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Original Article

The Relation of Body Mass Index and Blood Pressure in Iranian Children and Adolescents Aged 7- 18 Years Old

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Abstract

Background: The obesity and hypertension are the major risk factors of several life threatening diseases. The present study was aimed to investigate the relation between body mass index (BMI) the validated index of adiposity and different aspect of blood pressure (BP).

Methods: Systolic and diastolic blood pressures and also weight and height of 7 to 18 years old children and adolescent collected in 2002 and 2004 respectively. Data was consisted of 14865 schoolchildren and adolescents from representative sample of country. BMI was classified according to CDC 2000 standards into normal (BMI<85th percentile), at risk of overweight (BMI≥85th and <95th percentile) and overweight (BMI≥ 95th percentile). Then, age-sex specific prevalence of being overweight was derived. ANOVA was used to investigate the effect of BMI on systolic blood pressure and diastolic blood pressure and mean arterial pressure of participants.

Results: Mean systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial blood pressure (MAP) significantly increased with BMI ($P< 0.0001$) and age groups ($P< 0.0001$), and was significantly ($P< 0.0001$) higher in boys than girls especially in older ages. ($P< 0.0001$, interaction of age and BMI level). The proportion of being overweight was significantly higher in boys than girls was (7.4% vs. 3.6%; $P< 0.0001$).

Conclusion: There is an association between BP and BMI in children and adolescence. SBP, DBP and MAP are associated with rise in BMI and age, which was lower in girls. This data can provide basics for public health policy makers and primary prevention policies in the country.

Keyword: *Blood pressure, Body mass index (BMI), Relation, Children, Adolescents*

Introduction

The obesity is known as one of the most important health problems. Its prevalence is increasing rapidly in all ages including children all over the world (1-3). Obesity is usually defined by the BMI, which provides an index of weight relative to height and is generally considered a valid index of adiposity (4). Obesity is considered as a gateway disease, which can lead to heterogeneous diseases such as metabolic syndrome, diabetes different gastrointestinal and respiratory disease, and certain type of cancers and hypertension (HTN) (5-7).

Hypertension is believed as a significant risk factor of adulthood diseases and unfortunately is getting more prevalent rapidly (6). HTN is associated with the incidence of stroke, coronary heart disease, congestive heart failure and renal insufficiency (8). It has been shown that high BP in adults can be originated from childhood period (7, 9). Therefore, preventive intervention during early life might reduce the burden of the disease (9).

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Several studies have declared that there is a relation between HTN and adiposity (5, 10-12). It is observed that the level of BP and prevalence of high BP is higher in the overweight and obese children and adolescents (1). Several studies around the world have found the relation between BMI and high BP in school-aged adolescents (4, 13, 14). Two studies in Iran also found similar results for Iranian children and adolescents (9, 15).

This study aimed to investigate the association between BMI and BP with respect to age and gender among Iranian children and adolescent 7 to 18 yr old. This is the first study looking at this relation on a representative sample of population in Iran.

Materials and Methods

Data on systolic and diastolic blood pressures and also weight and height from a sample of 8,848 primary school children aged 7-12 yr old [4,476 girls (50.6%) and 4,372 boys (49.4 %)] which was collected in 2002 combined with similar data gathered in 2004 on 6017 guidance and secondary school children aged 12-18 yr old [2,571 (45.7%) girls and 3,266 (54.3%)] in Tehran, as a representative of Iran (9, 16), to investigate the relation of BMI and BP.

Tehran is the capital city of Iran and is divided into 20 regions for administrative purposes. In both studies, in each region of the city, one all boys' school and one all girls' school were randomly selected from the list of schools. Trained medical staff measured systolic and diastolic pressures, weight, and height of healthy children and adolescent and rounded it to the nearest mmHg, kilogram, and centimeter, respectively. The criteria for being healthy and full detail of procedure of measurement of BP and weight as well as height are reported elsewhere (9, 16). Exact age of children was obtained from student identification cards and recorded in complete years.

