



Anthropometric markers for fat obesity in Indonesian children aged 7 to 12 years in Yogyakarta Province, Indonesia

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ABSTRACT

Background: Obesity must be determined precisely and accurately in order for intervention efforts to be more effective. Anthropometric measurement is accurate, simple, inexpensive, and non-invasive to perform, making it useful as a screening tool for body fat.

Objective: The purpose of this study is to assess the performance of anthropometric indicators in assessing fat obesity in Indonesian children aged 7 to 12 years in Yogyakarta Province.

Materials and Methods: Participants included 514 Javanese children (260 boys, 254 girls) aged 7-12 years who lived in Bantul and Kulon Progo Regencies and were healthy and willing to participate. Disabled children were excluded. Data were taken in 1998 including body weight, height, wrists, abdomen, waist and hip circumference, and skinfold thickness at biceps, triceps, subscapular, and suprailiac. Body mass index (BMI), body frame, waist-hip ratio (WHR), and waist-to-height ratio (WHtR) were further calculated. Body fat was estimated from skinfold thickness. Statistical analysis using ANOVA and Receiver Operating Characteristics (ROC) tests were performed.

Results: The ANOVA test results showed that age was the main factor of significant variation ($p < 0.001$) for all variables, while gender was significant for wrist circumference ($p < 0.05$), body frame ($p < 0.05$), and WHR ($p < 0.001$). Gender and age are simultaneously significant only for height ($p < 0.001$). ROC analysis showed that abdominal circumference in boys and waist circumference in girls had the widest area under the curve (AUC), while height had the smallest AUC in both genders. BMI had the highest AUC in boys (AUC= 0.984; $p < 0.001$) and girls (AUC= 0.972; $p < 0.001$).

Conclusion: Abdominal circumference in boys and waist circumference in girls performed better than other anthropometric indicators for assessing body fat obesity. While, BMI outperforms all other anthropometric indices in both genders.

Keywords: Anthropometry; Body mass index; Waist-to-height ratio; Fat obesity; Children

BACKGROUND

Overweight and obesity are becoming increasingly serious public health issues in children around the world. It was estimated that 20% (over 390 million) of children and adolescents aged 5-19 years in worldwide were overweight (including obese).¹ Therefore, childhood obesity is a serious health issue.² Children who are overweight are more likely to develop diabetes, obesity, chronic noncommunicable diseases, and certain types of cancer, in addition to cognitive, behavioral, and emotional issues.³ As a result of the increasing prevalence of overweight and obesity in children, screening tools are required to determine obesity and identify the associated risk factors and diseases.

Body mass index (BMI) is a tool commonly used in epidemiological research to determine childhood obesity. However, since BMI cannot distinguish between the components of body fat, muscle, and skeletal mass, it can lead to errors in the identification of obesity.⁴ Furthermore, obesity, as defined by the World Health Organization, is a condition characterized by excessive body fat that can lead to health problems.⁵ Therefore, assessing body fat is critical in both the diagnosis and treatment of childhood obesity.⁶ Standard body fat measurement methods such as DEXA⁷, however, are typically difficult to implement in clinical and field study. When standard tools are unavailable, simple body measurements such as height and weight⁶, sitting height, arm and waist circumference, and skin fold thickness⁷ can be used to estimate body fat in children. Data meta-analysis studies in multi-ethnic children aged 4-15 years revealed that models developed using simple anthropometric measures to predict body fat levels were used in many studies with high predictive ability and low individual error, indicating that models can be applied across ages, genders, and ethnicities.⁸ This study shows that anthropometric prediction models can improve the accuracy of body fat measurements in children when compared to BMI, allowing for more effective clinical obesity surveillance, prevention, and management, as well as public health monitoring.⁸

