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Original Article

Association of BMI measurements to waist circumference and waist-to-height ratio in overweight and obese children

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Abstract

Background Early monitoring of visceral fat is important to prevent the worsening of obesity in children. In recent years, waist circumference (WC) and waist-to-height ratio (WHtR) measurements have gained attention as an anthropometric indexes for obesity in children. They are an easy-to-use, inexpensive, specific to visceral fat and safe monitoring methods for children. International reference values, however, do not exist for any of the two measures to determine obesity in children.

Objective To compare WC and WHtR to body mass index (BMI) status in overweight and obese children.

Methods This cross-sectional study included overweight and obese children aged 10-12 years from four primary schools in Semarang, Central Java. Subjects underwent anthropometric measurements including weight, height, and waist circumference. Subjects were classified as obese (≥P95) or overweight (P85≤P<P95) using BMI percentiles according to age and sex. Chi-square test was used to assess for associations between categorical variables and multivariate logistic regression analysis was used to identify a dominant variable.

Results Forty-two obese and 23 overweight children were studied. Children with higher values of WC (PR=1.879) and WHtR (PR=8.352) had a higher prevalence of having higher BMI status (obese). Using multivariate analysis, WHtR was the more dominant variable associated with BMI status, compared to WC.

Conclusion Higher WC (cut off P90) and WHtR (cut off 0.5) have a significant associations with greater obesity children aged 10-12 years. Compared to WC, WHtR is a stronger predictive factor for obesity. **[Paediatr Indones. 2020;60:131-6; doi: http://dx.doi.org/10.14238/pi60.3.2020.131-6]**.

Keywords: *waist circumference; waist-to-height ratio; obesity; children*

Obesity is one of the leading global mortality risks.[1] Worldwide obesity has nearly tripled since 1975.[2] Childhood obesity is associated with a higher chance of obesity in adulthood. The degree of obesity in adulthood is associated with several metabolic and cardiovascular complications.[3] The prevalence of overweight and obesity in 5 to 19-year-old children and adolescents increased from 4% in 1975 to 18% in 2016.[4] Indonesia itself in 2013, had the highest prevalence of overnourishment in aged 5-12 years group which is 18.8%, with overweight 10.8% and obese 8%.[5]

Obesity is defined as abnormal or execessive fat accumulation that may impair health.[4] The WHO noted that the site of fat accumulation makes a difference in terms of increasing health risk. People with visceral fat are more likely to have chronic inflammation and associated with a higher chance of serious illness than those with subcutaneous fat.[6,7] Early monitoring of visceral fat is important to prevent

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the worsening of obesity in children. Although BMI has been widely used to measure obesity, it has limitations, in that BMI does not indicate body composition or the pattern of fat distribution. Magnetic resonance Imaging (MRI) is considered to be the gold standard to assess visceral fat, but this technique is expensixe and is impractical for routine clinical settings or large-scale studies.[8,9] In recent years, waist circumference (WC) and waist-to-height Ratio (WHtR) measurements have gained attention as an anthropometric indexes for obesity in children.[9,10] They are an easy-to-use, inexpensive, accurate and safe monitoring methods for children. International reference values, however, do not exist for any of the two measures to determine obesity in children. The objective of this study was to compare WC and WHtR to BMI status in overweight and obese children aged 10-12 years.

Method

This cross-sectional study was done to evaluate the usefulness of WC and WHtR to assess for obesity in children. This study was conducted from April to August 2019 at four primary schools in Semarang, Central Java, and employed a consecutive sampling method. The inclusion criteria were overweight and obese children by BMI aged 10 to 12 years whose parents or guardians allowed them to undergo anthropometric measurements such as weight, height and waist circumference. The exclusion criteria were students who were taking long-term medication (ec. corticosteroid), or were normal or underweight by BMI.

This study was approved by the Research Ethics Committee of Dr. Kariadi General Hospital Semarang. Subjects' parents or guardians provided written informed consent. After informed consent was obtained, students underwent history taking for collection of basic demographic data, as well as their history of drug use. Students who met the inclusion criteria underwent anthropometric measurements of weight, height and waist circumference.

Body weight was measured in kilograms using Body Impedance analysis *Tanita® BC 601*, with a measurement scale up to 270 kg and precision of 0.1 kg. Height was measured in centimeters with to the nearest 0.1 cm. 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 normal expiration, with the subject standing upright, feet together, and with no clothes covering, to the nearest 0.5 cm. To minimize measurement bias, measurements were done twice then averaged, if the difference was less than 1 cm. If the difference exceeded 1 cm, the measurement was repeated.

