764 |
| Height (cm)[a] | 145.8±0.6 | 145.2±0.9 | 0.673 | 169.4±0.5 | 168.6±0.7 | 0.393 |
| Weight (kg)[a] | 36.9±0.6 | 39.6±0.9 | 0.048 | 68.3±1.1 | 65.3±1.6 | 0.209 |
| BMI (kg/m$^2$)[a] | 17.0±0.2 | 17.6±0.3 | 0.199 | 23.6±0.4 | 22.8±0.5 | 0.321 |
| Overweight | 16(6.3) | 5(3.1) | 0.153 | 67(26.5) | 39(24.5) | 0.659 |
| Obesity | 15(5.9) | 2(1.3) | 0.020 | 31(12.3) | 24(15.1) | 0.409 |
| SBP (mmHg)[a] | 104.1±1.0 | 109.3±1.4 | 0.014 | 120.5±1.2 | 114.1±1.8 | 0.017 |
| DBP (mmHg)[a] | 64.6±0.8 | 70.4±1.2 | 0.001 | 77.3±0.9 | 74.5±1.3 | 0.168 |
| Pre-hypertension | 11(4.3) | 20(12.6) | 0.002 | 104(41.1) | 45(28.3) | 0.008 |
| Hypertension | 35(13.8) | 28(17.6) | 0.300 | 33(13.0) | 28(17.6) | 0.204 |
| Family History of Hypertension | 37(14.8) | 43(27.0) | 0.002 | 37(14.8) | 43(27.0) | 0.002 |

***Note.*** BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure. [a]Mean and standard error were listed through covariance analysis, with age and sex as concomitant variables.

At baseline, pubertal subjects had higher weight, SBP, DBP, and prevalence of pre-hypertension, and a lower prevalence of obesity (all *P*<0.05), and similar height, BMI, prevalence of being overweight and hypertension compared with those in the pre-pubertal sub-cohort (all *P*>0.05). In the follow-up period, mean SBP and the prevalence of pre-hypertension were lower in the pubertal sub-cohort than those in the pre-pubertal sub-cohort (both *P*<0.05), while height, weight, BMI, DBP, prevalence of being overweight, obesity, and hypertension were similar in the two sub-cohorts (all *P*>0.05).

***Changes in BP between 1987 and 2005***

Table 3 shows the changes and regression coefficients of BP from childhood to adulthood. BP increased more in pre-pubertal subjects than in pubertal participants from 1987 to 2005, with similar results in boys and girls. Greater increases in BP were observed in boys than in girls in either sub-cohort.

**Table 3.** Changes and Regression Coefficients of Blood Pressure between 1987 and 2005 ($\bar{X}\pm S$)

| Group | *n* | Systolic Blood Pressure (mmHg) | | | | | Diastolic Blood Pressure (mmHg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1987 | 2005 | d | $\beta^a$ | *P*-value | 1987 | 2005 | d | $\beta^a$ | *P*-value |
| **Pre-puberty** | | | | | | | | | | | |
| All | 253 | 101.5±10.3 | 118.8±16.3 | 17.3 | 0.34 | <0.001 | 63.7±9.0 | 75.4±10.6 | 11.7 | 0.12 | 0.017 |
| Male | 133 | 103.5±10.8 | 127.1±15.3 | 23.6 | 0.27 | <0.001 | 64.8±9.3 | 79.6±10.1 | 14.8 | 0.11 | 0.131 |
| Female | 120 | 99.4±9.2 | 109.7±11.9 | 10.3 | 0.57 | <0.001 | 62.5±8.6 | 70.8±9.1 | 8.3 | 0.16 | 0.072 |
| **Puberty** | | | | | | | | | | | |
| All | 159 | 113.5±12.3 | 116.8±14.7 | 3.3 | 0.34 | <0.001 | 71.7±8.7 | 77.6±12.5 | 5.9 | 0.31 | <0.001 |
| Male | 86 | 116.2±12.6 | 123.1±15.2 | 6.9 | 0.34 | <0.001 | 73.4±8.5 | 82.4±13.0 | 9.0 | 0.41 | <0.001 |
| Female | 73 | 110.2±11.2 | 109.3±10.0 | -0.9 | 0.41 | 0.001 | 69.8±8.7 | 71.9±9.0 | 2.1 | 0.27 | 0.024 |

***Note.*** [a]Standardized regression coefficient through linear regression analysis after adjustment for age, sex, body mass index in childhood and adulthood.

