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Original Article

Tri-ponderal mass index *vs.* body mass index to determine obesity and central obesity in adolescents

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Abstract

Background Tri-ponderal mass index (TMI) is as accurate as body mass index (BMI) in predicting body fat in children and adolescents. Despite TMI simplicity, there have been few studies comparing the sensitivity and specificity of TMI and BMI in determining obesity and central obesity in adolescents.

Objective To compare the sensitivity and specificity of TMI and BMI in determining general obesity and central obesity in adolescents.

Methods This cross-sectional study was conducted in Surakarta. Healthy school children aged 12 to 17 years underwent TMI, BMI, and waist circumference measurements in 2016, 2017, 2019. Tri-ponderal mass index was calculated as the weight divided by the height in metres cubed (kg/m^3). General obesity was defined by the *International Obesity Task Force* (IOTF) classification of overweight-obese. The BMI-WHO overweight/obesity was defined as over the 85th percentile of the BMI SDS (WHO growth reference). Central obesity was defined as waist-to-height ratio (WtHR) $\geq$ 0.5. The sensitivity and specificity of TMI and BMI were calculated.

Results A total of 1,173 children and adolescents (837 girls, 336 boys) aged 12-17 years were recruited into this study. The overall prevalences of obesity by BMI-WHO, TMI, BMI-IOTF, and WtHR were 22.68%, 14.92%, 20.55%, and 32.74%, respectively. The sensitivity of BMI-WHO *vs.* TMI for general obesity was 100.00% *vs.* 77.71%, respectively (girls) and 100.00% *vs.* 59.52%, respectively (boys). The specificity was 98.24% *vs.* 99.56%, respectively (girls) and 98.84% *vs.* 100%, respectively (boys). The sensitivity of BMI-WHO *vs.* TMI for central obesity was 58.77% vs 48.82%, respectively (girls), and 47.40% vs. 27.75%, respectively (boys). The specificity was 92.81% *vs.* 96.49%, respectively (girls), and 90.80% *vs.* 98.77%, respectively (boys).

Conclusion Tri-ponderal mass index consistently showed higher specificity and lower sensitivity than BMI in assessing general and central obesity. **[Paediatr Indones. 2024;64:501-8; DOI: https://doi.org/10.14238/pi64.6.2024.501-8].**

Keywords: *anaemic mother; hemoglobin, ferritin; vitamin D*

Obesity is one of the most common pediatric chronic diseases, affecting current and long-term health of children and adolescents. A complex interplay of socioecological, environmental, and genetic factors in children and families leads to childhood obesity.[1] Obesity raises the risk of early childhood puberty, irregular adolescent menstruation, obstructive sleep apnea (OSA), and other sleep disorders, as well as cardiovascular risk factors such as metabolic syndrome, prediabetes, type 2 diabetes, high cholesterol, hypertension, and non-alcoholic fatty liver disease (NAFLD). Furthermore, psychological problems like anxiety, depression, low self-esteem, poor body image, negative peer interactions, and eating disorders can affect obese kids and teenagers.[2]

The gold standard for body composition measurement is dual-energy x-ray absorptiometry (DXA), which can identify, locate, as well as quantify body fat. However, this method is costly and not widely

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available in clinical settings. Body mass index (BMI) is one of the most used screening measurements for excess body adiposity. Pediatric BMI is age and sex-specific in interpretation.[1] A child or adolescent is considered obese when BMI is equal to or more than the 95th percentile. While BMI Z-scores can be translated into BMI percentiles, the resulting percentiles must be rounded and may incorrectly place some children of average weight in the underweight or overweight range. Therefore, pediatric BMI Z-scores may be used in research, while BMI percentiles are best used in clinical settings, to avoid these errors.[2]

Body mass index has high specificity and low sensitivity in detecting excess adiposity. It may under or over-detect excess adiposity, as it does not directly measure the body muscle composition and fat content.[1] It has long been known that people with normal BMIs can be overweight; this condition, known as normal-weight obesity (NWO), has been linked to an increased risk of cardiovascular disease (CVD).[3] The prevalences of abdominal obesity in children aged 7-9 years with normal weight and overweight in Greece were 1.66-6.8% and 21.8-49.1%, respectively.[4] Similarly, central obesity was evident in normal-weight children and adolescents in China.[3] The failure to detect central obesity using BMI might be related to the inability of BMI to account for body proportion, especially during adolescent growth.[5] Considering that waist circumference measurement seems to be more sensitive in determining cardiovascular risk and is more common than BMI-defined obesity, it may be necessary to include waist circumference measurement in the screening process for pediatric obesity.[4] Waist-to-height ratio (WtHR) screening can be an efficient clinical tool, particularly in overweight children and adolescents.[6,7]

A study proposed TMI as a better body fat index than BMI *z*-scores. Tri-ponderal mass index was found to be consistent during adolescence and had less overweight misclassification. It is also less complicated to use in clinical settings. Instead of the several complex age and sex-specific criteria required for BMI in adolescents, TMI uses only one threshold for each sex.[8] Previous research has revealed that TMI has demonstrated similar or better ability to predict body fat percentage in children and adolescents compared to BMI.[7,9,10] It is particularly valuable when combined with other indicators.[7,9,10] The TMI has been proposed as a advantageous screening tool for determining the risk of obesity in children and has been proven to be beneficial in clinical settings where BMI may underestimate the comorbidities.[7,11,12] The TMI was perceived to have moderate discriminatory power for predicting metabolic syndrome (MetS).[13,14] Nevertheless, the TMI is not considerably better than the BMI at detecting specific cardiovascular risk factors.[9,15] In childhood brain tumors survivors, TMI has been confirmed as a reliable measure of adiposity.[16]

To the best of our knowledge, there has been limited research in Indonesia comparing BMI and TMI in adolescents. Thus, we aimed to compare sensitivity, specificity, and area under the curve of TMI and BMI for assessing obesity and central obesity in adolescents.