CDC 2000 standards (17) were used to classify BMI of children and adolescents into three groups according to their sex and age (BMI<85th percentile where considered as normal, BMI≥85th and <95th percentile as at risk for overweight and BMI≥95th percentile as overweight (which also contains obese children) (9). Then, age-sex specific prevalence of overweight was derived. The chi-squared test was used to compare the proportion of different BMI categories in boys and girls. The effect of BMI on SBP and DBP and MAP of Iranian children and adolescents was investigated using ANOVA. Data were analyzed using STATA 9.0. *P* value less than 0.05 was considered significant in all analyses.

Results

Systolic and diastolic blood pressure (mmHg) together with weight (kg) and height (cm) of 14,865 of healthy Iranian children and adolescents aged 7-18 yr old used for this study. Of these 7,635 (51.4%) were male and 7,230 (48.6%) were female.

Body Mass Index was computed as weight/ height^2 after rescaling height from centimeter to meter. Specific age-sex mean (±SD) of BMI, SBP and DBP are presented in Table 1. As Table 1 indicates both for boys and girls mean of BMI, SBP and DBP increases with age and is higher in boys ($P< 0.0001$). Weighted average of BMI difference (according to their sample sizes at each age group) of boys and girls was 0.37 kg/mt^2. These differences for SBP and DBP were 2.3 mmHg and 0.7 mmHg, respectively.

The percentages of normal weight children (BMI<85th percentile), children at risk for overweight (BMI 85th to 94th percentile) and overweight (BMI≥95th percentile) for each age group are presented in Table 2. Overall, 84.0% of the children weighted normal, 10.4% were at risk for overweight, and 5.6% were overweight. The chi-squared test showed that the proportion of being overweight was significantly higher in boys than girls was (7.4% vs. 3.6%; $P< 0.0001$) and was significantly higher in older age groups of boys than girls ($P< 0.001$).

For boys, girls, and each category of BMI, the mean (±SD) of SBP were computed and presented in Table 3. Analysis of variance (ANOVA) showed that the mean of SBP significantly in-

creases with BMI rise and age in each BMI groups, although SBP rise is significantly higher in boys ($P< 0.0001$; Table 3).

The mean of DBP values for each BMI and age groups are shown for boys and girls separately in Table 4. As this Table shows the mean of DBP is also increases with BMI and age for boys and girls. Analysis of variance showed that mean DBP significantly increases with age ($P< 0.0001$) and BMI group ($P< 0.0001$), and was significantly ($P< 0.0001$) higher in boys than girls especially in older ages. ($P< 0.0001$, interaction of age and BMI level; Table 3 and 4).

Table 5 provides the MAP for both sexes according to each age and BMI groups. As same as SBP and DBP, the MAP significantly increases with age and BMI and is higher in boys than girls. Moreover, the amount of this increase is higher in older age group of boys than girls ($P< 0.0001$).

Table 1: Body Mass Index (BMI (kg/m^2) and systolic and diastolic blood pressures according to age and sex

Age (yr)	n	BMI ($kg/m^{2)}$	SBP (mmHg)	DBP (mmHg)
Boys				
7	494	14.9±2.0	100.9±7.6	57.9±9.9
8	701	15.3±2.3	103.5±7.5	59.4±10.1
9	764	16.0±2.4	106.5±7.9	61.7±9.2
10	990	16.5±2.7	108.9±7.6	66.0±7.0
11	1096	17.1±2.8	110.2±7.6	66.8±6.8
12	460	18.1±3.7	109.2±9.4	66.9±7.5
13	554	20.1±4.1	109.2±11.1	68.9±7.2
14	521	20.2±3.9	112.1±11.2	70.6±8.1
15	537	21.3±4.1	115.1±10.6	72.8±7.3
16	558	21.2±4.0	117.6±10.0	73.4±7.1
17	456	21.6±4.2	117.1±10.2	73.4±7.6
18	504	22.0±4.0	120.6±10.7	75.2±7.7
Girls				
7	489	14.8±2.2	101.7±7.8	57.6±9.7
8	700	15.0±2.4	103.7±7.4	59.3±9.8
9	835	15.4±2.5	105.6±7.5	61.9±9.1
10	985	16.4±3.0	109.3±7.9	65.5±7.2
11	1120	16.9±3.1	111.1±8.1	66.2±7.3
12	569	17.8±3.5	110.6±10.3	66.3±9.5
13	398	19.3±3.8	107.3±10.6	70.3±8.6
14	350	20.1±3.8	108.6±10.3	71.9±9.4
15	345	20.9±3.4	108.4±10.5	70.7±8.6
16	397	20.9±3.3	109.3±10.5	71.0±9.2
17	441	20.9±3.2	108.9±10.6	71.0±8.5
18	601	21.2±3.2	109.9±10.2	71.1±8.7

