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Original Article

Waist circumference, body mass index, and skinfold thickness as potential risk factors for high blood pressure in adolescents

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Abstract

Background The prevalence of hypertension in children and adolescents has increased with the rising obesity epidemic. Recent studies have found that prevalence of hypertension was higher in obese children or adolescents than in the normal weight ones. Anthropometric measurements such as body mass index (BMI), waist circumference, and skinfold thickness have been used as criteria to determine obesity in children and adolescents. Increased waist circumference has been most closely related to increased blood pressure.

Objective To compare waist circumference, BMI, and skinfold thickness as potential risk factors for hypertension in adolescents.

Methods This cross-sectional study was conducted in May 2014 in three senior high schools in Medan, North Sumatera, and included 253 students with normal urinalysis test. All subjects underwent blood pressure, waist circumference, tricep- and subscapular-skinfold thickness (TST and SST), body weight, and body height measurements. The study population was categorized into underweight, normoweight, overweight, and obese, according to four different criteria: waist circumference, BMI, TST, and SST; all variables were analyzed for possible correlations with systolic and diastolic blood pressure.

Results There were significant positive correlations between systolic blood pressure and waist circumference (OR 7.933; 95%CI 2.20 to 28.65; P=0.011) as well as BMI (OR 4.137; 95%CI 1.16 to 14.75; P=0.041). There were also significant correlations between diastolic blood pressure and waist circumference (OR 3.17; 95%CI 1.83 to 5.51; P=0.002), BMI (P=0.0001; OR=3.69), TST (OR 4.73; 95%CI 2.31 to 9.69; P=0.0001), and SST (OR 3.74; 95%CI 2.35 to 5.94; P=0.0001). Multivariate analysis showed that waist circumference was a predictive factor for systolic blood pressure (OR 9.667), but not for diastolic blood pressure.

Conclusion Waist circumference is the strongest, significant, predictive factor for elevated systolic blood pressure; meanwhile BMI, SST, and TST could be predictive factors for elevated diastolic blood pressure. **[Paediatr Indones. 2019;59:79-86; doi: http://dx.doi.org/10.14238/pi59.2.2019.79-86]**.

Keywords:*waist circumference; body mass index; skinfold thickness; blood pressure; adolescents*

Hypertension in children and adolescents has become an important medical problem and a widely-studied topic in recent decades, due to its increased prevalence and resulting sequelae.[1] The prevalence of hypertension in children and adolescents has increased with the rising obesity epidemic. Obesity may eventually lead to metabolic syndrome, consisting of central obesity,

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hypertension, dyslipidemia, and impaired glucose tolerance.[2] Obesity is one of the major health problems often encountered in adolescents.[3] A relationship between obesity and hypertension in children and adolescents has been reported in a wide variety of ethnic groups and races, with higher blood pressure or a higher prevalence of hypertension in obese children and adolescents compared to normal weight ones.[4-6] Body mass index (BMI) is a standard usually used to identify the state of obesity in children and adolescents, but it does not describe the overall levels of body fat in an individual. Because of the limitations of BMI, waist circumference has been used to assess body fat. Compared with BMI, waist circumference is a better index to screen for metabolic abnormalities.[7-9]

Skinfold thickness is an anthropometric parameter that can be used to determine body fat stores and their distribution; central body fat can be measured from the subscapular skinfold thickness (SST) and peripheral body fat can be measured from the triceps skinfold thickness (TST). Skinfold thickness was associated with blood pressure in children and adolescents.[10] Waist circumference is an important method to diagnose central obesity in clinical practice, because of its accuracy and simple technique.[8,11] Waist circumference and its variants, such as the ratio of waist and hip circumference and ratio of waist circumference to height, have been frequently used to assess central obesity, but mainly in adults. Waist circumference has also been used by the International Diabetes Federation (IDF) as a criteria to determine central obesity in adolescents with metabolic syndrome.[12] This study was done to compare waist circumference, BMI, and skinfold thickness as predictive factors of hypertension in adolescents.

Methods

This study was a cross-sectional study to compare waist circumference, body mass index, TST, and SST as predictive factors of high blood pressure in adolescents. This study was conducted in May 2014 at three private senior high schools in Medan, North Sumatera. The inclusion criteria were students aged 15 to 17 years whose parents or guardians allowed them to undergo urinalysis examination, anthropometric measurements such as height, weight, skinfold thickness, and waist circumference, as well as blood pressure examination. The exclusion criteria were students who were taking anti-hypertensive drugs or other drugs which could affect blood pressure, or those likely to suffer from secondary hypertension, which was screened by urinalysis results of proteinuria $\geq +2$, hematuria, or nitrite positive.