Subjects' BMI were calculated using the weight and height measurements and classified according to age and sex as obese for $\geq P_{95}$ and overweight for $P_{85}<P<P_{95}$.[11] For WC, subjects were classified as WC $\geq P_{90}$ or WC$<P_{90}$.[12-16] Waist circumference percentiles for children were based on data from CDC.[17] WHtR was calculated using WC and height measurements, and classified as WHtR ≥ 0.5 and WHtR <0.5.[9,10,18-21] For height, subjects were classified as tall ($\geq P_{95}$), normal ($P_5 \leq P<P_{95}$) or short ($<P_5$), using criteria and percentiles from CDC.[17]

Data were analyzed using *SPSS statistical software version 23.0* with a significance level of $P<0.05$ and 95% confidence interval (CI). Descriptive data were shown in percentage, mean and standard deviation. Fisher's exact and Chi-square tests were used to analyze for possible associations between WC and WHtR with BMI status. Multivariate logistic regression was used to further analyze for a dominant variable.

Results

Of 88 students at four primary schools who met the inclusion criteria, 20 students refused to join the study. Due to parent's objections, the Tanner staging examination could not be performed. Of the 68 students who were willing to join, 3 students had attained menarche. Hence, the final sample comprised 65 students. Subjects' mean age was 10.75 years. The demographic characteristics of subjects are shown in **Table 1**.

Twenty-four subjects (36.9%) had WC $\geq P_{90}$. Chi-square test revealed a significant correlation between WC and BMI status ($P<0.001$), as shown in **Table 2**. The prevalence ratio (PR) value was 1.879 (95%CI 1.343 to 2.630), indicating that children with WC $\geq P_{90}$ had a 1.879 times increased risk of being obese (by BMI) compared to those with WC $<P_{90}$.

Fifty-four subjects (83.1%) had WHtR ≥0.5. Chi-square test revealed a significant correlation between WHtR and BMI status (P<0.001), as shown in **Table 3**. The PR value was 8.352 (95%CI 1.281 to 54.449), indicating that children with WHtR ≥0.5 had a 8.352 times increased risk of being obese by BMI compared to those with WHtR <0.5.

Fifty-six subjects (86.1%) had normal height (P5≤P<P95). Chi-square test revealed that height and BMI status did not have a significant correlation (P>0.05), as shown in **Table 4**.

Multiple logistic regression analysis revealed that WHtR (P=0.011) was the more dominant variable of the two associated with obesity by BMI. The PR value was 17.273 (95%CI 1.942 to 153.664), indicating that the risk of obesity by BMI in children with WHtR ≥0.5 was 17.273 times higher than in children with WHtR <0.5, as shown in **Table 5**.

Table 1. Demographic characteristics of subjects

Characteristics	(N=65)
Gender, n(%)	
Male	42 (64.6)
Female	23 (35.4)
Age, n(%)	
10 years	28 (43.1)
11 years	25 (38.5)
2 years	12 (18.5)
Weight, kg	
Mean (SD)	53.3 (10.9)
Median (range)	53.8 (34.2-91.2)
Height, cm	
Mean (SD)	144.5 (7.8)
Median (range)	144 (126-164)
Height category, n(%)	
Tall	4 (6.1)
Normal	56 (86.2)
Short	5 (7.7)
Body mass index, kg/m2	
Mean (SD)	25.4 (3.8)
Median (range)	24.65 (19.8-34.7)
BMI status, n(%)	
Obese	42 (67.7)
Overweight	23 (32.3)
WC, cm	
Mean (SD)	82.4 (10.6)
Median (range)	83 (60-110.5)
WC category, n(%)	
≥P90	24 (36.9)
<P90	41 (63.1)
WHtR	
Mean (SD)	0.57 (0.07)
Median (range)	0.572 (0.43-0.74)
WHtR category, n(%)	
≥0.5	54 (83.1)
<0.5	11 (16.9)

Discussion

We found a higher prevalence of obesity in boys (64,6%) than girls (35,4%). A previous study reported that the higher prevalence of obesity in boys was due to their higher average energy and carbohydrate intake compared to that of girls.[22] In addition, children in this age group become more aware of their bodies.[22,23] Thus, girls in this age group may start to restrict their diet.[22]

