

Relationship between BMI and blood pressure in girls and boys

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Abstract

Aim: To investigate the relationship between BMI and blood pressure as this is of crucial interest in evaluating both public health and the clinical impact of the so-called obesity epidemic.

Methods: Data were gathered from 1899 children aged between 6 and 14 years, analysing and evaluating a possible relationship between BMI and systolic and diastolic blood pressure values for both girls and boys. Each child was classified on the basis of age- and sex-specific BMI percentile as normal weight (<85th percentile), overweight (\geq 85th and <95th percentile) or obese (\geq 95th percentile).

Results: In comparisons among age–sex–BMI percentile groups, systolic and diastolic blood pressure values were higher in obese and overweight groups than in normal weight groups for both sexes. Although BMI among girls was higher than among boys in all three percentile groups, there were no significant differences between sexes with respect to blood pressure values.

Conclusion: The present findings emphasize the importance of the prevention of obesity in order to prevent future related problems such as hypertension in children and adolescents.

Keywords
Body mass index
Obesity
Blood pressure
Overweight

Obesity has become an increasingly important medical problem in children and adolescents. Many of the outcomes associated with obesity that were previously thought of as diseases of adults are now affecting children as well⁽¹⁾.

Obesity is associated with elevated blood pressure both in adults and children⁽²⁾. Higher blood pressure in childhood is considered to be predictive of sustained hypertension in young adulthood. It is reported that, following age, race/ethnicity and sex standardization, systolic blood pressure (SBP) was 1.4 mmHg higher and diastolic blood pressure (DBP) was 3.3 mmHg higher in 1999–2000 than in 1988–1994. This increase in blood pressure among children and adolescents was statistically significant and was largely but not entirely due to the increased prevalence of overweight in children^(3,4).

Childhood obesity is usually defined according to age- and sex-specific BMI cut-off points⁽⁵⁾. The BMI provides an index of weight relative to height, and is generally considered, with some limitations, to be a valid index of adiposity⁽⁶⁾. Age, gender, ethnicity, weight and height were ascertained⁽⁷⁾. BMI in childhood changes substantially with age, as does blood pressure^(8,9). At birth the median BMI may be as low as 13 kg/m², increases to 17 kg/m² at 1 year of age, decreases to 15.5 kg/m² at age 6 years and then increases to 21 kg/m² at age 20 years. In the USA, the 85th and 95th percentiles of BMI for age and sex based on nationally representative survey data

have been recommended as cut-off points to identify overweight and obesity⁽⁸⁾.

The present paper evaluates the correlation between BMI and SBP and DBP with respect to age and gender among Turkish children.

Material and methods

A study was carried out on 1899 children between the ages of 6 and 14 years in weekly public screening days at Kocaeli Metropolitan Maternity and Children Hospital in Turkey during 2002.

During the public screening, a history of every child was taken from parents and recorded. Children who had major disorders (cardiac, respiratory, renal or haematological disorders) were not considered in the study. The medical examination of the children was carried out by a doctor in a quiet, warm and comfortable polyclinic room.

Heights and weights were measured on children with shoes off and wearing the least possible clothes. Height was measured in centimetres using a stadiometer attached to the wall; weight was measured in kilograms using an electronic scale (Tefal 79490).

Children were rested for 15 min before their blood pressure was taken. Blood pressure was measured with the child in seated position according to paediatric measurement guidelines⁽¹⁰⁾ by auscultation with an appropriate

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sized cuff and an aneroid sphygmomanometer. The fifth Korotkoff sound was used to determine DBP. Three blood pressure measurements were taken at 3 min intervals and the average value of these three measurements was recorded. Blood pressure, height and weight were always measured by the same doctor to ensure uniformity of recording.

BMI (kg/m^2) was calculated as weight in kilograms divided by the square of height in metres. Sex- and age-specific BMI percentiles were calculated for each child according to the 2000 growth standards of the US Centers for Disease Control and Prevention (CDC)⁽¹¹⁾. The children were divided into three groups: those with BMI < 85th percentile were classified as normal weight, those with BMI \geq 85th and < 95th percentile were classified as overweight and those with BMI \geq 95th percentile as obese.