This study was approved by the Research Ethics Committee of the University of Sumatera Utara Faculty of Medicine. Subjects' parents or guardians provided written, informed consent. After informed consent was obtained, students underwent history-taking to obtain basic demographic data, as well as their history of the disease and drug use. The simple urinalysis examination was done using Verify® urine dipsticks. Those with proteinuria, hematuria, and/or positive for nitrites were excluded. Students who met the inclusion criteria underwent anthropometric measurements of weight, height, TST, SST, and waist circumference.

Body weight was measured in kilograms using Chinese-made *Camry*® scales, with a measurement scale up to 100 kg and precision of 0.1 kilograms. Height was measured in centimeters using a stadiometer to the nearest 0.1 centimeter. Skinfold thickness was measured in millimeters with an *Accu-measure*® skinfold calliper made in Germany, with an accuracy of 0.1 millimeters. Skinfold thickness measurements were carried out three times and averaged. Based on skinfold thickness, subjects were categorized as underweight for below the 50th percentile, normoweight for 50th to 85th percentile, overweight for >85th to 90th percentile, or obese for above the 90th percentile. Waist circumference was measured with a non-elastic measuring tape at the midpoint between adjacent last ribs and the peak of the iliac crest, at the end of a normal expiration, with the subject standing upright, feet together, arms at the sides, and wearing thin clothing, with a precision of 0.1 centimeters. Measurements were done twice, then averaged if the difference was less than 1 centimeter. If the difference exceeded 1 centimeter, the measurement was repeated. Using waist circumference, subjects were categorized as underweight for below 50th percentile, normoweight for 50th to 85th percentile, overweight for >85th to 90th percentile, and obese for above 90th percentile. Waist circumference and skinfold thickness percentiles for children and adolescents were based on data from the

4th *National Health and Nutrition Examination Survey* (NHANES IV).[13]

Blood pressure was measured after resting at least 5 minutes, with the patient in the sitting position, the right arm placed at the heart level, using a *NOVA®* mercury sphygmomanometer. Measurements were performed three times, then averaged. Systolic blood pressure was determined at the Korotkoff I sounds and diastolic blood pressure was set when the Korotkoff sounds disappeared. Blood pressure was classified according to the Task Force on High Blood Pressure Education Program as normal if less than the 90th percentile, prehypertension when between 90th and 95th percentiles, and hypertension when above the 95th percentile, according to age, sex, and height.[11] Students who had elevated blood pressure were recommended to be monitored regularly in order to evaluate the need for anti-hypertensive drugs or other interventions.

Subjects' BMIs were calculated using the results of weight and height measurements. BMI was classified according to age and sex as underweight for below 50th percentile, normoweight for 50th to 85th percentile, overweight for >85th to 95th percentile, and obese for above the 95th percentile.[13]

Data were analyzed using *SPSS statistical software version 19.0* with a significance level of $P<0.05$ and 95% confidence interval (CI). Descriptive data were mean, percentage, and standard deviation. Fisher's exact and Chi-square tests were used to analyze the relationships between waist circumference, BMI, and skinfold thickness with systolic and diastolic blood pressure. Multivariate logistic regression with the enter method was used to further analyze for possible relationships between waist circumference, BMI, and skinfold thickness with blood pressures.

Results

Of 393 students at three senior high schools who met the inclusion criteria, 140 students refused to join the study. Of the 253 students who were willing to join, 5 students had hematuria, but after re-analysis, we discovered that these 5 students were menstruating girls, so the urinalysis results were considered to be false positive, and the 5 were included in the study. Hence, the final sample numbered was 253 students.

Subjects' mean age was 16.56 years. Only 18 respondents (7.1%) had a known parental history of hypertension. The demographic characteristics of the study population are shown in **Table 1**.

Table 1. Demographic characteristics of the study population

Demographic characteristics	(N=253)
Sex, n (%)	
Male	129 (51)
Female	124 (49)
Mean age (SD), years	16.56 (0.67)
Birth weight, n (%)	
≤ 2,500 grams	(0.4)
> 2,500 grams	59 (23.3)
Forgot/Unknown	193 (76.3)
Parental history of hypertension, n (%)	
Unknown	112 (44.3)
No	123 (48.6)
Yes	18 (7.1)

Subjects were categorized as underweight, normoweight, overweight, or obese based on their waist circumference, BMI, TST, and SST measurements. Blood pressure was classified into normal and increased (prehypertension and hypertension), respectively, for systolic and diastolic blood pressures. The anthropometric and hemodynamic characteristics of study population are shown in **Table 2**.