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Some anthropometric parameters can also be used to predict health risk factors. In estimating cardio-metabolic risk factors in school-age children in Mexico, waist-to-height ratio (WHtR) performed just as well as waist circumference and z-BMI.⁹ WHtR can be used to detect cardiometabolic risk in Chinese children as young as 3-6 years, as well as aged 7-17 years in both boys and girls.¹⁰ In the big data of Pakistani children and adolescents aged 2-19 years, Asif and his colleagues,¹¹ discovered that anthropometric measures (height; weight; upper middle arms, neck, wrists, waist, and hip circumference) and their derived indices (BMI, waist-hip ratio/WHR, WHtR) were valid proxies for predicting body fat, general or central obesity, and cardiovascular risk in boys and girls. A special cut-off point for the parameter has also been developed, which can be used to diagnose overweight and obesity in Pakistani children for both genders.

Anthropometric measurements, which are significant predictors of body fat mass, can be useful in identifying the effects of body fat on health risks in children's epidemiological research. Childhood obesity is very important to determine because it has a tendency to cause health problems, an increasing prevalence of obesity, and the health risk factors that accompany obese children into adulthood. Therefore, tools for identifying obesity that can accurately diagnose a child who is truly obese are required, so that such children can be treated further with appropriate interventions to prevent risk factors. This study looked at several anthropometric measures and indices as predictors of body obesity in children aged 7 to 12 years old in Yogyakarta Province.

MATERIALS AND METHODS

Subjects

This is an observational, descriptive, and analytical study with a cross-sectional design. Data was collected between August and November of 2018. Children in grades 1-6 from SDN Giriwungu, Bantul Regency, SDN 1 Sentolo, and SDN 2 Sentolo, Kulonprogo Regency, Yogyakarta Province participated. Inclusion criteria include Yogyakarta Province elementary school students in grades 1-6, boys and girls, aged 7-12 years, ethnic Javanese, healthy, and willing to participate in research as evidenced by informed consent signed by the student's parent or guardian. Meanwhile, children with disabilities are among the exclusion criteria. There were 514 children who took part (260 boys, 254 girls). The Medical and Health Research Ethics Commission, Faculty of Medicine, Public Health, and Nursing, Gadjah Mada University, provided research ethics No. KE/FK/0803EC/2018.

Measurements

Height, weight, wrist, waist, abdomen, and hip circumferences, as well as skinfold thickness on the triceps, biceps, subscapula, and suprailiaca, were all measured. An anthropometer measuring set is used to measure height to the nearest 0.1 cm (GPM, Switzerland, Ltd). The Harpenden tape meter is used to measure the circumference to the nearest 0.1 cm. Harpenden skinfold calipers were used to measure skinfold thickness to the nearest 0.2 mm. All anthropometric measurements were taken in accordance with the International Society for the Advancement of Kinanthropometry's guidelines.¹² Body mass index (BMI), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and body frame were calculated. BMI was defined from weight (kg) divided by square of height (m), WHR from waist circumference (cm) divided by hip circumference (cm), WHtR from waist circumference (cm) divided by height (cm), and body frame from height (cm) divided by wrist circumference (cm).

Percent of body fat (%BF) was assessed using the Durnin and Rahaman equations (13):

$$BD = 1.1690 - 0.0788 \log \text{sum } 4 \text{ skinfolds (boy)}$$

$$BD = 1.2063 - 0.0999 \log \text{sum } 4 \text{ skinfolds (girl)}$$

$$\%BF = ([4.95/BD] - 4.5) \times 100$$

where BD is the body density.

Statistical Analyses

A two-way ANOVA test was used in this study to determine the differences in anthropometric measures in participants based on age and gender. The best anthropometric predictor was determined using Receiver Operating Characteristic (ROC) analysis based on area under curve (AUC) analysis using %BF obesity as a reference.

