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Original Article

Glycated hemoglobin HbA1c, waist circumference, and waist-to-height ratio in overweight and obese adolescents

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Abstract

Background Central obesity has been associated with a high risk of insulin resistance. Waist circumference and waist-to-height ratio are anthropometric indices for determining central obesity and have been associated with increased blood pressure, cholesterol, and insulin levels. In adults, fat distribution around the waist is a valid predictor of glycated hemoglobin (HbA1c) levels, and is currently recommended by experts as a diagnostic tool for diabetes. Central obesity measurement has advantages over fasting blood glucose and oral glucose tolerance tests, as it is simple and inexpensive to perform.

Objective To assess for correlations between HbA1c level and waist circumference as well as waist-to-height ratio and to assess factors potentially associated with HbA1c levels in overweight and obese adolescents.

Methods This cross-sectional study was done in four junior high schools in Yogyakarta, which were obtained by cluster sampling. Overweight and obese students who were generally healthy were included in the study. Subjects underwent waist circumference and waist-to-height ratio measurements, as well as blood tests for HbA1clevels.

Results Sixty-seven children participated in the study, with 48 girls (71.6%) and 19 boys (28.4%). Waist circumference and HbA1c levels were not significantly associated (r=0.178; P=0.15). However, waist-to-height ratio and HbA1c levels had a weak positive correlation (r=0.21; P=0.04). Linear regression analysis revealed that waist-to-height ratio had a significant association with HbA1c level (P=0.02), but age, sex, and nutritional status did not.

Conclusion Waist-to-height ratio is correlated with HbA1c levels in overweight and obese adolescents. **[Paediatr Indones. 2017;57:57-62. doi: http://dx.doi.org/10.14238/pi57.2.2017.57-62]**.

Keywords: *waist circumference; waist-to-height ratio; glycated hemoglobin; obesity; adolescent*

The number of obese and overweight children has increased more than 100% in the past 30 years.[1] According to the *World Health Organization* (WHO) in 2010, more than 40 million children under 5 years of age were overweight.[2] In Indonesia, about 14% of children and 19.1% of adolescents were categorized as overweight, while the national prevalence of obesity in children aged 13-15 years reached 2.5%.[3] A Yogyakarta study in junior high school students reported that 6.41%of adolescents were obese.[4]

Obesity in childhood often continues into adolescence and adulthood.[5,6] Obesity is a risk factor for cardiovascular disorders and metabolic diseases, such as coronary heart disease, hypertension, atherosclerosis, and diabetes mellitus.[7] Eighty percent of patients with type 2 diabetes mellitus in children are overweight children, while 60-90% are obese. A diagnosis of diabetes mellitus can be confirmed by examination of fasting blood glucose and the oral

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glucose tolerance test (OGTT). Alternatively, the *American Diabetes Association* (ADA), *International Diabetes Federation* (IDF), *European Association for the Study of Diabetes* (EASD), and *New Zealand Society for the Study of Diabetes* (NZSSD) recommended a glycosylated hemoglobin (HbAlc) cut-off point > 6.5% for diagnosing diabetes mellitus.[8] HbAlc examination is a blood test to evaluate blood sugar control, as it gives an average blood sugar over a period of 6-12 weeks. In a cohort study involving obese children and adolescents of various ethnicities, 21% of children and adolescents had HbA1c levels of 5.7-6.4%, and 1% had HbA1c levels > 6.5%, putting them at risk for diabetes.[9]

Waist circumference is an anthropometric measurement widely used to predict cardiometabolic syndrome in obese children and adolescents.[10] Another anthropometric indicator is the waist circumference to height ratio.[11,12] The waist-to-height ratio can be used to estimate body fat distribution.[13,14] In adults, central obesity has been associated with HbAlc levels.[15] However, waist circumference and waist-to-height ratio have not been widely used in children and adolescents as predictors for cardiovascular disorders and metabolic diseases in connection with HbAlc levels. The purpose of this study was to assess for possible correlations between HbA1c level and waist circumference and waist-to-height ratio, as well as to evaluate potential factors associated with HbA1c levels in overweight and obese adolescents.

Methods

This cross-sectional study was done in overweight and obese adolescents who were junior high school students in Yogyakarta in November-December 2013. The study was conducted in junior high school students because no such study had been conducted in adolescents, and obesity in adolescence is likely to continue into adulthood.

