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Original Article

Body Mass Index Is Important Determinant of Blood Pressure in Adolescents

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ABSTRACT

Background and Objectives: Obesity is an important risk factor for development of hypertension. We investigated the association between body mass index (BMI) and blood pressure in adolescents.

Materials and Methods: This cross-sectional study was performed on 694 adolescents aged 12-18 years from middle and high schools located in 4 districts of Shiraz, Iran. Height, weight, and systolic and diastolic blood pressures were measured according to standard procedures.

Results: The prevalence of overweight/obesity and elevated systolic and diastolic blood pressures was 22.0%, 16.8%, and 13.3%, respectively. Compared to girls, boys had higher rates of overweight/obesity and elevated blood pressure. With the increase of age, the prevalence of overweight decreased (20.6% in 15-18 years compared to 34.3% in 12-14 years) and that of elevated blood pressure increased (33.2% vs.14.6% for systolic and 22.2% vs. 10.3% for diastolic blood pressure) in the boys whereas the prevalence of overweight/obesity and elevated blood pressure did not change among the girls. In both sexes, elevated blood pressure had a positive association with BMI categories independent of age; this association was observed even in normal versus low BMI categories.

Conclusions: A strong association between BMI and elevated blood pressure advocates using strategies for the control of weight and prevention of obesity in adolescents.

Keywords: Adolescents, Body mass index, Obesity, Blood pressure

Introduction

Hypertension is an important risk factor for metabolic and cardiovascular diseases (1). Although hypertension is, generally, thought to be a disease relative to mid and late adulthood, recent concerns have arisen for the increasing rate of hypertension in early ages, i.e. childhood and adolescence (2).

Numerous conditions may stimulate hypertension in children and adolescents (3); one of the most important of which is obesity (4). Due to consumption of high-energy snacks, too much screen time, and insufficient physical activity (5), the rate of obesity in children and adolescents has rapidly increased in the recent decades (6). It is estimated that half to two thirds of children in the developed countries will be overweight in the coming years (6).

Overweight children and adolescents have a higher rate of hypertension than their normal-weight counterparts (7, 8). Children's obesity not only increases the risk of hypertension during childhood but also increases the risk of developing hypertension in later life (9) regardless of the adulthood body mass index (BMI) (10).

A group of investigators have recently reported that, during 2010-2011, 7% and 11.8% of adolescents aged 11-17 years in Shiraz were obese and hypertensive, respectively (11). However, the possible association

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between obesity and hypertension was not investigated. We assessed the prevalence of overweight/obesity and elevated blood pressure (prehypertension and hypertension) in adolescents aged 12-18 years and investigated the association between overweight and elevated blood pressure in this population.

Materials and Methods

This cross-sectional study was performed between December 2013 and May 2014 on 694 adolescents (339 boys and 355 girls) aged 12-18 years from middle and high schools located in all 4 districts of Shiraz, Iran. The sample size was calculated according to the prevalence of obesity in Shiraz adolescents (7%) (11), the confidence level of 99%, and the margin of error of 2.5%.

Participants were selected by the multistage cluster random sampling from both the governmental and non-governmental schools. Students were included if they were apparently healthy and desired to participate in the study. Students with serious illnesses, including but not limited to metabolic disorders, cardiovascular diseases, cancer, and anorexia nervosa, and those who were on medications that affect blood pressure or appetite were excluded. Written informed consent was obtained from all subjects prior to their participation. The study was conducted in accordance with the Ethics Committee of Shiraz University of Medical Sciences (Reference number: 92-01-42-5880) and with ethical principles of World Medical Association Declaration of Helsinki of 1964 and all subsequent revisions (12).

Data collection. Demographic information was gathered through the interview by using a researcher-made questionnaire. Socioeconomic status was assessed using the Family Affluence Scale (FAS), a valid questionnaire consisting of four simple questions about personal bedroom, number of cars, number of computers, and frequency of traveling for vacations (13).

Measurements. Height was measured to the nearest 0.1 cm using a non-stretchable tape fixed on the wall. For height measurement, the child was standing without shoes with heels, buttocks and shoulders touching the wall. Weight was measured with minimal clothing to the nearest 0.1 kg by a digital scale (Glamor BS-801, Hitachi, China). BMI was computed by dividing weight in kilograms by the square of height in meters. Z-scores of BMI (BMIZ) were obtained by Epi-Info software version 3.5.3 according to the standards of the Center for Disease Control and Prevention and World Health Organization (14).