Children were compared with respect to BMI and BMI percentile. The SBP and DBP of children in each of the BMI percentile groups were compared. In addition, the correlation of SBP and DBP with BMI was evaluated within each group according to age and gender cumulatively.

Statistical evaluation of the results was performed using simple multiple linear regression analysis in the SPSS statistical software package version 14 (SPSS Inc., Chicago, IL, USA). All significance tests were based at the 0.05 level of significance.

Results

One thousand eight hundred and ninety-nine children with a male:female ratio of 1033:866 and with a mean age of 9.52 (SD 2.62) years were enrolled in the present study. As stated earlier, children were divided into three groups according to BMI percentiles based on the 2000 CDC growth standards⁽¹¹⁾. The number of children and mean age, weight, height, BMI, SBP and DBP in each BMI percentile group of girls and boys are shown in Table 1.

The table reveals that BMI, SBP and DBP were higher in the obese group than the normal weight group. BMI values for girls were higher than for boys in all three BMI percentile groups, but the difference was not statistically significant.

SBP and DBP were compared between girls and boys (Table 2). Simple multiple linear regression analysis was used that included age and BMI as factors (Model 1) in girls and boys separately (formula = SBP – age + factor(BMI) and formula = DBP – age + factor(BMI)). Adjustment for BMI had a significant effect in the model for SBP and DBP in both girls and boys. There was a statistically significant increase in both in SBP ($P < 0.001$) and DBP ($P < 0.001$) with increasing BMI category (Table 2).

A second simple multiple linear regression analysis (Model 2) was applied to SBP and DBP values in the normal weight, overweight and obese groups separately (Table 3). The adjusted BMI value was significantly

Table 2 Linear regression model (Model 1) of the effect of age and BMI on systolic and diastolic blood pressure values in girls and boys: Turkish children aged 6–14 years

Entered variable	β	<i>t</i>	<i>P</i>	Adjusted R^2
Girls				
SBP				
Age	0.382	10.40	<0.001	0.243
BMI	0.161	4.38	<0.001	
DBP				
Age	0.366	9.87	<0.001	0.231
BMI	0.163	4.39	<0.001	
Boys				
SBP				
Age	0.374	11.50	<0.001	0.248
BMI	0.183	5.64	<0.001	
DBP				
Age	0.339	10.24	<0.001	0.221
BMI	0.190	5.76	<0.001	

SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 1 Mean age, weight, height, BMI, systolic and diastolic blood pressure values in girls and boys according to weight status based on BMI percentile*: Turkish children aged 6–14 years

	Normal weight (<i>n</i> 1693)		Overweight (<i>n</i> 147)		Obese (<i>n</i> 59)	
	Mean	SD	Mean	SD	Mean	SD
Girls						
	<i>n</i> 782		<i>n</i> 58		<i>n</i> 26	
Age (years)	9.41	2.57	10.31	2.56	9.73	2.60
Weight (kg)	29.13	10.42	43.21	13.60	47.01	18.77
Height (cm)	131.29	15.64	139.44	15.86	135.38	18.50
BMI (kg/m^2)	16.30	2.19	21.46	2.56	24.52	4.10
SBP (mmHg)	92.80	13.37	97.98	13.90	98.84	18.34
DBP (mmHg)	60.93	9.36	64.94	8.18	65.57	11.94
Boys						
	<i>n</i> 911		<i>n</i> 89		<i>n</i> 33	
Age (years)	9.54	2.65	10.03	2.78	8.54	2.48
Weight (kg)	29.50	10.43	40.86	14.63	39.04	12.93
Height (cm)	132.68	16.31	138.23	17.58	131.10	14.54
BMI (kg/m^2)	16.18	1.96	20.50	2.48	22.03	2.62
SBP (mmHg)	93.47	13.37	97.44	13.63	98.78	13.23
DBP (mmHg)	60.55	9.43	64.22	8.59	63.78	9.38

SBP, systolic blood pressure; DBP, diastolic blood pressure.