With regards to waist circumference, most respondents were categorized as underweight (65.2%). However, the majority of respondents were categorized as normoweight based on BMI examination (50.2%). Using TST and SST measurements, most respondents were categorized as normoweight (75.1%) and (48.2%), respectively].

Blood pressure examinations revealed that 9 subjects (3.6%) had elevated systolic blood pressure and 48 subjects (19%) had elevated diastolic blood pressure. Fisher's exact test revealed a significant correlation between waist circumference and systolic blood pressure ($P=0.011$). The OR value was 7.933, meaning adolescents with waist circumference categories of overweight and obese had an increased risk of elevated systolic blood pressure by 7.933 times compared to the underweight and normoweight categories. We also found a significant correlation between BMI and elevated systolic blood pressure (OR 4.137; $P=0.041$). This OR indicates that adolescents with BMI categories of overweight and obese had an 4.137 times increased risk of elevated systolic blood pressure compared to underweight and normoweight adolescents. However, SST and TST had no significant correlations with systolic blood pressure (P>0.05), as shown in Table 3.

Table 2. Anthropometric and hemodynamic characteristics of the study population

Anthropometric and hemodynamic characteristics	(N = 253)
Waist circumference, n (%)	
Underweight	165 (65.2)
Normoweight	73 (28.9)
Overweight	8 (3.2)
Obese	7 (2.8)
Body mass index, n (%)	
Underweight	85 (33.6)
Normoweight	127 (50.2)
Overweight	26 (10.3)
Obese	15 (5.9)
Tricep skinfold thickness (TST), n (%)	
Underweight	28 (11.1)
Normoweight	190 (75.1)
Overweight	14 (5.5)
Obese	21 (8.3)
Subscapular skinfold thickness (SST), n (%)	
Underweight	1 (0.4)
Normoweight	122 (48.2)
Overweight	61 (24.1)
Obese	69 (27.3)
Systolic blood pressure (SBP), n (%)	110.15
Mean (SD), mmHg	(7.99)
Range, mmHg	88-128
Normal	244 (96.4)
Increased (prehypertension and hypertension)	9 (3.6)
Diastolic blood pressure (DBP), n (%)	
Mean (SD), mmHg	73.20 (6.55)
Range, mmHg	60-95
Normal	205 (81)
Increased (prehypertension and hypertension)	48 (19)

Statistical analyses revealed significant correlations between waist circumference and diastolic blood pressure (OR=3.17; P=0.002), BMI and diastolic blood pressure (OR=3.69; P=0.0001), SST and diastolic blood pressure (OR=4.73; P=0.0001), as well as TST and diastolic blood pressure (OR=3.74; P=0.0001) (**Table 4**).

Multiple logistic regression analysis with the enter method revealed that the only independent variable that could be used to predict systolic blood pressure was waist circumference. The OR value obtained from the multivariate equation was 9.667, which means that the risk of elevated systolic blood pressure in adolescents with an overweight/obese waist circumference was 9.667 times higher than in adolescents with an underweight/normoweight waist circumference, as shown in **Table 5**.

Multiple logistic regression with the enter method also revealed that the independent variables that could be used to predict elevated diastolic blood pressure were BMI, SST, and TST [(OR 2.808, P=0.013,); (OR 3.377, P=0.008); and (OR 2.729, P=0.022), respectively] (**Table 6**).

Discussion

In recent years of routine blood pressure checks, the prevalence of hypertension in school-aged children has increased from 2% to 5%.[11,14,15] The 2007 Indonesian Ministry of Health Survey (*Riset Kesehatan*

Table 3. Correlations between waist circumference, BMI, TST, and SST with systolic blood pressure

Variables	SBP		OR	95% CI	P value
	Normal	Increased			
Waist circumference, n (%)					
Overweight and obese	12 (80)	3 (20)	7.933	2.20 to 28.65	0.011
Underweight and normoweight	232 (97.5)	6 (2.5)			
BMI, n (%)					
Overweight and obese	37 (90.2)	4 (9.8)	4.137	1.16 to 14.75	0.041
Underweight and normoweight	207 (97.6)	5 (2.4)			
SST, n (%)					
Overweight and obese	123 (94.6)	7 (5.4)	3.312	0.7 to 15.63	0.173
Underweight and normoweight	121 (98.4)	2 (1.6)			
TST, n (%)					
Overweight and obese	32 (91.4)	3 (8.6	3.114	0.82 to 11.88	0.113
Underweight and normoweight	212 (97.2)	6 (2.8)			