RESULTS

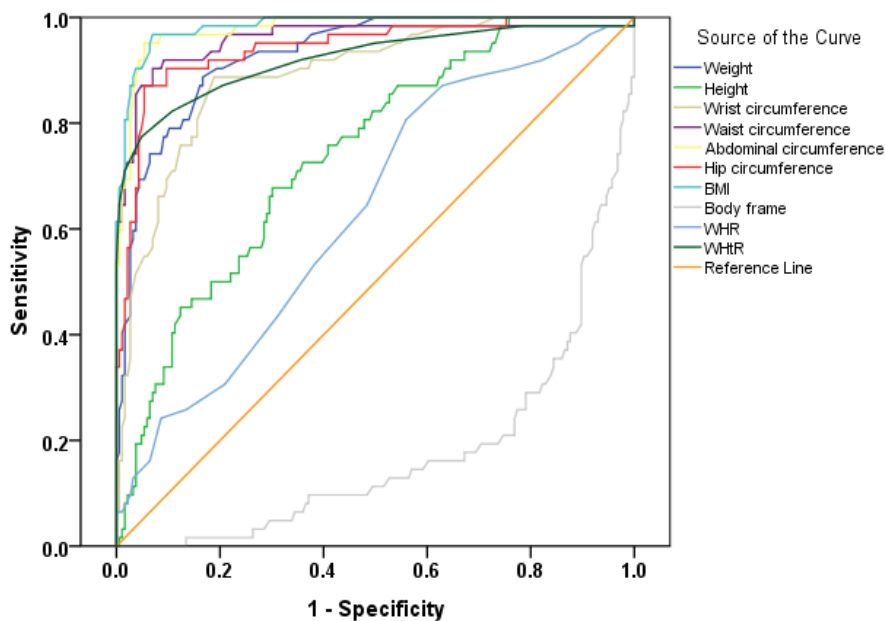
This study included 514 children aged 7 to 12 years old (260 boys and 254 girls) from Bantul and Kulonprogo Regencies in Yogyakarta. There was no statistically significant difference in the number of study subjects between boys and girls in each age group from 7 to 12 years ($p= 0.800$). The ANOVA test results show that age is the primary source of significant variation ($p<0.001$) for all parameters (Table 1). Gender was significant for neck circumference, LPT, and body frame ($p<0.05$), triceps skinfold, and WHR ($p<0.001$); however, gender and age combined are only significant for height ($p<0.001$).

Table 1. The ANOVA Results for Anthropometric Measurements and Indices of Yogyakarta Province Children Aged 7 to 12 Years.

	p		
	Gender	Age	Gender & Age
Age (years)	0.926	<0.001**	0.229
Weight (kg)	0.301	<0.001**	0.702
Height (cm)	0.948	<0.001**	0.017*
Wrist circumference (cm)	0.025*	<0.001**	0.062
Waist circumference (cm)	0.094	<0.001**	0.668
Abdominal circumference (cm)	0.129	<0.001**	0.764
Hip circumference (cm)	0.105	<0.001**	0.097
BMI	0.153	<0.001**	0.886
Body frame	0.046*	<0.001**	0.489
WHR	<0.001**	<0.001**	0.552
WHtR	0.055	<0.001**	0.854
%BF	0.614	<0.001**	0.790

* $p<0.05$; ** $p<0.01$; p: significance; BMI: Body mass index; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; BF: Body fat

The results of a Receiver Operating Characteristic (ROC) analysis of anthropometric measures for % BF obesity in boys and girls are shown in Figures 1 and 2. Abdominal circumference in boys (Figure 1) and waist circumference in girls (Figure 2) have the largest area under the curve (AUC) among the anthropometric measures, while height has the smallest curve area in both genders. Among anthropometric indices, BMI has the largest area under the AUC curve in both boys and girls, while body frame has the smallest (Figure 1).



Diagonal segments are produced by ties.