Inclusion criteria were junior high school students aged 12-15 years who met the criteria for overweight and obesity (BMI Z-score>+1 SD), were generally healthy, and willing to participate in the study. Subjects'parents provided signed informed consents. Exclusion criteria were students with congenital heart defects, kidney problems, and other severe medical conditions, taking long-term steroid therapy, or were not present during study data retrieval.

Waist circumference measurements were done with subjects in an upright position, feet 25-30 cm apart, without shoes, and the researcher located at the subject's side. We measured subjects'waist circumferences at the midpoint between the peak of the illiacal crest and the lower edge of the last rib, in an axillary midline.[16] Waist-to-height ratio was obtained by dividing the waist circumference (in centimeters) by height (in centimeters).[17] Subjects provided 5 mL blood specimens for examination of HbA1c levels by high-performance liquid chromatography (HPLC) in a private laboratory.

To analyze for correlations between HbAlc level and waist circumference as well as waist-to-height ratio, we used Spearman's correlation test. Multivariate analysis with linear regression test was used to assess variables potentially associated with HbA1c levels. This study was approved by the Medical Ethics Committee of Universitas Gadjah Mada Medical School, Yogyakarta, Central Java, Indonesia.

Results

Four junior high schools in Yogyakarta were randomly selected by cluster sampling: *Bopkri 5, IT Abu Bakar, SMP Negeri 3*, and *SMP Muhammadiyah*. Of 405 students initially screened, 93 students were overweight and obese (23%). Of these 93 children, 26 were excluded because they did not complete the examinations (23 children), had a history of serious illness (1 child), or had steroid treatment (2 children). The study profile is shown in **Figure 1**.

We included 67 subjects, comprising 48 girls (72%) and 19 boys (28%). Their age range was 12-15 years, with a mean age of 13.5 (95%CI 13.28 to 13.77) years. Forty-two subjects (63%) were overweight and 25 subjects (37%) were obese. Subjects' mean HbA1c was 5.6% (95%CI 5.49 to 5.65).

Normalization of Kolmogorov-Smirnov test revealed that waist circumference and waist-to-height ratio data were not normally distributed. Hence, we used Spearman's correlation test to analyze for associations. We found that waist circumference did not have any correlation with HbA1c level (r=0.18; P=0.15) in our overweight and obese subjects. However, waist-to-height ratio had a weak significant

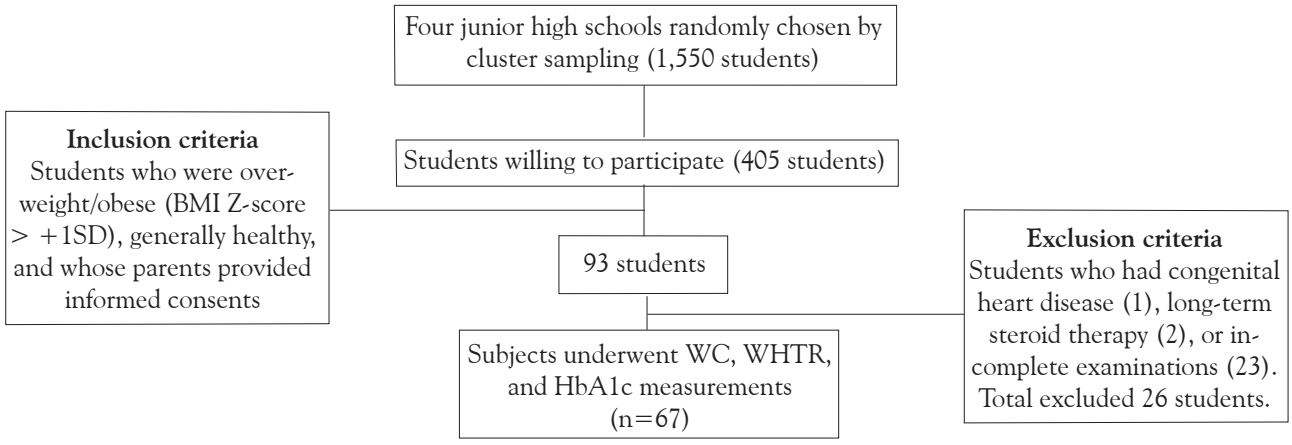

Figure 1. The course of study.
WC=waist circumference; WHTR=waist-to-height ratio

correlation with HbA1c levels (r=0.21; P=0.04) (**Table 1, Figure 2**).