Table 4. Correlations of waist circumference, BMI, TST, and SST with diastolic blood pressure

Variables	SBP		OR	95% CI	P value
	Normal	Increased			
Waist circumference, n (%)					
Overweight and obese	7 (46.7)	8 (53.3)	3.17	1.83 to 5.51	0.002[a]
Underweight and normoweight	198 (83.2)	40 (16.8)			
BMI, n (%)					
Overweight and obese	21 (51.2)	20 (48.8)	3.69	2.32 to 5.89	0.0001[b]
Underweight and normoweight	184 (86.8)	28 (13.2)			
SST, n (%)					
Overweight and obese	90 (69.2)	40 (30.8)	4.73	2.31 to 9.69	0.0001[b]
Underweight and normoweight	115 (93.5)	8 (6.5)			
TST, n (%)					
Overweight and obese	17 (48.6)	18 (51.4)	3.74	2.35 to 5.94	0.0001[b]
Underweight and normoweight	188 (86.2)	30 (13.8)			

[a]Fisher's exact, [b]Chi-square

Table 5. Multiple logistic regression analysis of waist circumference, BMI, TST, and SST with systolic blood pressure

Variables	Coefficient	OR	95%CI	P value
1st analysis				
Waist circumference	1794	6.011	0.799 to 45.204	0.081
BMI	0.609	1.839	0.316 to 10.718	0.498
SST	0.710	2.033	0.328 to 12.599	0.446
TST*	-0.235	0.791	0.111 to 5.618	0.815
Constant	-4.153	0.016		0.000
2nd analysis				
Waist circumference	1.682	5.375	0.901 to 32.066	0.065
BMI	0.573	1.773	0.311 to 10.097	0.519
SST	0.667	1.948	0.324 to 11.727	0.467
Constant	-4.147	0.016		0.000
3rd analysis				
Waist circumference	1.964	7.124	1.469 to 34.557	0.015
TST	0.327	2.318	0.431 to 12.470	0.841
Constant	-4.147	0.016		0.000
4th analysis				
Waist circumference	2.269	9.667	2.152 to 43.430	0.003
Constant	-3.655	0.026		0.000

*not analyzed because P>0.05

Table 6. Multiple logistic regression analysis of waist circumference, BMI, TST, and SST with diastolic blood pressure

Variables	Coefficient	OR	95%CI	P value
1st analysis				
Waist circumference*	0.208	1.232	0.334 to 4.574	0.754
BMI	0.995	2.704	1.155 to 6.330	0.022
SST	1.221	3.390	1.385 to 8.298	0.008
TST	0.955	2.599	1.047 to 6.451	0.039
Constant	-2.692	0.068		0.000
2nd analysis				
BMI	1.032	2.808	1.241 to 6.352	0.013
SST	1.217	3.377	1.380 to 8.266	0.008
TST	1.004	2.729	1.159 to 6.423	0.022
Constant	-2.692	0.068		0.000

*not analyzed because P>0.05 for all

Dasar/RISKESDAS) noted a hypertension prevalence of 8.4% in adolescents aged 15 to 17 years.[16] In China, the prevalence of hypertension and prehypertension increased dramatically between 1991 and 2004, with an average increase of 6.38% in children and 8.31% in adolescents.[17] The prevalences of hypertension in adolescents in Turkey was 4.4%,[18] while that in Tunisia, Northern Africa was 39.8%.[19]

We categorized normal vs. increased blood pressure according to systolic and diastolic blood pressure measurements. The prevalence of hypertension and prehypertension by systolic blood pressure was 3.6%, and that defined by diastolic blood pressure was 19%. The overall prevalence of hypertension and prehypertension that defined both by systolic and diastolic blood pressure was 2.4%.

An early symptom of hypertension due to obesity is isolated systolic hypertension (ISH), which is an increase in systolic blood pressure without a subsequent increase in diastolic blood pressure. The term ISH is often used in adults, in which the primary mechanism is due to increased arterial stiffness caused by atherosclerotic vascular disease.[20-22] In obese children, ISH may be caused by hyperactivity of the sympathetic nervous system, which can increase the activity of the renin-angiotensin system, leading to an increase in arterial stiffness by lowering the content of elastin and increasing collagen in the arterial wall. Proliferation of muscle cells in the arterial wall increases arterial thickness and stiffness, and decreases arterial contractility.[21,22] Previous studies have found the prevalence of ISH to be approximately 50% in obese children and 30% in normoweight children. A US study on screening for hypertension and obesity in school children found the prevalence of ISH to be about 95%.[20]

In our study, of nine students with increased systolic blood pressure, four students (44.4%) had ISH. Of students with ISH, one student met the overweight criteria by SST, and one student met the overweight criteria based on BMI and TST, but met the obese criteria based on subscapular skinfold thickness. In addition, one student met the overweight criteria based on waist circumference and SST, while one student met the normoweight criteria based on all parameters.