From childhood to adulthood, the regression coefficients of SBP were similar in the two sub-cohorts (both $\beta$=0.34, *P*<0.001). Pubertal boys had a higher coefficient of SBP than their pre-pubertal counterparts, while the result was the opposite in girls. For both sexes, the regression coefficient of DBP was larger in the pubertal sub-cohort ($\beta$=0.31, *P*<0.001) than that in the pre-pubertal sub-cohort ($\beta$=0.12, *P*=0.017), while results were similar in boys and girls.

***Predictive Effect of Adult Hypertension***

Table 4 shows the ORs and 95% CIs for adult hypertension based on pre-pubertal and pubertal hypertension. More children with pre-hypertension or hypertension in puberty developed hypertension during adulthood compared with pre-pubertal subjects (20.0% *vs.* 9.1% for pre-hypertension; 50.0% *vs.* 34.3% for hypertension).

**Table 4.** Odds Ratios and 95% Confidence Intervals for Adult Hypertension

| Groups | *n* | *n1*(%) | Wald $x^2$ | *P*-value | *OR*[a] | *95%* CI |
|---|---|---|---|---|---|---|
| **Pre-puberty** | | | | | | |
| Normal BP | 207 | 20(9.7) | | | 1.00 | |
| Pre-hypertension | 11 | 1(9.1) | 0.05 | 0.819[b] | 0.76 | 0.08 - 7.77 |
| Hypertension | 35 | 12(34.3) | 2.72 | 0.099[c] | 2.71 | 0.83 - 8.85 |
| **Puberty** | | | | | | |
| Normal BP | 111 | 10(9.0) | | | 1.00 | |
| Pre-hypertension | 20 | 4(20.0) | 0.29 | 0.592[d] | 1.50 | 0.34 - 6.58 |
| Hypertension | 28 | 14(50.0) | 14.25 | <0.001 | 10.00 | 3.03 - 33.07 |

***Note.*** *OR*: Odds ratio; *CI*: Confidence interval; BP: Blood pressure. [a]Adjustment for age, sex, family history of hypertension, obesity in childhood and adulthood; [b]power=0.036; [c]power=0.576; [d]power=0.115.

After adjustment for age, sex, family history of hypertension, obesity in childhood and adulthood, children with pre-pubertal pre-hypertension or hypertension had a similar risk of developing adult hypertension, with an OR (95% CI) of 0.76 (0.08-7.77) and 2.71 (0.83-8.85), respectively, compared with children with normal BP in pre-puberty. In the pubertal sub-cohort, pubertal pre-hypertension predicted a similar risk for adult hypertension as normotension, with an OR (95% CI) of 1.50 (0.34-6.58). However, individuals with pubertal hypertension were at a 10-fold risk of developing adult hypertension compared with their normotensive counterparts, with an OR (95% CI) of 10.00 (3.03-33.07).

## DISCUSSION

In this study, 253 pre-pubertal children and 159 pubertal adolescents were followed-up after 18 years. We found that the association of BP between childhood and adulthood was stronger in the pubertal sub-cohort, and individuals with pubertal hypertension had a higher risk of developing hypertension in adulthood compared with the pre-pubertal sub-cohort.

Adolescents experience complex physiological and hormonal changes during puberty. During adolescence, BP is related to pubertal status[16], with great increases with age[17]. Sexual maturation during adolescence is positively associated with the level of BP[18-19], and it is also a predictor of BP when the effect of weight and skeletal age are omitted[20]. This could partly explain our results of higher BP levels at baseline in pubertal subjects than those in pre-pubertal participants, after adjustment for sex and age.

In the current study, BP levels increased from childhood to adulthood. The association between childhood and adulthood was stronger for SBP than for DBP, after adjustment for age, sex and BMI. This finding is probably because SBP increases with increasing height and adiposity[21-23], but DBP does not appear to rise consistently with height[23]. We found that SBP and DBP were greatly increased in the pre-pubertal sub-cohort compared with those in the pubertal sub-cohort. After adjustment for age, sex and BMI, the associations of SBP and DBP levels between childhood and adulthood were stronger in the pubertal sub-cohort than those in the pre-pubertal sub-cohort. This can be explained by previous findings that BP tracking increases with baseline age, ie, older children have a strong BP tracking into adulthood[6].