Table 2: Distribution of BMI of Tehran children according to age and sex

Age (yr)	BMI (kg/m^2)			Total
	<85th percentile	85th to 94th percentile	>95th percentile	
Boys	n (%)	n (%)	n (%)	n (%)
7	435 (88.1)	37 (7.5)	22 (4.4)	494 (100)
8	627 (89.5)	40 (5.7)	34 (4.8)	701 (100)
9	673 (88.1)	51 (6.7)	40 (5.2)	764 (100)
10	857 (86.5)	76 (7.7)	57 (5.8)	990 (100)
11	918 (83.8)	126 (11.5)	52 (4.7)	1096 (100)
12	371 (80.7)	52 (11.3)	37 (8.0)	460 (100)

Table 2: Countinued…

13	366 (66.0)	115 (20.8)	73 (13.2)	554 (100)
14	389 (74.6)	81 (15.6)	51 (9.8)	521 (100)
15	385 (71.7)	84 (15.6)	68 (12.7)	537 (100)
16	437 (78.4)	70 (12.5)	51 (9.1)	558 (100)
17	358 (78.5)	59 (12.9)	39 (8. 6)	456 (100)
18	420 (83.4)	44 (8.7)	40 (7.9)	504 (100)
Boys total	6,236 (81.6)	835 (10.9)	564 (7.4)	7,635 (100)
Girls				
7	438 (89.6)	26 (5.3)	25 (5.1)	489 (100)
8	623 (89.0)	51 (7.3)	26 (3.7)	700 (100)
9	763 (91.3)	48 (5.8)	24 (2.9)	835 (100)
10	848 (86.1)	91 (9.2)	46 (4.7)	985 (100)
11	959 (85.7)	127 (11.3)	34 (3.0)	1120 (100)
12	485 (85.2)	57 (10.0)	27 (4.8)	569 (100)
13	312 (78.4)	60 (15.1)	26 (6.5)	398 (100)
14	278 (79.4)	48 (13.7)	24 (6.9)	350 (100%)
15	272 (78.8)	73 (21.2)	0 (0)	345 (100)
16	340 (85.7)	45 (11.3)	12 (3.0)	397 (100)
17	391 (88.7)	42 (9.5)	8 (1.8)	441 (100)
18	541 (90.0)	50 (8.3)	10 (1.7)	601(100)
Girls total	6,250 (86.4)	718 (9.9)	262 (3.6)	7,230 (100)
Total	12,484 (84.0)	1,553 (10.4)	826 (5.6)	14,865 (100)

Table 3: Mean (±SD) of systolic blood pressure according to BMI, age and sex

Age (yr)	**BMI (kg/m^2)**		
	<85th percentile	**85th to 94th percentile**	**>95th percentile**
SBP (mmHg)			
Boys			
7	100.4±7.4	104.4±7.0	104.9±8.9
8	103.1±7.4	105.0±6.9	109.2±6.4
9	106.0±7.8	109.0±7.9	112.2±6.1
10	108.3±7.5	112.0±6.7	114.1±7.0
11	109.6±7.4	113.4±7.6	113.6±7.7
12	108.0±9.3	113.4±8.8	115.7±7.6
13	107.3±11.0	112.5±10.7	113.2±10.1
14	110.9±10.9	115.1±10.0	116.1±13.4
15	113.9±10.0	116.3±10.0	120.4±12.3
16	116.6±9.8	119.7±9.3	123.6±10.0
17	115.9±10.2	120.4±8.0	122.8±10.5
18	119.8±10.8	124.1±9.2	124.8±9.1
Girls			
7	101.4±7.8	102.8±8.0	104.6±7.3
8	103.5±7.4	104.8±7.6	107.0±6.3
9	105.4±7.4	107.5±8.4	109.8±8.3
10	108.6±7.6	112.4±7.9	117.0±7.9
11	110.4±7.9	114.6±7.7	116.5±9.9
12	110.2±10.0	111.9±11.8	114.7±11.4
13	105.7±10.4	111.6±9.4	115.8±9.9
14	107.4±9.7	113.0±11.3	114.5±10.3
15	107.6±10.1	111.6±11.3	-
16	108.2±10.2	115.9±10.2	115.1±9.7
17	108.2±10.3	114.3±10.9	116.9±11.9
18	109.5±10.1	112.5±9.8	115.1±12.5

