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Research Article

Correlations Between Anthropometric Measurements, Somatotype and Blood Pressure in Children Aged 7-12 Years in Yogyakarta Province, Indonesia

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Abstract

Background and Objective: Anthropometric and somatotype measurements are useful in the assessment of growth and development and may vary with health in children and adolescents. It is known that high endomorphic scores are associated with hypertension in later adulthood. This study aimed to examine the relationships among anthropometric, somatotype and blood pressure measurements in healthy elementary school students. **Materials and Methods:** The study was conducted with 493 boys and girls, aged 7-12 years, in Yogyakarta province, Indonesia. Weight, height, somatotype components and both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded. The Pearson correlation coefficient and multiple linear regression were used, considering p<0.05 as the cut-off for statistical significance. **Results:** The results showed that significant correlations (p<0.01) existed for height and endomorphic component with blood pressure, with r = 0.18 (height) and r = 0.11 (endomorphy). The mean somatotype of boys was 2.1-4.6-2.8 (balance mesomorph) and of girls was 2.2-4.1-3.0 (central). The mean blood pressure measurements for boys were 90.3±11.6 (SBP) and 61.1±10.6 (DBP) and for girls were 87.6±10.5 (SBP) and 59.9±9.4 (DBP). **Conclusion:** Higher values of height and endomorphic component measurements were correlated with higher blood pressure in children aged 7-12 years in Yogyakarta province, Indonesia

Key words: Blood pressure, height, Javanese children, somatotype, weight

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Hypertension occurs not only in adults but also in children and adolescents. The condition is a problem for children and adolescents because continuing to adulthood with hypertension leads to higher risk of morbidity and mortality. Although the clinical prevalence of hypertension is lower in children and adolescents compared with adults, considerable evidence exists that essential hypertension in adults can start in childhood or adolescence.

The incidence of hypertension in children and adolescents is estimated to be between 1 and 3%. In a study of 14,686 children aged 10-15 years, Sinaiko *et al.*[1] found that 4.2% of children had hypertension. Less than 5% of children and a higher proportion of adolescents, have hypertension at a given blood glucose level. The incidence of hypertension increases with age, ranging from 15% in young adulthood to 60% in people aged 65 and older. In Indonesia, the reported incidence of hypertension in children and adolescents varies from 3.11-4.6%. Research by Fujita *et al.*[2] suggested that there was a relationship between blood pressure and height. Further studies showed that basing blood pressure references on height measurements was useful to support children and adolescents appropriately to prevent lifestyle and risk factors. There is evidence to suggest that hypertension in children and adolescents can initiate hypertension in adults. The presence of such hypertension may contribute to the early development of cardiac artery disease. Recent reports suggested that early development of atherosclerosis in children and adolescents may be associated with hypertension in children[3].

Several studies on anthropometrics and blood pressure by Lone *et al.*[3], De Hoog *et al.*[4] and others found that increases in height and weight, as well as body mass index, are positively correlated with childhood hypertension. Moser *et al.*[5] reported that total body fat is a better predictor of the risk of high blood pressure than abdominal fat, while Burgos *et al.*[6] suggested that waist circumference was associated with cardiovascular disease and is a predictor of hypertension in children and adolescents.

The association between somatotype and disease was first investigated by Sheldon in 1963, the results of which indicated that there was a relationship between somatotype and abnormal behaviours or bodily functions[7]. William *et al.*[8] suggested that in patients with coronary heart disease, the endomorphic component was significantly correlated to waist circumference, waist-hip ratio and waist sagittal diameter. Several studies have shown an association between somatotype component and cardiovascular disease[6,9-10]. The association between blood pressure and anthropometric characteristics, including somatotype components, were investigated by Kalichman *et al.*[9] in 1503 healthy adults; these findings suggest the existence of common physiological paths in the development of body physique and blood pressure regulation.

A study by Burgos *et al.*[6] on children aged 7-18 indicated that there was a significant relationship between blood pressure and somatotype components (ectomorphy). Herrera *et al.*[10] found an inverse association between ectomorphic components and blood pressure, i.e., an increase in the ectomorphy value decreases blood pressure.