Figure 1. Receiver Operating Characteristics (ROC) of Anthropometric Measures for %BF Obesity in Boys Aged 7 to 12 Years

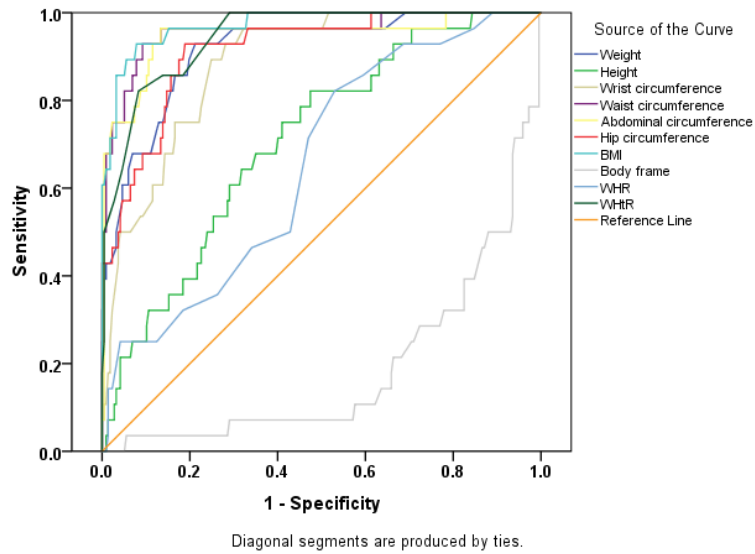


Figure 2. Receiver Operating Characteristics (ROC) of Anthropometric Measures for %BF Obesity in Girls Aged 7 to 12 Years

The curve area in Table 2 shows that BMI (AUC= 0.984) have the highest AUC in boys and girls (AUC= 0.972). Other anthropometric indicators, such as wrist, waist, abdominal and hip circumferences, and WHtR in boys (AUC= 0.892 - 0.980) and wrist, waist, abdominal, and hip circumferences, and WHtR in girls (AUC= 0.885 - 0.956), also perform well, with AUCs of 90% or higher (Table 2).

Table 2. The Area Under the Curve (AUC) Anthropometric Measurements and Indices of Yogyakarta Province Children Aged 7 to 12 Years.

	Boys (N= 260)		Girls (N= 254)	
	AUC	SE	AUC	SE
Weight (kg)	0.932	0.017**	0.915	0.028**
Height (cm)	0.744	0.034**	0.710	0.048**
Wrist circumference (cm)	0.892	0.023**	0.885	0.027**
Waist circumference (cm)	0.959	0.018**	0.956	0.023**
Abdominal circumference (cm)	0.980	0.008**	0.946	0.028**
Hip circumference (cm)	0.942	0.018**	0.914	0.026**
BMI	0.984	0.006**	0.972	0.016**
Body frame	0.177	0.031**	0.186	0.020**
WHR	0.637	0.040**	0.654	0.024**
WHtR	0.921	0.024**	0.946	0.026**

*p<0.05; **p<0.001; N: number of subjects; SE: Standard error; BMI: Body mass index; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio

DISCUSSION

This study looked at several anthropometric measures and indices as predictors of fat obesity in children aged 7 to 12 years in Yogyakarta Province. The findings revealed that abdominal circumference in boys and waist circumference in girls performed best as anthropometric indicators for assessing fat obesity. While, among anthropometric indices, BMI performs best in boys and girls.

ROC analysis of anthropometric measures of boys and girls against fat obesity revealed that abdominal circumference in boys and waist circumference in girls are the anthropometric measures with the largest area of the curve that perform the best. Although BMI has the highest performance in both boys and girls among the anthropometric indices, another index, WHtR, also has a high performance with AUC = 0.921 in boys and 0.946 in girls (see Table 2). According to the findings of several other studies, WHtR has high performance in