We did linear regression analysis between independent variables and dependent variable levels of HbA1c. On univariate analysis we found that variables that had a value of P <0.25 were age, nutritional status, waist circumference, and waist-to-height ratio. Multivariate analyses were done to assess for associations between HbA1c level and other factors. The waist-to-height ratio was the only variable significantly associated with HbA1c level (P=0.02), while age, sex, and nutritional status had no effect on HbA1c levels (P values were 0.10, 0.34, and 0.45, respectively) (**Table 2**).

Table 1.HbA1c level,waist circumference, and waist-to-height ratio in overweight and obese adolescents

N=67	HbA1c level	P value
Waist circumference	r=0.17	0.18
Waist-to-height ratio	r=0.21	0.04

Discussion

The prevalences of overweight and obesity in junior high school adolescents in Yogyakarta were 16.8% and 6.2%, respectively. These percentages were higher

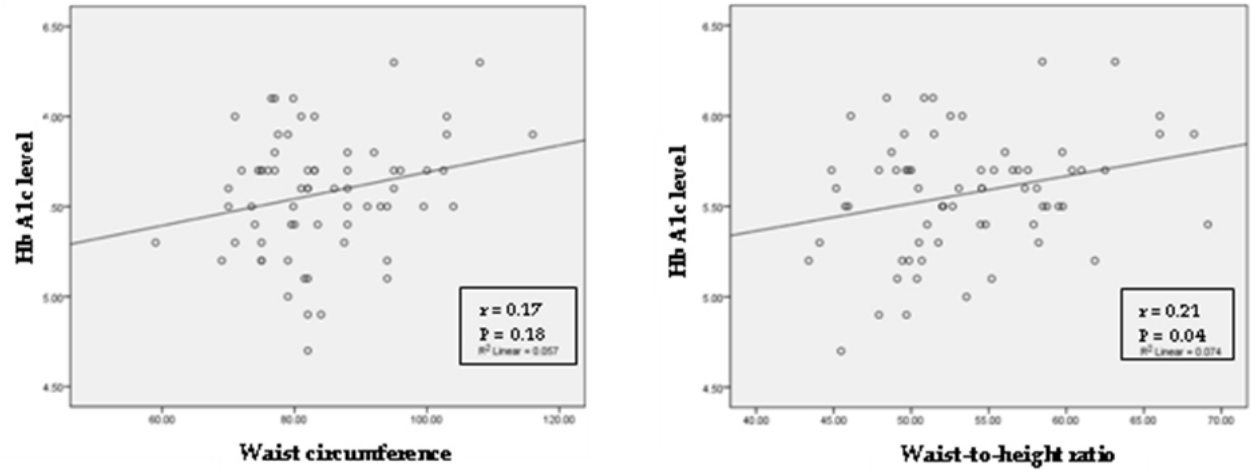

Figure 2. Scatter plots of HbA1c level, waist circumference, and waist-to-height ratio in overweight and obese adolescents

Table 2. Univariate and multivariate linear regression analyses of variables with potential associations with HbA1c levels in overweight and obese adolescents

Variables	Univariate linear regression		Multivariate linear regression	
	ß (95%CI)	P value	ß (95%CI)	P value
Age, year	-0.19 (-0.14 to 0.02)	0.13	-0.19 (-0.14 to 0.01)	0.10
Gender (1=boy, 2=girl)	0.12 (-0.09 to 0.27)	0.34	(-0.14 to 0.01)	
Nutritional status (1=overweight, 2=obese)	0.16 (-0.06 to 0.27)	0.20	-0.14 (-0.34 to 0.15)	0.45
Waist-to-height ratio	0.02 (0.00 to 0.03)	0.03	0.28 (0.00 to 0.03)	0.02

than that of a 2004 study that reported the percentage of obese adolescents in Yogyakarta to be 5.0%.[18]