Research on the relation of anthropometrics and somatotypes to the blood pressure of children and adolescents among 7-12 years of age groups is very important in clinical epidemiology and paediatrics to achieve a better understanding of the morphological and physiological changes that occur during growth. Earlier detection of hypertension reduces the incidence of and risk factors for cardiovascular disease. One of the most feasible and inexpensive screening methods is anthropometry and somatotyping. However, few studies have been conducted with children and adolescents in Indonesia, therefore, this study was conducted to examine the relationships between somatotype and anthropometric size with blood pressure and to identify the most significant predictor of blood pressure in Indonesian children.

MATERIALS AND METHODS

Participants: The present study used cross-sectional data from school students aged 7-12 years old. A total of 493 students (248 boys and 245 girls) from three elementary schools in Yogyakarta province, Indonesia, were included. Yogyakarta is one of the large cities on Java Island, Indonesia. Data collection was conducted in August and September 2017. Inclusion criteria were children who were Javanese, healthy, lacking mental and physical disabilities. Exclusion criteria were athletes and those under intensive medical care or on medication. Researchers provided complete and clear information to the subjects about the study's purpose and procedures. Prior to taking measurements, the researchers distributed questionnaires (regarding nutritional, socioeconomic and physical activity data) and informed consent requests to the parents of the students. The study protocol was approved by the Medical and Health Research Ethics Committee of the Faculty of Medicine, Public

Health and Nursing, Universitas Gadjah Mada in Yogyakarta (No. KE/FK/1108/2017). The subjects' fathers were labourers (35.2%), entrepreneurs (26.2%), private employees (20.5%), civil servants (7.4%) and others (10.7%), while the children's mothers were labourers (32.4%), housewives (23.4%), private employees (16.2%), entrepreneurs (16.2%) and others (11.8%). With regard to the education level of the participants' parents, almost half of the fathers had graduated from high school (49.4%); others had completed junior high (22.2%), elementary (20%) and undergraduate (8.3%) education. The children's mothers had graduated from senior high school (44.3%), junior high (28.6%), primary school (16.2%) and undergraduate (5.4%).

Upon completion of the questionnaires, blood pressure and ten anthropometric measurements were recorded for each participant. The data collected were age, height, weight, four skinfold measurements (triceps, subscapular, suprailiac and mid-calf), two bone diameters (humerus and femur) and two limb girths (upper arm and calf). Blood pressures were assessed using a stethoscope and gauge. The gauge uses a scale called "millimetres of mercury" (mmHg) to measure the pressure in blood vessels. Body mass was assessed on a calibrated digital scale with a precision of 0.1 kg with the participant wearing minimal clothing. Height was measured using a portable anthropometer (Holtain, UK) with a precision of 0.1 cm. Diameters were assessed using spreading callipers with a precision of 0.1 cm (Holtain, UK). Skinfolds were assessed using Harpenden callipers (Holtain, UK) with a precision of 0.2 mm and girth measurements were taken using a flexible steel tape (Lufkin, UK) with a precision of 0.1 cm. All anthropometric measurements were performed by a trained anthropometrist following the protocols of the International Society for the Advancement of Kinanthropometry[11].

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) and anthropometric somatotype were also recorded. The somatotype components were calculated according to the Heath-Carter anthropometric method with "stature-corrected endomorphy", using the following equations[7]:

$$\text{Endomorphy} = -0.7182 + 0.1415\,(X) - 0.00068\,(X^2) + 0.0000014\,(X^3)$$

Where:

$$X = \text{Triceps skinfold (mm)} + \text{subscapular skinfold (mm)} + \text{suprailiac skinfold (mm)} \times 170.18/\text{stature (cm)}$$

$$\text{Mesomorphy} = \{(0.858 \times \text{humerus breadth (cm)}\} + \{0.601 \times \text{femur breadth (cm)}\} + \{0.188 \times \text{corrected arm girth (cm)}\} + \{0.161 \times \text{corrected calf girth (cm)}\} - (\text{stature} \times 0.131) + 4.5$$