*Normal weight defined as BMI < 85th percentile, overweight as BMI \geq 85th and < 95th percentile and obese as BMI \geq 95th percentile; sex- and age-specific BMI percentiles calculated according to the 2000 growth charts of the US Centers for Disease Control and Prevention⁽¹¹⁾.

related ($P < 0.001$) to both SBP and DBP in the normal weight, overweight and obese groups. An increase of 1 unit of BMI was associated with, on average, a 0.60 mmHg increase in SBP and a 0.64 mmHg increase in DBP in the obese children. BMI also had an effect on blood pressure in normal weight children as well (Table 3). There were no significant differences between girls and boys with respect to the impact of BMI on SBP and DBP ($P > 0.05$) (Table 3).

SBP and DBP were higher in the obese and overweight groups than in the normal weight groups in both girls and boys. Table 4 shows mean SBP, DBP and BMI values according to age and BMI category separately for both

sexes. BMI, SBP and DBP increased significantly in girls and boys from 6 to 14 years old. The mean SBP and DBP values were also significantly higher in the overweight and obese groups compared with the normal weight groups in both girls and boys.

Discussion

The relationship between BMI and blood pressure is of crucial interest in evaluating both public health and the clinical impact of the so-called obesity epidemic (i.e. increasing prevalence of childhood obesity). In the present study conducted among 1899 children, 3.1% were obese and 7.7% were overweight. A higher percentage of boys than of girls were at or above the 85th percentile of BMI.

The positive correlation of blood pressure and obesity in children has also been observed in other studies. Sorof and Daniels⁽¹⁾ reported that, among all demographic and clinical factors analysed, BMI was most strongly associated with hypertension. Burke *et al.*⁽⁹⁾ recently described an independent association between high blood pressure and overweight and obesity, as defined by the International Obesity Task Force, in a prospective study carried out in an Australian cohort of children followed up from age 9 to 25 years, as did Genovesi *et al.*⁽¹²⁾ in a cross-sectional study carried out in a sample of schoolchildren living in northern Italy. Mirza *et al.*⁽¹³⁾ found the same trend that the mean SBP value was significantly higher in overweight children.

Table 3 Linear regression model (Model 2) of the effect of gender and BMI on systolic and diastolic blood pressure values in normal weight, overweight and obese groups based on BMI percentile*: Turkish children aged 6–14 years

Entered variable	Gender		BMI (kg/m ²)		Adjusted R ²
	β	P	β	P	
SBP					
Normal weight	0.037	0.104	0.384	<0.001	0.147
Overweight	0.087	0.213	0.578	<0.001	0.313
Obese	0.210	0.079	0.605	<0.001	0.297
DBP					
Normal weight	-0.009	0.682	0.367	<0.001	0.134
Overweight	0.047	0.527	0.486	<0.001	0.219
Obese	0.142	0.212	0.648	<0.001	0.354

SBP, systolic blood pressure; DBP, diastolic blood pressure.
*Normal weight defined as BMI < 85th percentile, overweight as BMI ≥ 85th and <95th percentile and obese as BMI ≥ 95th percentile; sex- and age-specific BMI percentiles calculated according to the 2000 growth charts of the US Centers for Disease Control and Prevention⁽¹¹⁾.

Table 4 Mean systolic and diastolic blood pressure and BMI in girls and boys according to age and weight status based on BMI percentile*: Turkish children aged 6–14 years