both genders, such as Asif and colleagues¹¹ reported AUCs = 0.855 and 0.844 for obesity in boys and girls, respectively. A study of 7-year-olds from ten European countries participating in the WHO Europe Childhood Obesity Surveillance Initiative (COSI) discovered that waist circumference and WHtR could provide additional information about the prevalence of central obesity in children.² There are differences between the countries observed - Bulgaria, Czechia, Greece, Ireland, Latvia, Lithuania, North Macedonia, Norway, Spain, and Sweden. Waist circumference in the 50th and 90th percentiles (according to COSI and 'Identification and prevention of Diet- and Lifestyle-induced health effects in Children and Infants' [IDEFICS] cut-off values) and WHtR above 0.5 are useful as indicators of abdominal obesity in children aged 7-7.9 years, according to the study. Bacopoulou et al.¹⁴ agree that the WHtR 0.5 cut-off should be used as a threshold for obesity in Greek adolescents. Furthermore, Fujita et al.¹⁵ reported that WHtR, waist circumference, and BMI can identify children with excess abdominal fat as measured by DEXA, making it useful for school-age health checks.

In our study, waist circumference in girls and abdominal circumference in boys performed well in assessing fat obesity, which is consistent with previous research, such as that of Pelegrini et al.¹⁶ in Brazilian adolescents, who found that waist circumference, along with WHtR and BMI, had the largest AUC in relation to relatively high body fat. Waist circumference can also help predict some of the health problems associated with obesity. Tong and colleagues¹⁷ discovered in Chinese children that waist circumference, as an indicator of abdominal obesity, was positively associated with residual cholesterol as a risk factor for cardiovascular disease. According to Seidell, waist circumference is more closely related to cardiovascular disease risk factors than other anthropometric measures.¹⁸ However, Aguilar-Morales et al.⁹ discovered that waist circumference, along with WHtR and BMI, predicted cardio-metabolic lipidic risk factors in the same way. Aristizabal et al.¹⁹ discovered that BMI, rather than waist circumference and WHtR, provided comparable information on cardiometabolic risk factors. A WHtR 0.5 was superior in detecting an increased risk of LDL-c increase in Mexican schoolchildren.⁹ WHtR may also be recommended in Chinese children and adolescents for identifying hypertension, dyslipidemia, and cardiometabolic risk factors in boys and girls [10]. As a result, it is suggested that WHtR be used as a screening tool to accurately identify children affected by cardiometabolic risk factors.²⁰ A meta-analysis study found that WHtR performed well in identifying clustered CMRs across racial populations.²¹

However, the dispute's findings persist. Using a multivariate regression model, Lee and colleagues²² discovered that waist circumference was significantly more efficient than BMI in predicting insulin resistance, blood pressure, cholesterol levels, and serum triglycerides. This makes waist circumference a unique source of information about health risk factors, particularly in children.²³ Furthermore, Darsini et al.²⁴ found that having a large waist circumference increases the risk of developing hypertension, type 2 diabetes, hypercholesterolemia, joint pain, lower back pain, and hyperuricemia in a systematic review. As a result, it may be a more significant and accurate predictor of general health than BMI.

This study supports the use of BMI other than waist and WHtR in the evaluation of obesity. The advantage of BMI over other anthropometric measures is that it only uses weight and height measurements, which are simpler than waist circumference and WHtR. Furthermore, BMI has been used globally, allowing comparisons between regions and populations over time.¹⁹ Even so, additional anthropometric indicators such as waist circumference and WHtR are also useful and can be used in screening for fat obesity in children.¹⁶ In recent studies, we discovered that abdominal circumference has a high performance for detecting obesity, comparable to, if not better than, waist circumference, gaining important knowledge and value from this measure. Because abdominal circumference can represent central obesity as well as waist circumference, it may be useful in identifying fat obesity.

This study adds to our understanding of obesity in Indonesian children aged 7 to 12 years old by including body fat analysis in the evaluation of obesity, as well as the utility of several anthropometric indicators in determining obesity. Because of the small number of samples used in this study, the cut-off points for obesity based on such anthropometric measures cannot be determined. The restricted sampling area also limits the generalizability of our findings to all Indonesian children. Furthermore, the cross-sectional method is incapable of analyzing causal relationships. More research is needed to develop a national cut-off point for obesity based on anthropometric indicators in a longitudinal study design and large national representative samples in order to define cut-offs fat obesity in children aged 7-12 years old.