Table 4: Mean (±SD) of diastolic blood pressure according to BMI, age and sex

Age (yr)	BMI (kg/m^2)		
	<85th percentile	85th to 94th percentile	>95th percentile
DBP (mmHg)			
Boys			
7	57.6±10.0	59.5±8.9	61.5±7.7
8	58.9±10.2	62.7±9.3	63.4±8.5
9	61.3±9.3	64.6±8.6	65.4±7.6
10	65.8±7.0	68.4±6.5	66.8±6.9
11	66.6±6.8	67.6±7.0	68.8±5.3
12	66.1±7.3	70.8±7.1	70.1±7.3
13	68.0±7.2	70.3±6.7	71.4±7.2
14	69.7±8.0	72.6±8.0	74.1±6.9
15	72.4±7.1	73.4±7.0	74.9±8.6
16	72.9±7.3	75.0±5.8	75.4±6.7
17	72.9±7.6	73.5±7.3	77.5±6.2
18	74.8±7.5	76.9±8.6	77.5±8.3
Girls			
7	57.3±9.8	61.0±7.0	58.6±9.5
8	58.9±9.9	61.8±8.1	63.1±9.5
9	61.6±9.1	62.2±7.8	70.1±7.6
10	65.2±7.1	67.6±6.4	67.6±8.2
11	66.0±7.4	67.5±6.6	68.5±7.7
12	66.2±9.6	66.9±8.1	68.7±9.9
13	69.7±8.7	73.6±7.9	71.1±8.0
14	70.9±9.6	75.5±8.0	76.4±7.4
15	70.2±8.7	72.6±7.9	-
16	70.5±9.3	74.1±9.1	74.3±5.2
17	70.5±8.4	74.7±7.3	74.0±11.1
18	70.9±8.6	72.5±9.4	71.5±8.2

Table 5: Mean (±SD) of arterial blood pressure according to BMI, age and sex

Age (yr)	BMI (kg/m^2)		
	<85th percentile	85th to 94th percentile	≥95th percentile
Boys			
7	71.9±7.8	74.5±6.3	75.9±5.9
8	73.6±7.7	76.8±7.1	78.7±5.9
9	76.2±7.4	79.4±6.8	81.0±6.1
10	79.9±6.0	82.9±5.6	82.5±5.4
11	80.9±5.9	82.9±6.1	83.8±5.2
12	80.0±6.6	85.0±6.0	85.3±6.3
13	81.1±7.3	84.4±6.6	85.3±6.9
14	83.4±7.9	86.8±7.6	88.1±7.7
15	86.2±7.0	87.7±7.0	90.1±8.5
16	87.4±6.9	89.9±5.7	91.5±6.6
17	87.2±7.4	89.2±5.9	92.6±6.7
18	89.8±7.5	92.6±8.0	93.3±7.8
Girls			
7	72.0±7.3	74.9±5.0	73.9±6.7
8	73.8±7.4	76.2±6.5	77.7±6.8
9	76.2±7.1	77.3±6.7	83.3±6.9
10	79.6±5.9	82.6±5.7	84.0±6.9
11	80.8±6.2	83.2±5.3	84.5±6.8
12	80.8±8.3	81.9±7.8	84.0±8.5
13	81.7±8.2	86.2±7.3	86.0±7.0
14	83.0±8.3	88.0±8.1	89.1±7.7
15	82.6±8.0	85.6±8.1	-
16	83.1±8.4	88.1±8.3	87.9±6.0
17	83.1±8.0	87.9±6.7	88.3±10.4
18	83.8±8.1	85.8±8.5	86.0±8.9

Discussion

This study assessed the association between BMI and BP among Iranian children and adolescents 7 to 18 yr old. This study indicates that elevated BP is more prevalent among overweight healthy children and adolescents. We demonstrated that the mean of SBP, DBP and MAP are significantly associated with increase in amount of BMI that is detectable in all age groups. Furthermore, in an ecological view, an increase in age is associated with increase in BP and Iranian boys have higher BP compared with their girls' peers respecting each age and BMI groups.