Where:

$$\text{Corrected arm girth} = [\text{upper arm girth (cm)} - \text{triceps skinfold (mm)}/10]$$

Where:

$$\text{Corrected calf girth} = [\text{calf girth (cm)} - \text{calf skinfold (mm)}/10]$$

Ectomorphy: Three different equations were used to calculate ectomorphy depending on the stature-weight ratio (HWR), i.e., stature/cube root of weight:

- If HWR is greater than or equal to 40.75, then

$$\text{Ectomorphy} = 0.732 \times \text{HWR} - 28.58$$

- If HWR is less than 40.75 but more than 38.25, then

$$\text{Ectomorphy} = 0.463 \times \text{HWR} - 17.63$$

- If HWR is equal to or less than 38.25, then

$$\text{Ectomorphy} = 0.1$$

Plotting the Somatotype: The somatotypes of individuals or the mean somatotype of a target group were plotted on the Carter somatochart after calculating the X and Y coordinate values using the following formula[7]:

$$X = \text{Ectomorphy} - \text{Endomorphy}$$

$$Y = 2 \times \text{Mesomorphy} - (\text{Endomorphy} + \text{Ectomorphy})$$

Means and standard deviations of all variables are presented in the Table 1 including age, height, weight, BMI (height/cube root of weight), endomorphy, mesomorphy and ectomorphy. The individual somatotypes in each sample were plotted on a somatochart and the patterns of distribution by somatotype group were observed.

Statistical analyses: Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS), version 23.0. The Pearson correlation coefficient and multiple linear regressions were used to find significant associations between somatotype and blood pressure and to determine the most significant indicators of blood pressure from anthropometric measurements and somatotype component. One-way ANOVA was used to test the differences of anthropometric measurements and somatotypes between boys and girls.

Table 1: Means and standard deviations of height, weight, somatotype component and systolic and diastolic blood pressure measurements in boys and girls aged 7-12 years

	Boys (N = 248)		Girls (N = 245)		
Variables	Mean	SD	Mean	SD	p-value
Height (m)	1.28	0.10	1.28	0.11	0.719
Weight (kg)	28.51	10.14	28.03	9.21	0.519
Body mass index (kg/m^2)	16.85	3.66	16.49	3.19	0.259
Endomorphy	2.05	1.47	2.22	1.18	0.147
Mesomorphy	4.57	1.48	4.09	1.34	0.000**
Ectomorphy	2.81	1.45	2.96	1.47	0.247
Systole (mmHg)	90.31	11.63	87.56	10.51	0.006**
Diastole (mmHg)	61.15	10.57	59.89	9.40	0.166

**p<0.01

RESULTS

Table 1 shows the means and standard deviations of age, height and weight, somatotype components (endomorphy, mesomorphy, ectomorphy), SBP and DBP based on age group (7 -12 years). Table 2 and 3 illustrate the relationship between height, weight, somatotype components and blood pressure (systolic and diastolic) in boys and girls aged 7-12 years in Yogyakarta province.

In boys, the mean values of the endomorphy component and SBP were greater than those of the girls ($p<0.05$), with differences of 0.48 endomorphy component units and 2.75 mmHg SBP. Pearson correlation analysis showed that all variables indicated strong correlations ® between 0.507 and 0.803; $p<0.01$). Variables of height, weight, body mass index and the three components of somatotype showed weak associations with SBP and DBP, with coefficients ranging from 0.22-0.43 (Table 2). In addition, multiple linear regression analysis indicated that only height ($p<0.001$ for SBP and $p<0.05$ for DBP) and endomorphy ($p<0.01$ for both SBP and DBP) influenced blood pressure (Table 3).