CONCLUSIONS

In our study, abdominal circumference in boys and waist circumference in girls performed the best of anthropometric measures for assessing fat obesity in children aged 7 to 12 years in Yogyakarta Province. Meanwhile, among the anthropometric indices, BMI performed the best in identifying fat obesity in both genders, followed by WHtR. This study supports the use of BMI by adding other indicators such as waist circumference, abdominal circumference, and WHtR in determining childhood obesity.

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REFERENCES

1. World Health Organization. Obesity and overweight. Updated 1 March 2024. Available at <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>. Assessed 1 May 2024.
2. Braunerová RT, Kunešová M, Heinen MM, Rutter H, Hassapidou M, Duleva V, et al. Waist circumference and waist-to-height ratio in 7-year-old children-WHO childhood obesity surveillance initiative. *Obes Rev* 2021;22 Suppl 6:e13208. doi: 10.1111/obr.13208. Epub 2021 Aug 17. PMID: 34402567.
3. United Nations Children's Fund - Regional Office for Latin America and the Caribbean. 2021. Report 2021: Childhood Overweight a Call for Prevention in Latin America and the Caribbean. Available at <https://www.unicef.org/lac/media/29386/file/Overweight-report-2021.pdf>. Assessed 1 June 2023.
4. Bell LM, Curran JA, Byrne S, Roby H, Suriano K, Timothy WJ, & Davis EA. High incidence of obesity co-morbidities in young children: A cross-sectional study. *J Paediatr Child Health*. 2011;47(12): 911-917. doi: 10.1111/j.1440-1754.2011.02102.x
5. World Health Organization. 2012. Waist circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation Geneva, 8-11 December 2008. Geneva, Switzerland: WHO Press; 2011. Available at 9789241501491_eng.pdf (who.int). Assessed 1 June 2023.
6. Licenziati MR, Ballarin G, Iannuzzo G, Lonardo MS, Di Vincenzo O, Iannuzzi A, et al. A height-weight formula to measure body fat in childhood obesity. *Ital J Pediatr* 2022;48(1):106. doi: 10.1186/s13052-022-01285-8. PMID: 35729585; PMCID: PMC9210685.
7. Ortiz-Hernández L, Vega López AV, Ramos-Ibáñez N, Cázares Lara LJ, Medina Gómez RJ, Pérez-Salgado D. Equations based on anthropometry to predict body fat measured by absorptiometry in schoolchildren and adolescents. *J Pediatr (Rio J)* 2017;93(4):365-373. doi: 10.1016/j.jped.2016.08.
8. Hudda MT, Fewtrell MS, Haroun D, Lum S, Williams JE, Wells JCK, et al. Development and validation of a prediction model for fat mass in children and adolescents: Meta-analysis using individual participant data. *BMJ* 2019;366:14293. doi: 10.1136/bmj.14293. PMID: 31340931; PMCID: PMC6650932.
9. Aguilar-Morales I, Colin-Ramirez E, Rivera-Mancía S, Vallejo M, Vázquez-Antona C. Performance of waist-to-height ratio, waist circumference, and body mass index in discriminating cardio-metabolic risk factors in a sample of school-aged Mexican children. *Nutrients* 2018;10(12):1850. doi: 10.3390/nu10121850. PMID: 30513720; PMCID: PMC6316407.Chen et al., 2022
10. Chen R, Ji L, Chen Y, Meng L. Weight-to-height ratio and body roundness index are superior indicators to assess cardio-metabolic risks in Chinese children and adolescents: Compared with body mass index and a body shape index. *Transl Pediatr* 2022;11(3):318-329. doi: 10.21037/tp-21-479. PMID: 35378962; PMCID: PMC8976678.
11. Asif M, Aslam M, Ullah K, Qasim M, Afzal K, Abbas A, et al. Diagnostic performance and appropriate cut-offs of different anthropometric indicators for detecting children with overweight and obesity. *Biomed Res Int* 2021;1608760. doi: 10.1155/2021/1608760. PMID: 34568486; PMCID: PMC84579.
12. Marfell-Jones M., Olds T, Stewart A, Carter L. International Standards for Anthropometric Assessment. Lower Hutt, Melbourne: International Society for the Advancement of Kinanthropometry. 2006.
13. Durnin JVGA and Rahaman MM. The assessment of the amount of fat in the human body from the measurement of skinfold thickness. *British J Nutr* 1967;21:681-688.