Our study showed a significant association between WC ≥P90 and obesity in children (95%CI 1.343 to 2.630; P<0.001). Children with WC $\geq P_{90}$ had a 1.879 times increased risk of being obese (by BMI) compared to those with WC $<P_{90}$. A previous study in Norway also found a significant association between WC and BMI.[24] A person with obesity had excess fat accumulation on their body that will continue to fill possible space in the body such as under the skin or between visceral organs.[25] Based on location, fat can be classified into visceral/central and subcutaneous/peripheral.[26] Subcutaneous fat accumulation occurs during excess energy intake (high-caloric diet) with limited energy expenditure (physical inactivity). When the subcutaneous storage

Table 2. Association between WC and BMI status

Waist circumference	Obese n (%)	Overweight n (%)	PR	95%Ci	P value
$\geq P_{90}$	22 (52.4)	2 (8.7)	1.879	1.343 to 2.630	<0.001
$<P_{90}$	20 (47.6)	21 (91.3)			
Total	42 (64.6)	23 *35.4)			

Table 3. Association between WHtR and BMI status

WHtR	Obese n (%)	Overweight n (%)	PR	95%Ci	P value
≥0.5	41 (97.6)	13 (56.5)	8.352	1.281 tp 54/449	<0.001
<0.5	1 (2.4)	10 (43.5)			
Total	42 (64.6)	23 (35.4)			

Table 4. Association between height and BMI status

WHtR	Obese n (%)	Overweight n (%)	PR	95%Ci	P value
Tall	4 (9.5)	3 (13)	0.372	0.68 to 2.049	0.123
Normal	37 (88)	19 (82.6)			
Short	1 (2.5)	1 (43.4)			
Total	42 (64.6)	23 (35.4)			

Table 5. Multivariate logistic regression analysis of WC and WtHR with BMI status

Variables	PR	95%CI	P value
WC	6.368	1.252 to 32.402	0.026
WHtR	17.273	1.942 to 153.664	0.011

capacity is exceeded or its ability to generate new adipocytes is impaired, fat begins to accumulate in areas outside the subcutaneous tissue, typically in visceral areas.[27] Waist circumference measurement can be used to determine fat mass and predict visceral fat. An Australian study noted that WC was a significant predictor of intraperitoneal abdominal adipose tissue mass (IPATM) and retroperitoneal adipose tissue mass (RPATM) predictor.[15] As such, high visceral fat measured by WC was typically found in subjects with higher level of obesity.

We also found a significant association between WHtR ≥0,5 and obese in children (95%CI 1.281 to 54.449; P<0.001). Children with WHtR ≥0.5 had a 8.352 times increased risk of being obese by BMI compared to those with WHtR <0.5. A Bangladesh study also showed a significant positive association between WHtR and BMI.[28] Height varies among population, as well as in children of varies ages. Height impacts the distribution of fat, where an increase of height could be followed by an increase of WC. This statement is in agreement with the CDC reference for anthropometric measurement that height and WC showed an increasing trend with age.[17] Hence, WHtR gained attention as a measurement of visceral fat. WHtR had a strong correlation with visceral fat in Chinese study (r=0.868). Our subject showed that high fat accumulation are not accompanied by higher height, since obese (88%) and overweight (82.6%) mostly had a normal height. When a child's calorie intake is more than sufficient to achieve linear growth, the excess would then be stored as subcutaneous and visceral fat.[29] Similarly, a previous Indonesian study reported that an increase of BMI was not followed by an equal of height increase. The average height in girls was not significantly different between those who were obese and normal weight.[30] Therefore, high visceral fat measured by WHtR could be found in subjects with higher level of obesity. This measurement may allow the same boundary values for children and adults, and is not affected by age and ethnicity.[10] Both measurements had significant associations with BMI status, therefore we performed a multivariate analysis. Compared to WC, WHtR was the more dominant variable associated with BMI status.

Our study provides evidence that WC (cut off P_{90}) and WHtR (cut off 0.5) have a significant association with BMI status in children aged 10-12 years. Compared to WC, WHtR is a stronger predictive factor for obesity. The limitations of our study were using consecutive sampling that could result a selection bias, not having normoweight subject as an inclusion could result information bias and using a questionnaire as a subjective measurement to exclude subjects who has reached puberty could result a measurement bias. Further studies are needed using random sampling, and an objective measurement such as Tanner staging to accurately assess puberty, also adding normoweight as a sample.

Conflict of Interest

None declared.

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