The final model of regression for height and endomorphy component as predictors of blood pressure (SBP and DBP) were as follows:

- Height as a predictor (X):

SBP : Y = 75,001+0.391 X
DBP : Y = 49.686+0.383 X

- Endomorphy component as predictor (X):

SBP : Y = 82.365+3.080 X
DBP : Y = 55,276+2,458 X

Where:
Y = Blood pressure
SBP = Systolic blood pressure
DBP = Diastolic blood pressure

Table 2: Pearson correlation between height, weight, somatotype components and blood pressure

Variables	Systolic blood pressure	Diastolic blood pressure
Height (m)	0.334**	0.316**
Weight (kg)	0.428**	0.371**
Body mass index (kg/m^2)	0.264**	0.250**
Endomorphy	0.369**	0.328**
Mesomorphy	0.297**	0.182**
Ectomorphy	-0.219**	-0.170**

**p<0.01

DISCUSSION

Anthropometric characteristics: The results of analysis of variance on the characteristics of participants aged 7-12 years showed that girls were on average 0.3 cm shorter and 0.48 kg heavier than boys. When stratified by age group, the mean heights and weights of boys did not show significant differences from girls, except for weight in the 7-year age group. This result was not commonly found because heights and weights of boys were higher than girls at the same age; this finding was in agreement with a study by Rahmawati *et al.*[12] in children aged 7-18 years in three regions of Indonesia. According to Wirakusumah[13], the peak bone mass varies in each person; generally, boys were larger than girls, which was probably because boys' bone mass (±1200 g) was higher than that of girls (±800 g). Growth rates of children are rapid in the first year and then slow from approximately 3-4 years of age until puberty. During childhood, two of the most important hormones are growth hormone (GH) and thyroid hormone (TH). At puberty, with the influence of oestrogen and testosterone, the rate of growth increases, with annual rates of 8.3 cm for girls and 9.5 cm for boys[14]; this increase is associated with increased oestradiol hormone secretion in both boys and girls[15]. This state is likely to cause boys to have larger body sizes than girls of the same age. However, our study does not support that interpretation, because most girls have not yet experienced menarche. Moreover, girls generally have an early puberty period than boys; hence, they may start growing faster, although boys

Table 3: Multiple linear regression analysis with stepwise method for height, body weight, BMI and somatotype component on blood pressure

	Systole blood pressure		Diastole blood pressure	
Predictor	β coefficient	p-value	β coefficient	p-value
Height (m)	0.391	0.000**	0.383	0.043*
Weight (kg)	0.047	0.352	0.470	0.510
Body mass index (kg/m^2)	-0.046	0.390	-0.210	0.817
Endomorphy	3.080	0.000**	2.458	0.000**
Mesomorphy	0.098	0.076	-0.056	0.321
Ectomorphy	0.045	0.419	0.085	0.197

*p<0.05, **p<0.01

catch up and surpass girls a few years later[10]. Table 1 shows the increases in height and weight with increasing age in boys and girls.

Somatotype: Somatotyping is one useful technique for evaluating the characteristics of the human body that involves the quantification of the body's shape and composition. Somatotype or body type is often used to determine nutritional and growth status as well as disease risk factors, including blood pressure. In this study, there were differences in somatotype between boys and girls at 9, 11 and 12 years, at which boys were more mesomorphic and less endomorphic than girls.

One-way ANOVA on the characteristics of children in Yogyakarta aged 7-12 years indicated that the mean endomorphy and systolic blood pressure of boys were significantly higher than those of girls, with a 0.48 unit difference in endomorphy and 1.37 mmHg difference in SBP. These findings suggest that boys might be more muscular than girls; however, the means of SBP and DBP of boys and girls in our samples were lower than in Turkish children of the same ages[16].

Among all age groups, a significant difference was found only between the endomorphy components of boys and girls at age 12. This finding suggested that boys and girls had significant differences in body composition, including the components of fat, bone and muscle. Carter and Heath[7] indicated that females are usually more endomorphic than males and children are usually different from adolescents, adults and older people. However, regarding somatotype category, this study showed that boys and girls did not show changes in somatotype according to chronological age, i.e.,belonging to the category of ecto-mesomorph, which is dominant in the mesomorphy component followed by ectomorphy component (Table 1). This result may be due to strong similarities in physical activity and nutritional status at each age, as dietary factors and physical activity greatly affect somatotype[7,9]. Our results showed that, based on body composition, boys were more muscular than girls; this