<https://doi.org/10.1079/BJN19670070>

14. Bacopoulou F, Efthymiou V, Landis G, Rentoumis A, Chrousos GP. Waist circumference, waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among Greek adolescents. *BMC Pediatr* 2015;15:50. doi: 10.1186/s12887-015-0366-z. PMID: 25935716; PMCID: PMC4446827
15. Fujita Y, Kouda K, Nakamura H, Iki M. Cut-off values of body mass index, waist circumference, and waist-to-height ratio to identify excess abdominal fat: population-based screening of Japanese school children. *J Epidemiol* 2011;21(3):191-6. doi: 10.2188/jea.je20100116. Epub 2011 Mar 30. PMID: 21467729; PMCID: PMC3899408.
16. Pelegrini A, Silva DA, Silva JM, Grigollo L, Petroski EL. Indicadores antropométricos de obesidade na predição de gordura corporal elevada em adolescentes [Anthropometric indicators of obesity in the prediction of high body fat in adolescents]. *Rev Paul Pediatr* 2015;33(1):56-62. doi: 10.1016/j.rpped.2014.06.007. PMID: 25649384; PMCID: PMC4436957.
17. Tong J, Li X, Liang X, Tang F, Ren Y, Hao G, et al. The relationship of remnant cholesterol and abdominal obesity in children: A cross-sectional study. *Front Cardiovasc Med* 2022;9:929560. doi: 10.3389/fcvm.2022.929560. PMID: 35966536; PMCID: PMC9363601.
18. Seidell JC. (2010). Waist circumference and waist/hip ratio in relation to all-cause mortality, cancer and sleep apnea. *Eur J Clin Nutr* 2010;64:35-41.
19. Aristizabal JC, Barona J, Hoyos M, Ruiz M, Marín C. Association between anthropometric indices and cardiometabolic risk factors in pre-school children. *BMC Pediatr* 2015;15:170. doi: 10.1186/s12887-015-0500-y. PMID: 26546280; PMCID: PMC4636828.
20. Dou Y, Jiang Y, Yan Y, Chen H, Zhang Y, Chen X, et al. Waist-to-height ratio as a screening tool for cardiometabolic risk in children and adolescents: A nationwide cross-sectional study in China. *BMJ Open*. 2020;10(6):e037040. doi: 10.1136/bmjopen-2020-037040. PMID: 32565476; PMCID: PMC7311015.
21. Jiang Y, Dou Y, Chen H, Zhang Y, Chen X, Wang Y, et al. Performance of waist-to-height ratio as a screening tool for identifying cardiometabolic risk in children: A meta-analysis. *Diabetol Metab Syndr* 2021;13(1):66. doi: 10.1186/s13098-021-00688-7. PMID: 34127061; PMCID: PMC8201900.
22. Lee CMY, Huxley RR, Wildman RP, and Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: A meta-analysis. *J Clin Epidemiol* 2008;61(7):646-653. doi: <http://dx.doi.org/10.1016/j.jclinepi.2007.08.012>
23. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, et al. Assessment of child and adolescent overweight and obesity. *Pediatrics* 2007;120(Supplement 4):S193-S228. doi: 10.1542/peds.2007-2329D.
24. Darsini D, Hamidah H, Notobroto HB, Cahyono EA. Health risks associated with high waist circumference: A systematic review. *J Public Health Res* 2020;9(2):1811. doi: 10.4081/jphr.2020.1811. PMID: 32728557; PMCID: PMC7376462.