In this study, data was collected from different located primary, guidance, and high schools of Tehran and it was assumed the representative sample of Iranian children and adolescents (18). We collected the data from all 20 regions of Tehran. Analysis was performed on 14,865 individual that are unique in whole country until now. As data resulted from sampling from different schools in Tehran, the effect of clustering on finding was also considered. We calculated intraclass correlation that was 0.182, 0.132 and 0.183 for systolic, diastolic and MAP, respectively. Moreover, when intraclass correlation is less than 0.5, the findings in ANOVA and estimation of standard deviations would barely differ without cluster data consideration (19).

Previous studies in consistent with our study have reported a significant association between BMI and BP (14, 20-25). Hernandez et al. also confirmed a positive relation between BMI and BP (26). A prospective cohort study hold on 22071 individuals in Harvard school revealed positive relation between BMI and BP (27). Cindy et al. also supported that BMI and BP are related together (28) Two studies about obese children with normal clinical BP showed a high prevalence of elevated ambulatory BP in comparison to their leaner counterparts (29, 30). Two studies in Iran and Turkey expressed association between BMI and BP. Despite the fact that the last two studies in Iran and Turkey were only based on small numbers of children compared with our study (15, 31). All findings from the above studies supported our result in this survey.

The impact of gender on the association of BMI and BP is controversial. Outcome obtained from study conducted in Quebec, Canada in adolescents aged 12-18 yr remarked that intra-abdominal fat have direct relation with BP which was less prominent in girls (32). Ataei et al. also showed higher BMI in less than 7 yr old boys than their girls' counterparts in a sample of 3186 children from Tehran (9). In contrast to woman, Chen et al. observed a linear relation between the 2 yr BMI changes and HTN development among men. This relation only observed in menopause women (33). On the other hand, Zuhal et al. reported that sex had no effect on BMI and BP relation (4). Our study suggests that association between BMI and BP is more considerable in boys. Probable reason of different BP trend in men and women can come from effect of sex hormone in sodium excretion and renal homodynamic response to salt. Regarding that, women have higher sensitivity to sodium intake after menopause (34).

In the present study, 10.4% children and adolescents were at risk for overweight and 5.6% were overweight. In general, similar to BP, BMI was significantly higher in boys than girls. A survey in Turkey in 2004, which was conducted on 15 to 18 yr old adolescents, found that approximately 3% were overweight and 11% were at risk for overweight (31). Another study conducted on 1899 children 6 to 14 yr old in turkey in 2002 recognized that higher percent of boys than girls lay at or above 85 percentile of BMI (4). Cynthia et al. in USA also reported that boys have higher percentage in overweight, obesity, and risk for obesity groups than girls do in both 1999-2000 and 2007-2008 surveys (35, 36). Unlike our result, Kimani et al. showed that rural South Africa 10 to 20 yr old girls have higher prevalence of obesity and overweight than boys in a 2007 survey (37).

The result of this study about increasing BMI with age is consistent with several studies. A study in California in 2004, which studied 5 to 15 yr old children and adolescents, showed that BMI in-

creases with age (28). Aayatollahi et al. with studying on 2,397 children aged 6.5 to 11.5 yr old showed that BMI increased with age (38).

High BMI and elevated BP are among the important risk factors of cardiovascular disease, diabetes mellitus, HTN and dyslipidemia (9, 28, 39-42). Childhood BP predicts risk of cardiovascular disease in adulthood period and concomitant high BMI with elevated BP increase risk of cardiovascular disease (23). Dealing with high BMI and elevated BP can help to prevent the upcoming threats in adulthood period through public health policies as both high BMI and elevated BP are considerable risk factor for such diseases (43-45).

In conclusion, we have demonstrated that there was an association between blood pressure and body mass index in children and adolescents. We showed that SBP, DBP and MAP are associated with rise in BMI and age in the society. Generally, BP was lower in girls than boys in age range we studied were. This data can provide basics for public health policy makers to estimate the risk of cardiovascular disease through BMI and BP estimates of children and adolescence. This data can also be used for primary prevention policies in the country.

Ethical Considerations

All ethical issues including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc have been completely observed by the authors.

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