Blood pressure was measured by a digital wrist blood pressure monitor (Beurer BC30, Germany). Many brands of automated oscillometric wrist blood pressure devices have passed validation tests, and have been found suitable for measuring blood pressure based on the requirements of International Protocol of the European Society of Hypertension (15-17). For measuring blood pressure, the student seated in a chair and relaxed for 3 min before the cuff was placed on his/her left wrist. For students with a high blood pressure at the first monitoring, blood pressure was measured twice. Readings of equal to or greater than 90^{th} percentile of age- and sex-specific blood pressure percentile curves of Iranian children and adolescents were considered high, and interpreted as the sum of prehypertension and hypertension (18).

Statistical analysis. Z-scores of height (HAZ) and BMI (BMIZ) were calculated by Epi-Info software (ver. 3.4.3) according to the standards of CDC 2000. To determine whether BMIZ and blood pressure change with age, the participants were divided into two age categories: 12-14 years (early adolescence) and 15-18 years (late adolescence). The comparison between boys and girls or between the two age categories of 12-14 years and 15-18 years was performed with independent-samples t-test for quantitative variables like height, HAZ, BMIZ, systolic blood pressure (SBP), and diastolic blood pressure (DBP). The same comparisons for the categorical variables such as BMIZ, SBP, and DBP were done with Chi-square test. Logistic regression analysis was carried out for examining associations between high systolic and diastolic blood pressures and BMIZ categories with adjustments for age, parental BMI, FAS, parents' education, and maternal job. Normality of data was checked by Kolmogorov-Smirnov test, and non-parametric (i.e. Mann-Whitney's) test was used where required. A Pvalue<0.05 was considered statistically significant.

Results

Demographic characteristics of the study subjects are presented in Table 1.

Boys and girls significantly differed in anthropometric measurements (Table 2). Boys were taller and had better HAZ status compared to girls. There was no difference in the mean of BMIZ between the two sexes but the prevalence of overweight/obesity (BMIZ ≥ 1) was higher among boys (26.3% compared to 17.8% in girls). Boys also had significantly higher systolic and diastolic blood pressures and possessed elevated blood pressure more frequently than girls (25.0% and 17.3% of boys had high SBP and DBP, respectively, as compared to girls with 8.9% and 9.5%).

Table 1. Demographic characteristics of the study participants[1]

	Boys (n = 339)	Girls (n = 355)	Total	P value[2]
Age (y)				
12-14 y	146 (43.5)	138 (38.9)	284 (41.1)	0.3
15-18 y	190 (56.5)	217 (61.1)	407 (58.1)	
Father education				
Secondary	237 (70.7)	151 (43.8)	388 (57.1)	<0.001
College	98 (29.3)	194 (56.2)	292 (42.9)	
Mother education				
Secondary	235 (69.5)	169 (48.1)	404 (58.6)	<0.001
College	103 (30.5)	182 (51.9)	285 (41.4)	
Mother job				
Housewife	206 (61.1)	171 (77.0)	477 (69.2)	<0.001
Employed	131 (38.9)	81 (23.0)	212 (30.8)	
Family size				
≤ 4	196 (58.3)	207 (59.0)	403 (58.7)	0.9
> 4	140 (41.7)	144 (41.0)	284 (41.3)	
FAS				
Low (0-3)	92 (27.8)	81 (23.3)	173 (25.5)	0.04
Medium (4-5)	156 (47.1)	149 (42.9)	305 (45.0)	
High (6-7)	83 (25.1)	117 (33.7)	200 (29.5)	

[1] Data are presented as n (%). FAS, family affluence scale.
[2] Statistical differences between the two sexes were tested with Chi-square.

Table 2. Anthropometric characteristics of the students by sex[1]

	Boys	Girls	Total	P value[2]
Height (cm)	165.7 ± 10.2	159.3 ± 6.9	162.4 ± 9.3	<0.001
HAZ	-0.08 ± 1.1	-0.24 ± 0.97	-0.16 ± 1.0	0.045
BMIZ	-0.02 ± 1.3	-0.06 ± 1.2	-0.04 ± 1.3	0.7
BMIZ ≤-1	80 (24.0)	73 (21.0)	153 (22.4)	
-1> BMIZ <1	166 (49.7)	213 (61.2)	379 (55.6)	0.006
BMIZ ≥1	88 (26.3)	62 (17.8)	150 (22.0)	
SBP (mmHg)	106.5 ± 19.2	97.9 ± 15.2	102.1 ± 17.8	<0.001
$<90^{th}$	252 (75.0)	316 (91.1)	568 (83.2)	<0.001
$\geq 90^{th}$	84 (25.0)	31 (8.9)	115 (16.8)	
DBP (mmHg)	68.4 ± 12.4	64.3 ± 10.8	66.4 ± 11.8	<0.001
$<90^{th}$	278 (82.7)	314 (90.5)	592 (86.7)	0.003
$\geq 90^{th}$	58 (17.3)	33 (9.5)	91 (13.3)	

[1] Data are presented as Mean ± SD or n (%).
[2] The comparison between the two sexes was performed with independent t-test (for height, HAZ, and BMIZ) and Mann-Whitney's test (for SBP and DBP) for quantitative variables, and with Chi-square for qualitative variables.
Abbreviations: BMIZ, body mass index Z-score; DBP, diastolic blood pressure; FAS, family affluence scale; HAZ, height for age Z-score; SBP, systolic blood pressure.