Obesity may be due to lifestyle habits, such as eating high-fat foods and a lack of physical activity. Weight gain in children and adolescents is an important issue because it can continue into adulthood increasing the risk of cardiovascular diseases and metabolic disorders, such as diabetes.[19] Obesity can lead to the occurrence of type 2 diabetes, through an insulin resistance mechanism, namely, decreased insulin sensitivity which results in excessive insulin secretion by pancreatic ß-cells followed by hyperinsulinemia to maintain fasting blood glucose levels in the normal range. Beyond a certain point, compensating pancreatic ß-cells fail, causing hyperglycemia.[20,21] Central obesity is described as excessive fat deposits in the abdominal area, either subcutaneous fatty tissue or visceral adipose tissue rich in free fatty acids.[22] Therefore, cardiovascular diseases and metabolic disorders such as diabetes mellitus are more closely associated with central obesity than peripheral obesity.[23] Central obesity can be determined by waist circumference measurements > 90th percentile for age, and waist-to-height ratio ≥ 0.5.

We found no correlation between waist circumference and HbA1c level. In contrast, a Malaysian study reported that waist circumference was the only parameter associated with HbA1c levels, and not waist-to-height ratio or body mass index.[24] Measurement of waist circumference is simple to perform and has been shown to accurately detect the accumulation of abdominal fat, as compared to waist-to-hip ratio or body mass index measurements. Waist circumference alone was significantly more efficient for predicting insulin resistance, increased blood pressure, as well as increased serum cholesterol and triglyceride levels rather than body mass index. In children and adolescents, waist circumference > 90th percentile was associated with elevated insulin and lipid profiles, which are risk factors for cardiovascular disease and metabolic disorders.[25] However, our findings were consistent with data from previous studies, in that waist circumference and BMI were not significantly associated with HbA1c values, after controlling for age, race, sex, and height.[26] Since waist circumference does not take into account an individual's height, it has limited value for use in populations with wide varieties in heights, such as Indonesia.[27]

The waist-to-height ratio is an anthropometric index that can be used to easily detect visceral obesity and its association with cardiovascular diseases and metabolic disorders. The ratio is accurate for determining body fat, as it takes into account not only abdominal fat, but the percentage of muscle and waist circumference corrected by height, of each individual.[27] In our study, the waist-to-height ratio was significantly and positively correlated with HbA1c levels in overweight and obese adolescents. To date, no study reports have linked these two variables. But an earlier study in Yogyakarta stated that subjects with central obesity had a 1.21 times (95%CI 0.98 to 2.94) risk of impaired fasting glucose compared to a non-central obese group.[28] In contrast, a Malaysian study reported that waist-to-height ratio was not superior to waist circumference or BMI for predicting glycemic control in diabetes mellitus patients. This finding may be due to the fact that all study subjects, namely diabetes mellitus patients, regularly took medication including insulin, which could play a role in glycemic control. Such an anabolic effect may result in weight gain, increased appetite, and reduced glycosuria, with the end result of calorie retention.[24,29] Although not connected specifically with HbA1c

levels, previous studies in the United States, Japan, and some European countries showed a strong correlation between waist-to-height ratio and the risk of cardiovascular and metabolic diseases in overweight and obese adolescents. Hence, waist-to-height ratio has been proposed as an alternative measurement of central obesity in children.[14, 30]

Our multivariate analysis revealed that waist-to-height ratio was the only variable associated with HbA1c level (P=0.02), whereas age, sex, and nutritional status had no significant associations with HbA1c levels. Several previous studies stated that the waist-to-height ratio was the best measurement to determine central obesity and predict metabolic risks, because the waist-to-height ratio is a consistent value, as it is not influenced by differences in ethnicity and sex.[12] Furthermore, a previous study found that the prevalence of impaired glucose tolerance was significantly higher in the central obesity group compared to the non-central obesity group. Central obesity was the only risk factor for impaired glucose tolerance in obese adolescent girls in Yogyakarta with an OR of 4.6.[31] The use of body mass index (BMI) is not optimal for measuring the amount of fat tissue in children because it is influenced by age and race. In addition, high BMI cannot distinguish between excess fat or high muscle mass.[26,32]

In conclusion, waist-to-height ratio significantly associates with HbA1c level in overweight and obese adolescents.

Conflict of interest

None declared.

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