Chiolero *et al.* in the Seychelles, a developing country in Africa with a predominantly middle-class population, reported that overweight and obese (according to BMI) subjects aged 5 to 16 years had increased blood pressure, in 18% of boys and 26% of girls.[23] Another study in Egyptian adolescents aged 11 to 19 years by Abolfotouh et al. also noted a significant relationship between BMI and increased blood pressure, with OR 2.18.[24] In our study subjects who were categorized as overweight and obese based on BMI, 9.8% had increased systolic blood pressure and 48.8% had increased diastolic blood pressure, with significant relationships between overweight/obese status and increased systolic (OR 4.137) as well as diastolic (OR 3.69) blood pressures.

Aboulfotouh *et al.* in Egypt found a significant association between waist circumference and increased blood pressure, with OR 3.14.[24] Also, Guimares *et al.* found significant associations between waist circumference and systolic blood pressure (PR 1.8; 95%CI 1.0 to 3.0; P=0.036) as well as diastolic blood pressure (PR 1.4; 95%CI 0.8 to 0.24; P=NS), in adolescents aged 11 to 18 years in Salvador, Brazil.[25]

In our overweight and obese subjects based on waist circumference, 20% had increased systolic blood pressure, and 40% had increased diastolic blood pressure. There were significant correlations between higher waist circumference and increased systolic blood pressure (OR 7.933; 95%CI 2.20 to 28.65) as well as diastolic blood pressure (OR 3.17; 95%CI 1.83 to 5.51). Aboulfotouh *et al.* also found that waist circumference had a more significant correlation with blood pressure (OR 3.14; 95%CI 1.67 to 5.94) than did BMI (OR 2.18; 95%CI 1.38 to 3.44). Waist circumference is thought to reflect central obesity while BMI reflects overall obesity.[24] However, Guimaraes et al. found that BMI had a more significant correlation to increased systolic and diastolic blood pressures compared to waist circumference.[25] In our study, the relationship between waist circumference and systolic blood pressure was stronger compared to BMI, whereas for diastolic blood pressure, BMI had a more significant correlation compared to waist circumference.

Kajale *et al.* in India found that waist circumference, BMI and TST had significant relationships with systolic and diastolic blood pressures in children and adolescents.[26] Also, Freedman *et al.* in the Bogalusa Heart Study from 1981 until 1994 found that TST and SST had significant associations with increased blood pressure. They also found that BMI had a more significant impact on increased blood pressure than did the TST and SST.[27] We found no significant correlations between TST or SST and systolic blood pressure, but both had significant correlations with diastolic blood pressure (OR 3.74; 95%CI 2.35 to 5.94 for TST; OR 4.73; 95%CI 2.31 to 9.69 for SST). In particular, SST is a strong predictive factor for increased diastolic blood pressure in adolescents.

In Indonesia, Allamanda *et al.* conducted a study to investigate if waist circumference could be used as a predictor of hypertension in obese adolescents aged 12 to 17 years. They reported a cut-off value 88.95 centimeters to predict hypertension in adolescents, with sensitivity of 97.8% and specificity of 47.3%.[28] We also found that waist circumference could be used as a predictor for increased systolic blood pressure in overweight and obese adolescents (OR 9.667; 95%CI 2.152 to 43.430), but waist circumference was not predictive of increased diastolic blood pressure. However, we could not assign a cut-off value due to the small number of subjects with increased systolic blood pressure.

There were several limitations to this study. We did not analyze other factors that may also influence blood pressure, such as unhealthy living habits. We tried to study birth weight and parental history of hypertension, but much of the data were unknown. Also, although the blood pressure measurement was performed three times and averaged, the measurements were made on the same day. In addition, the number of subjects who met the criteria for overweight and obese was relatively small, such that our results may have differed from previous studies.

Both waist circumference and BMI had significant associations with systolic blood pressure, but waist circumference was more significant as a predictive factor for elevated systolic blood pressure in adolescents. Waist circumference, BMI, and skinfold thickness had significant associations with diastolic blood pressure, but only SST, TST and BMI could be predictors of elevated diastolic blood pressure, with SST as the most significant. Further studies are needed with a larger sample size of overweight and obese adolescents to more accurately assess for relationships between waist circumference, BMI, and skinfold thickness on blood pressure.

Conflict of Interest

None declared.

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