Comparison of BMIZ and blood pressure between the two age categories of 12-14 years and 15-18 years showed that, in boys, BMIZ was significantly lower in 15-19-year category, the frequency of underweight was higher, and that of overweight/obesity was lower in the 15-18 years old boys compared to those aged 12-14 years (Table 3). No significant difference in the mean values of BMIZ or the rates of weight disorders was observed between the two age categories in girls. Both systolic and diastolic blood pressures were higher in 15-18 years old boys and elevated blood pressure was also more frequent in this age group compared to the 12-14 years old boys. Contrarily to boys, there was no significant association for blood pressure between the age categories of girls except that the mean value of diastolic blood pressure was higher in the 15-18 years old girls.

Logistic regression analysis revealed that the increasing risk of elevated blood pressure was concomitant with the increase of BMIZ in both sexes (Table 4). Because age was an important determinant of blood pressure, it was added in the analysis as the covariate. After adjustment for age, more associations were observed between BMIZ and blood pressure, especially in boys.

Table 3. Comparisons of BMIZ, SBP, and DBP between two age categories (12-14 y and 15-18 y)[1]

	Boys			Girls		
	12-14 y	15-18 y	P[2]	12-14 y	15-18 y	P value
BMIZ	0.24 ± 1.3	- 0.22 ± 1.3	0.002	-0.07 ± 1.4	-0.04 ± 1.1	0.8
BMIZ ≤-1	20 (14.0)	58 (30.7)		27 (19.7)	46 (21.8)	
-1> BMIZ <1	74 (51.7)	92 (48.7)	<0.001	81 (59.1)	132 (62.6)	0.4
BMIZ ≥1	49 (34.3)	39 (20.6)		29 (21.2)	33 (15.6)	
SBP	99.5 ± 18.1	111.9 ± 18.3	<0.001	97.7 ± 15.9	98.0 ± 14.7	0.9
<90th	123 (85.4)	127 (66.8)		124 (89.9)	192 (91.9)	0.5
≥90th	21 (14.6)	63 (33.2)	<0.001	14 (10.1)	17 (8.1)	
DBP	65.1 ± 11.0	71.0 ± 12.7	<0.001	62.7 ± 10.4	65.4 ± 10.9	0.02
<90th	130 (89.7)	147 (77.8)	0.004	129 (93.5)	185 (88.5)	0.1
≥90th	15 (10.3)	42 (22.2)		9 (6.5)	24 (11.5)	

[1] Data are presented as Mean ± SD or n (%).
[2] The comparison between the two sexes was performed with independent t-test (for BMIZ) or Mann-Whitney's test (for SBP and DBP) for quantitative variables and with Chi-square for qualitative variables.
Abbreviations: BMIZ, body mass index Z-score; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Table 4. Logistic regression analysis of the association of BMIZ with blood pressure

	Boys		Girls	
	SBP ≥90th OR (95% CI)	DBP ≥90th OR (95% CI)	SBP ≥90th OR (95% CI)	DBP ≥90th OR (95% CI)
Unadjusted				
BMIZ ≤-1	Ref.	Ref.	Ref.	Ref.
-1> BMIZ <1	1.67 (0.97, 2.87)	2.16 (1.25, 3.75)	2.70 (1.51, 4.83)	1.73 (0.99, 3.01)
BMIZ ≥1	3.15 (1.62, 6.13)	4.40 (2.20, 8.77)	3.93 (1.90, 8.15)	2.86 (1.41, 5.80)
Adjusted[1]				
BMIZ ≤-1	Ref.	Ref.	Ref.	Ref.
-1> BMIZ <1	2.10 (1.18, 3.75)	2.68 (1.50, 4.79)	2.70 (1.50, 4.83)	1.75 (1.00, 3.05)
BMIZ ≥1	4.31 (2.11, 8.82)	5.78 (2.78, 12.0)	3.90 (1.88, 8.10)	3.03 (1.48, 6.19)

[1] Adjusted for age.
Abbreviations: BMIZ, body mass index Z-score; DBP, diastolic blood pressure; SBP, systolic blood.