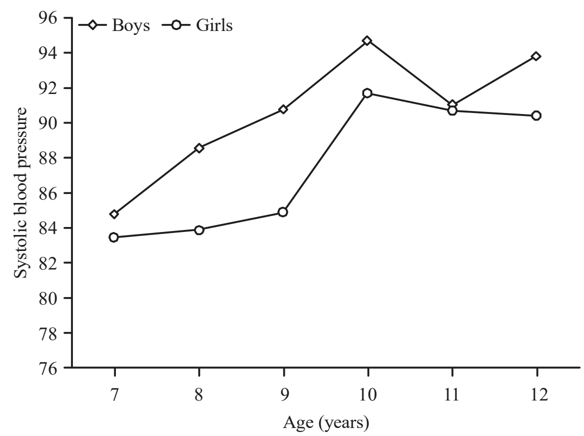

Fig. 1: Comparison of systolic blood pressure in boys and girls aged 7-12 years in Yogyakarta

observation is consistent with the conclusions of Rahmawati *et al.*[12] (2004), who studied children and adolescents in two different regions in Indonesia, that girls were more endomorphic and less mesomorphic than boys.

According to the American Heart Association (AHA)[17] and the American Academy of Pediatrics (AAP)[18], the normal systolic blood pressure of children aged 7-12 years ranges from 108-127 mmHg, whereas diastolic blood pressure ranges from 71-78 mmHg. In this study, the mean blood pressure measurements showed significant differences between boys and girls only at ages 8 and 9, when boys had higher systolic blood pressure. Both systolic and diastolic blood pressure values in our sample showed no significant differences with age (Fig. 1 and 2). According to recommendations from the AHA (2017)[17] and AAP (2017)[18] on normal blood pressure measurements, our data indicated that the sample population's mean blood pressure was lower than normal. While low blood pressure is a healthy target for adults, in children, low blood pressure can be dangerous. Hypotension may occur for various reasons, e.g., minor causes, such as dehydration. More serious causes could, however, be life-threatening, such as severe illness or shock. Dehydration is a condition that occurs when there is an imbalance between the

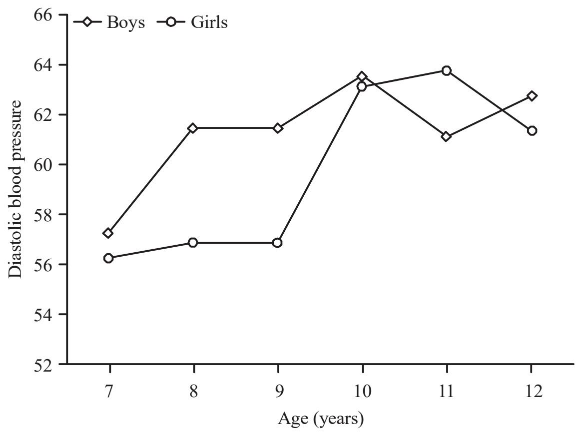

Fig. 2: Comparison of diastolic blood pressure in boys and girls aged 7-12 years in Yogyakarta

amount of water and fluid obtained and that needed by the body. One cause of dehydration is exercising on a hot day and orthostatic hypotension may also result from dehydration; however, the causes are not examined in the present study.

Relationships between anthropometric measurement, somatotype and blood pressure: The relationships between height, weight and blood pressure were positive and were stronger with height than weight. Similarly, studies from different parts of India also showed positive correlations of SBP and DBP with height and weight of adolescents. Taksande *et al.*[19] 1008 pound positive correlations of height with both SBP (r = 0.39) and DBP (r = 0.31). The authors also found positive correlations between adolescents' weight and SBP (r = 0.39) and DBP (r = 0.28). Saha *et al.*[20] reported signi cant positive correlations of blood pressure with height [SBP, r = 0.62 (boys) and 0.54 (girls); DBP, r = 0.52 (boys and girls)] and weight [SBP, r = 0.77 (boys) and 0.76 (girls); DBP, r = 0.76 (boys) and 0.63 (girls)] for both sexes.