The pattern of BP is different between adolescent boys and girls[20]. It has been shown that BP markedly increases during pre-pubescence and stabilizes after puberty in girls, while BP gradually increases from pubescence through the age of 18 years in boys[20]. In our study, a greater change in BP from 1987 to 2005 was observed in boys than in girls. This is in agreement with other findings that males have higher mean SBP and a greater rise over time in SBP than in females[21]. Some studies have also shown no significant sex difference in SBP tracking, and women have weaker DBP tracking than men[6]. The sex differences of BP tracking still need further investigation.

Puberty may be a vulnerable period in the development of high SBP and cardiovascular disease in adult life[24]. Hypertension in youth has been observed to increase, and higher BP in childhood and adolescence is also predictive of sustained hypertension in adulthood[25]. Age differences have been reported in the associations between childhood risk factors (including high BP) and subclinical atherosclerosis in adulthood, and these associations are stronger with increasing age[26]. In our study, individuals with pubertal hypertension had a 10-fold risk of developing hypertension in adulthood compared with children with normal BP. However, we didn’t find any risks of adult hypertension based on pre-pubertal hypertension, which is different from a previous finding that young children with elevated SBP were at greater risks of developing adult hypertension than older children and adolescents[7]. The probable reason for this discrepancy between studies is that the statistical power in the pre-pubertal group might have been too small to observe the risks of adult hypertension.

It still remains unclear whether the timing of puberty has a long-term effect on BP in adult life[27]. A previous study showed that age at puberty may be an important marker in the later development of hypertension[28]. Any association of age at puberty with adult BP may simply reflect the effect of differences in maturation on adult body size. Unfortunately, pubertal stages of the participants were not measured at the baseline survey in our study. Because of the small sample, we didn’t divide the sample into detailed subgroups to analyze the association of age at puberty with hypertension in childhood and adulthood.

The major strength of our study is that we used a longitudinal cohort to observe the predictive effect of adult hypertension. An accurate correlation of BP levels and hypertension between childhood and adulthood could be determined. Therefore, this study may provide valuable information on the tracking of BP and predictive effect of hypertension from childhood to adulthood.

However, there are several limitations in this study. First, only 13.1% of children and adolescents at baseline were visited in 2005. Many subjects were too busy at work to participate in this follow-up study, which was the main reason of loss to follow-up. Therefore, there was possible bias due to differential loss to follow-up in this study. Although many subjects were not followed up, many characteristics tended not to be substantially different between follow-up subjects and the entire BBS cohort. Second, the statistical power was reduced because of the small sample, especially in multiple logistic regression analysis. Further follow-up studies with a large sample should be conducted to retest this result. Furthermore, because of the small number of hypertensive children, we didn't observe any changes in the categories of hypertension (including systolic and diastolic hypertension) from childhood to adulthood. Third, pubertal information for boys was not collected at baseline. Many boys might have been misclassified in this study according to our grouping method of pre-puberty and puberty. Pubertal stages were also not measured at the baseline survey in this study. Fourth, the time interval between baseline and follow-up was too long, and some changes during this period might not have been observed. Hypertension is a disease, which can be affected by many factors including genetic and environmental risk factors. Furthermore, excessive salt intake may partly contribute to the onset of hypertension. Unfortunately, we didn't investigate these related risk factors of hypertension in the present study, except for obesity and a family history of hypertension. Further studies on salt consumption and other factors of hypertension are necessary to explain the associations of BP and hypertension from childhood to adulthood.

In conclusion, adolescents with hypertension during puberty are more likely to develop adult hypertension. Further longitudinal studies with a large amount of subjects should be conducted to retest this association.