Discussion

The present study showed a high prevalence of overweight/obesity (22.0%) and elevated blood pressure (including both prehypertension and hypertension) (16.8% and 13.3% for high SBP and DBP, respectively) among the adolescents aged 12-18 years in Shiraz. The prevalence of elevated blood pressure was higher in boys, especially those in older ages (15-18 years versus 12-14 years). A strong association was observed between blood pressure and BMIZ in both sexes, independent of age.

Although we found a higher rate of hypertension among adolescents than that in previous studies in Shiraz (11), some investigators have also reported high prevalence of prehypertension and hypertension among the adolescents of other locations in Iran. For instance, 15% was reported for the sum of prehypertension and hypertension in 10-18 years old adolescents in Tehran (19). Also 13.9% prehypertension and 19.4% hypertension were found in 14-17 years old girls in Tabriz (20). Similarly, reports of studies from other provinces are in agreement with our results for overweight/obesity. For instance, adolescent girls in Tabriz had 19.2% overweight and obesity (20).

There was no significant difference in the average of BMI between the two sexes; however, boys were more frequently seen in overweight/obesity category. Numerous studies have also revealed a higher rate of overweight/obesity in boys (21-24). It has been reported that the cutoff point of BMI at which the risk of hypertension increases is lower in boys than in girls (25).

In the present work, mean values of blood pressure and the prevalence of elevated blood pressure were higher among boys. Other investigators have also found higher measures of blood pressure (26, 27) and higher rates of elevated blood pressure (28-30) in adolescent boys compared to girls. Higher values of blood pressure in boys have been attributed to lower plasma concentrations of mid-regional pro-atrial natriuretic peptide that has diuretic and vasodilatory effects through stimulation of urinary sodium excretion (31).

Previous studies have shown an increase in overweight and obesity during adolescence (32, 33). Especially in girls, a higher likelihood of increasing BMI exists after the age of menarche (34). We did not observe a difference in BMI or prevalence of overweight/obesity between the age categories in girls, which could be because of the age range of participants that was above the usual age of menarche. On the other hand, we observed a decrease in the prevalence of overweight/obesity in boys from the age of 12-14 years to that of 15-18 years, which is contrary to the results of investigators from other countries (35). Nonetheless, there are studies from Iran with the same results as ours (36), indicating that ethnic, socio-economic, and cultural aspects may influence BMI change during adolescence. The reason of the lower prevalence of overweight/obesity in 15-18-year old boys compared to the 12-14-year old ones could be the increase of their height due to puberty.

As with BMI, the rate of hypertension has also been reported to increase with age in adolescents (37) though it has been more pronounced in boys (38, 39). In the current study, boys and girls differed in the values of blood pressure in different age groups; while the rate of elevated blood pressure was higher in older boys, no difference in the prevalence of elevated blood pressure was observed between the different age groups of girls. Similarly, Goharian et al. reported that while post-pubertal boys had higher SBP compared to pubertal boys, there was no difference in blood pressure between the post-pubertal and pubertal girls (31). Testosterone, which increases during puberty, is proposed to lower the previously mentioned natriuretic peptide, and therefore, leads to the post-pubertal increase of blood pressure in boys (31).

Besides age, BMI was also an important determining factor for blood pressure. Interestingly, the association between overweight/obesity and elevated blood pressure occurred independent of age, indicating that BMI and blood pressure are associated throughout the adolescence. The positive correlation between BMI and blood pressure or between obesity and elevated blood pressure has been well known in both adolescents and adults (40). In few studies, the association between BMI and blood pressure or elevated blood pressure has even been found in normal weight adolescents (41, 42). In the current study, we observed that not only adolescents with overweight/obesity were at increased risk of hypertension but those with normal BMI also had a higher rate of elevated blood pressure when compared to adolescents with low BMI. An elevated second obesity index (i.e. waist circumference, triceps skinfold, and fat mass) may explain the increased risk of elevated blood pressure in children and adolescents with normal BMI (43). However, among other obesity indices, BMI had the most powerful relationship with blood pressure (44-46). In this regard, BMI has been suggested as a screening tool for high blood pressure in adolescents (47).

Our study had some limitations. We were not able to measure waist circumference, body composition, and fat mass, and therefore, could not explore possible associations between blood pressure and these variables. Also physical activity, an important confounding factor in the association between BMI and blood pressure, was not assessed, so its effect could not be controlled in the analysis.

Conclusions: The high prevalence of elevated blood pressure among the adolescent boys of this study is intimidating. Since BMI revealed a strong association with elevated blood pressure, strategies focusing on weight control and prevention of obesity are needed to be utilized in order to attenuate age-related increase of blood pressure in early ages.

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