A similar study in children aged 12-14 years showed a significant association between body weight and blood pressure[21], while another study in children and adolescents aged 2-19 years indicated that BMI increased due to excessive body weight and that obesity was significantly related to systolic and diastolic blood pressure. The effects of excess body weight on blood pressure have even been observed in children aged 2-5 years[22]. The amount of evidence on overweight and obesity is currently increasing. The main risk factors that cause obesity are unhealthy eating, behavioural factors, lack of physical activity and smoking; low maternal education is also a strong influence as a risk factor for obesity[23]. Martuti *et al.*[24] reported that 45% of children in Surakarta (a small city approximately 60 km from Yogyakarta) were obese with hypertriglyceridemia. A review of different populations in developing countries worldwide indicated that there is an inverse association between birth size and blood pressure during childhood and adolescence. Children with low birth weights tend to have higher systolic blood pressure, which corresponds with observations that the ponderal index is the most predictive measure given that increases in systolic blood pressure are associated with decreased growth in mid-late pregnancy[25].

While the association between weight and blood pressure is well defined, there is uncertainty about the relationship between height and blood pressure, as various studies have shown different results[26]. However, lower height in adults is believed to increase the risk of cardiovascular disease. Thus far, existing studies have sought to explore how fat distribution and metabolism in short-bodied people affect blood pressure. Concerning the relationship between somatotype and blood pressure, a significant positive association was found between endomorphy (the measure of adipose component) and systolic blood pressure; this result agrees with findings from studies in adults[10]. As such, a similar relationship with diastolic pressure was observed. An endomorphic body constitution during childhood may potentially lead to hypertension in adulthood. Therefore, understanding this relationship is essential for early diagnosis and prevention of hypertension and cardiovascular disease risk factors.

In our study, height and endomorphic component are significantly related to blood pressure, meaning that increased endomorphic value and height coincide with increased blood pressure values. These results contrasted with a study by Makgae *et al.*[27] on children aged 6-13 years, which found that blood pressure and the three components of somatotype were significantly associated. By means of multiple linear regression analyses we proposed predictive equations for estimating blood pressure (systole and diastole) with predictors of height and endomorph component. The equations for blood pressure using predictor of height were Y = 75.001+0.391 X1 for systolic and Y = 49.686+0.383 X1 for diastolic blood pressure, while using endomorph component were Y = 82.365+3.080 X1 for systolic and Y = 55.276+2.458 X1 for diastolic blood pressure. For example, applying the equations to determine systolic blood pressure in 7-12 years old children using height results in 75.001+0.391 (118.4) = 121.29 mmHg, while systolic blood pressure according to component 2 (endomorph) somatotype is 82.365+3.080 (1.5) = 89.98 mmHg. Estimating diastolic blood pressure in 7-12 years old children using height was

49.686+0.383 (118.4) = 95.03 mmHg and for diastolic blood pressure using component two (endomorph) somatotype was 55.276+2.458 (1.5) = 58.96 mmHg.

The association between endomorphic component and high blood pressure observed in this study appears plausible, given that the endomorphic component of somatotype represents fatness (as the sum of skinfold thicknesses); it is therefore supposed that increased skinfold thicknesses will increase blood pressure. Our results were supported by findings of Moser *et al*.[5], who found that the risk of high blood pressure was almost twice as high in children with triceps skinfold thickness above the 90th percentile compared with those with adequate subcutaneous adiposity.

CONCLUSION

We conclude that in children aged 7-12 years, height, weight and blood pressure increase with increasing age. Height and endomorphic component were significantly associated with systolic and diastolic blood pressure (p<0.01). The higher the height and value of the endomorphic component were, the higher the systolic and diastolic blood pressure values of children aged 7-12 years in Yogyakarta province, Indonesia.

SIGNIFICANCE STATEMENT

This study discovered significant correlations between children's anthropometric measurements, somatotype and blood pressure that could be useful for screening for hypertension. The study will help researchers to uncover critical areas of auxology that could not be previously explored. Thus, these results may contribute to the development of a new theory on the morphological and physiological changes that occur during the growth process.

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