## REFERENCES


1. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. JAMA, 2010; 303, 2043-50.
2. Kollias A, Antonodimitrakis P, Grammatikos E, et al. Trends in high blood pressure prevalence in Greek adolescents. J Hum Hypertens, 2009; 23, 385-90.
3. Ostchega Y, Carroll M, Prineas RJ, et al. Trends of elevated blood pressure among children and adolescents: data from the National Health and Nutrition Examination Survey 1988-2006. Am J Hypertens, 2009; 22, 59-67.
4. Flynn JT, Alderman MH. Characteristics of children with primary hypertension seen at a referral center. Pediatric nephrology, 2005; 20, 961-6.
5. Berenson GS, Wattigney WA, Bao W, et al. Rationale to study the early natural history of heart disease: the Bogalusa Heart Study. Am J Med Sci, 1995; 310 (Suppl 1), S22-8.
6. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. Circulation, 2008; 117, 3171-80.
7. Sun SS, Grave GD, Siervogel RM, et al. Systolic blood pressure in childhood predicts hypertension and metabolic syndrome later in life. Pediatrics, 2007; 119, 237-46.
8. Feber J, Ahmed M. Hypertension in children: new trends and challenges. Clin Sci (Lond), 2010; 119, 151-61.
9. Li J, Li JY, Liang LC, et al. A cross-sectional survey for blood pressure in children and adolescents. Chin J of Pediatr, 1991; 29, 34-6.
10. Research Group of Chinese Students' Physical Fitness and Health (1991). Report on the Physical Fitness and Health Surveillance of Chinese School Students. Beijing Science and Technology Publishing Company, Beijing.
11. Blumenthal S, Epps RP, Heavenrich R, et al. Report of the task force on blood pressure control in children. Pediatrics, 1977; 59, I-II, 797-820.
12. Ji CY. Report on childhood obesity in China (1)--body mass index reference for screening overweight and obesity in Chinese school-age children. Biomed Environ Sci, 2005; 18, 390-400.
13. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. Adv Data, 2000; (314), 1-27.
14. Mi J, Wang TY, Meng LH, et al. Development of blood pressure reference standards for Chinese children and adolescents. Chin J Evid Based Pediatr, 2010; 5, 4-14.
15. The committee on revising China Guideline for the Prevention and Treatment of Hypertension (2009). China Guideline for the Prevention and Treatment of Hypertension. Beijing.
16. He Q, Horlick M, Fedun B, et al. Trunk fat and blood pressure in children through puberty. Circulation, 2002; 105, 1093-8.
17. Shankar RR, Eckert GJ, Saha C, et al. The change in blood pressure during pubertal growth. J Clin Endocrinol Metab, 2005; 90, 163-7.
18. Rosner B, Prineas R, Daniels SR, et al. Blood pressure differences between blacks and whites in relation to body size among US children and adolescents. Am J Epidemiol, 2000; 151, 1007-19.
19. Daniels SR, Obarzanek E, Barton BA, et al. Sexual maturation and racial differences in blood pressure in girls: the National Heart, Lung, and Blood Institute Growth and Health Study. J Pediatr, 1996; 129, 208-13.
20. Cornoni-Huntley J, Harlan WR, Leaverton PE. Blood pressure in adolescence. The United States Health Examination survey. Hypertension, 1979; 1, 566-71.
21. Wang X, Poole JC, Treiber FA, et al. Ethnic and gender differences in ambulatory blood pressure trajectories: results from a 15-year longitudinal study in youth and young adults. Circulation, 2006; 114, 2780-7.
22. Harshfield GA, Barbeau P, Richey PA, et al. Racial differences in the influence of body size on ambulatory blood pressure in youths. Blood Press Monit, 2000; 5, 59-63.
23. O'Sullivan JJ, Derrick G, Griggs P, et al. Ambulatory blood pressure in schoolchildren. Arch Dis Child, 1999; 80, 529-32.
24. Sparen P, Vagero D, Shestov DB, et al. Long term mortality after severe starvation during the siege of Leningrad: prospective cohort study. BMJ, 2004; 328, 11.
25. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics, 2004; 114, 555-76.
26. Juonala M, Magnussen CG, Venn A, et al. Influence of Age on Associations Between Childhood Risk Factors and Carotid

Intima-Media Thickness in Adulthood: The Cardiovascular Risk in Young Finns Study, the Childhood Determinants of Adult Health Study, the Bogalusa Heart Study, and the Muscatine Study for the International Childhood Cardiovascular Cohort (i3C) Consortium. Circulation, 2010; 122, 2514-20.
27. Whincup PH, Cook DG, JMG. A life course approach to blood pressure. In: A life course approach to chronic disease epidemiology (Kuh D and Ben-Shlomo Y, Eds.), 2nd ed. Oxford Univ. Press, Oxford. 2004. pp 218-39.
28. Hardy R, Kuh D, Whincup PH, et al. Age at puberty and adult blood pressure and body size in a British birth cohort study. J Hypertens, 2006; 24, 59-66.