Age group (years)	Normal weight						Overweight						Obese					
	SBP (mmHg)		DBP (mmHg)		BMI (kg/m ²)		SBP (mmHg)		DBP (mmHg)		BMI (kg/m ²)		SBP (mmHg)		DBP (mmHg)		BMI (kg/m ²)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Girls																		
6	86.64	10.76	55.83	8.40	14.56	1.29	85.60	6.06	60.00	7.07	17.57	0.50	70.00	0.00	50.00	0.00	19.82	0.29
7	88.03	11.56	56.63	8.05	15.01	1.26	84.28	18.12	58.14	6.59	18.10	0.53	96.66	15.27	60.00	10.00	20.10	0.46
8	86.08	11.57	57.36	8.13	15.37	1.26	90.00	8.94	61.66	7.52	19.31	0.80	90.00	8.94	61.66	6.83	22.26	1.21
9	90.43	11.36	60.69	8.62	15.93	1.35	102.50	5.00	67.50	5.00	19.74	0.61	88.75	14.36	55.00	5.77	22.67	2.36
10	92.71	12.09	62.16	8.28	16.42	1.47	95.00	12.24	66.00	11.40	21.74	1.08	95.00	21.21	65.00	7.07	25.75	0.30
11	95.88	13.10	63.43	9.40	16.59	1.74	100.00	14.14	62.00	10.95	22.32	1.13	120.00	Inf	80.00	Inf	29.42	Inf
12	102.23	11.42	67.16	7.24	17.78	1.67	107.30	10.12	69.23	7.02	23.25	1.05	125.00	7.07	80.00	0.00	27.73	2.15
13	103.48	11.93	67.91	9.07	18.30	2.29	101.87	9.97	67.50	5.34	23.80	1.20	115.00	13.22	76.66	11.54	30.12	4.48
14	101.85	13.31	65.72	7.83	19.68	2.10	106.00	15.16	68.00	8.36	24.50	1.01	113.33	11.54	78.33	7.63	28.81	1.92
Boys																		
6	89.45	12.03	56.62	9.30	14.73	1.16	84.56	8.83	57.56	7.80	17.32	0.90	91.42	13.45	56.71	11.47	19.84	1.66
7	86.29	10.88	54.39	8.07	14.94	1.14	90.00	7.07	58.00	8.36	18.08	0.59	93.33	11.18	63.11	7.80	21.20	2.48
8	87.05	12.74	57.50	8.70	15.09	1.25	85.00	14.14	58.12	10.66	18.69	0.64	97.50	10.60	65.00	7.07	20.96	0.67
9	90.59	12.24	60.83	8.92	15.79	1.25	93.12	7.98	62.50	7.07	19.16	0.52	100.00	13.09	64.37	9.03	21.84	0.72
10	93.58	10.75	62.60	8.03	16.39	1.40	102.30	9.26	66.15	5.06	20.14	0.52	ND	ND	ND	ND	ND	ND
11	97.83	12.54	64.69	8.53	16.79	1.55	101.00	7.37	67.00	9.48	21.53	0.81	110.00	Inf	60.00	Inf	25.22	Inf
12	97.85	12.39	63.05	7.52	17.02	1.54	113.33	11.54	71.66	7.63	21.96	0.87	112.50	3.53	70.00	0.00	25.63	1.99
13	102.52	10.42	66.32	6.96	18.01	1.81	101.42	12.31	67.14	5.78	23.25	0.90	115.00	7.07	75.00	7.07	25.28	0.17
14	105.32	11.85	66.46	8.88	18.73	2.01	112.08	9.87	71.25	4.82	23.84	1.04	110.00	14.14	72.50	3.53	26.81	0.77

SBP, systolic blood pressure; DBP, diastolic blood pressure; Inf, infinity; ND, no data.
*Normal weight defined as BMI < 85th percentile, overweight as BMI ≥ 85th and <95th percentile and obese as BMI ≥ 95th percentile; sex- and age-specific BMI percentiles calculated according to the 2000 growth charts of the US Centers for Disease Control and Prevention⁽¹¹⁾.

In addition, the present study demonstrated a significant association between BMI and blood pressure detectable in all age groups including young children. The association of higher blood pressure with increasing BMI status was present in all age groups. Falkner *et al.*⁽³⁾ have reported a similar finding in all age groups as in our data and Reinehr *et al.*⁽¹⁴⁾ reported that children older than 12 years had a slightly increased risk of hypertension probably reflecting the influence of duration of obesity.

Our results indicated that age and BMI are strongly associated with both SBP and DBP in both sexes and that BMI, but not sex, is significantly associated with SBP and DBP, even within BMI groups. As a result, it can be concluded that the impact or effect of BMI on SBP and DBP is similar in girls and boys.

Paradis *et al.*⁽¹⁵⁾ reported that mean DBP did not differ between males and females. Mean SBP was similar among 9-year-old males and females, while the difference in SBP between males and females was 3–4 mmHg among 13-year-olds and 13–15 mmHg among 16-year-olds.

The present study has shown an association between blood pressure and BMI, suggesting that obesity is a strong risk factor and it is same among females and males. These findings emphasize the importance of the prevention of obesity in children and adolescents.

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