Methods

We aggregated anthropometric data (height, weight, and BMI) from 1,173 healthy students in Surakarta, consisting of 837 (71.35%) girls and 336 (28.64%) boys. Data collection was cross-sectional and conducted in 2016, 2017, and 2019, involving different individuals in each session. There was some age overlap among participants across these surveys.[17-19] In 2016, all subjects were girls due to the study conducted in special school for girls.[17] The study included physically healthy children aged 12-17 years, with written parental consent obtained for all participants. Children with chronic illnesses, a history of physical trauma (ascertained through interviews), or physical disabilities (identified via physical examinations) were not included in the study. The BMI calculation is weight (kg) divided by height-squared (m^2). Tri-ponderal mass index is calculated by dividing the body mass (kg) by height cubed (m^3).[8] General obesity was defined by the *International Obesity Task Force* (IOTF) classification of overweight-obese.[12] BMI-WHO overweight/obesity was defined as over the +1SD of the BMI SDS (WHO growth reference).[20] Using the 85th and 95th percentiles of the TMI for all individual subjects of each gender, tri-ponderal mass index thresholds for overweight and obesity without adjustment for age were determined.[8] Central obesity was defined as WtHR $\geq$ 0.5.[21] The sensitivity and specificity of TMI and BMI-WHO in defining general obesity and sensitivity and specificity of TMI and BMI-

WHO in defining central obesity based on WtHR were analyzed. Statistical analyses were conducted using *Stata/MP 14.0 sof tware*. Z-scores were calculated using the *ZANTHRO* command in *Stata/MP 14.0*.

Results

A total of 1,173 children and adolescents were included in this study, consisting of 837 girls and 336 boys. Most subjects were evaluated in 2019 (43%) and aged 17 years (29.5%). **Table 1** and **Figure 1** show the subjects' basic characteristics and scatterplots. The overall prevalences of obesity by BMI-WHO, TMI, general obesity, and central obesity were 22.68%, 14.92%, 20.55 %, and 32.74%, respectively (**Table 2**).

The sensitivities of BMI-WHO and TMI for general obesity were 100.00% and 77.71%, respectively (girls), and 100.00% and 59.52%, respectively (boys). The specificities of BMI-WHO and TMI for general obesity were 98.24% and 99.56%, respectively (girls), and 98.84% and 100%, respectively (boys). The AUCs were higher in the BMI-WHO of girls (0.99) and boys (0.97), compared to TMI of girls (0.89) and boys (0.80). The complete sensitivity and specificity comparison of BMI-WHO and TMI for general obesity is shown in **Table 3**.

A sensitivity and specificity comparison between BMI-WHO and TMI for central obesity is shown in **Table 4**. The sensitivities of BMI-WHO and TMI for central obesity were 58.77% and 48.82%, respectively (girls), and 47.40% and 27.75%, respectively (boys). The specificities of BMI-WHO and TMI for central obesity were 92.81% and 96.49%, respectively (girls), and 90.80% vs 98.77%, respectively (boys). The AUCs of girls for BMI-WHO (0.76) and TMI (0.73) were relatively higher compared to those of boys TMI (0.69) and BMI-WHO (0.63).

Table 1. Basic characteristics of subjects

Characteristics	Girls (n=837)	Boys (n=336)	Total (N=1,173)
Year of study, n (%)			
2016	444 (53.0)	0 (0.0)	444 (37.9)
2017	85 (10.2)	140 (41.7)	225 (19.2)
2019	308 (36.8)	196 (58.3)	504 (43.0)
Age in years, n (%)			
12	14 (1.7)	31 (9.2)	45 (3.8)
13	36 (4.3)	37 (11.0)	73 (6.2)
14	63 (7.5)	50 (14.9)	113 (9.6)
15	205 (24.5)	88 (26.2)	293 (25.0)
16	241 (28.8)	62 (18.5)	303 (25.8)
17	278 (33.2)	68 (20.2)	346 (29.5)
Mean BMI SDS (SD)	-0.04 (1.28)	0.05 (1.58)	-0.01 (1.37)
Mean TMI (SD)	13.78 (3.00)	12.98 (3.03)	13.55 (3.03)
Mean WtHR (SD)	0.46 (0.07)	0.48 (0.07)	0.47 (0.07)

Table 2. Obesity status of subjects

Characteristics	BMI-WHO	TMI*	BMI-IOTF	WtHR
Girls, n (%) [n=837]				
Normal	668 (79.81)	712 (85.07)	680 (81.24)	626 (74.79)
Overweight-obese	169 (20.19)	125 (14.93)	157 (18.76)	211 (25.21)
Boys, n (%) [n=336]				
Normal	239 (71.13)	286 (85.12)	252 (75.00)	163 (48.51)
Overweight-obese	97 (28.87)	50 (14.88)	84 (25.00)	173 (51.49)
All subjects, n (%) [N=1,173]				
Normal	907 (77.32)	998 (85.08)	932 (79.45)	789 (67.26)
Overweight-obese	266 (22.68)	175 (14.92)	241 (20.55)	384 (32.74)

*>85th percentile TMI cut-off[8]: 16.59 (girls), 15.83 (boys)

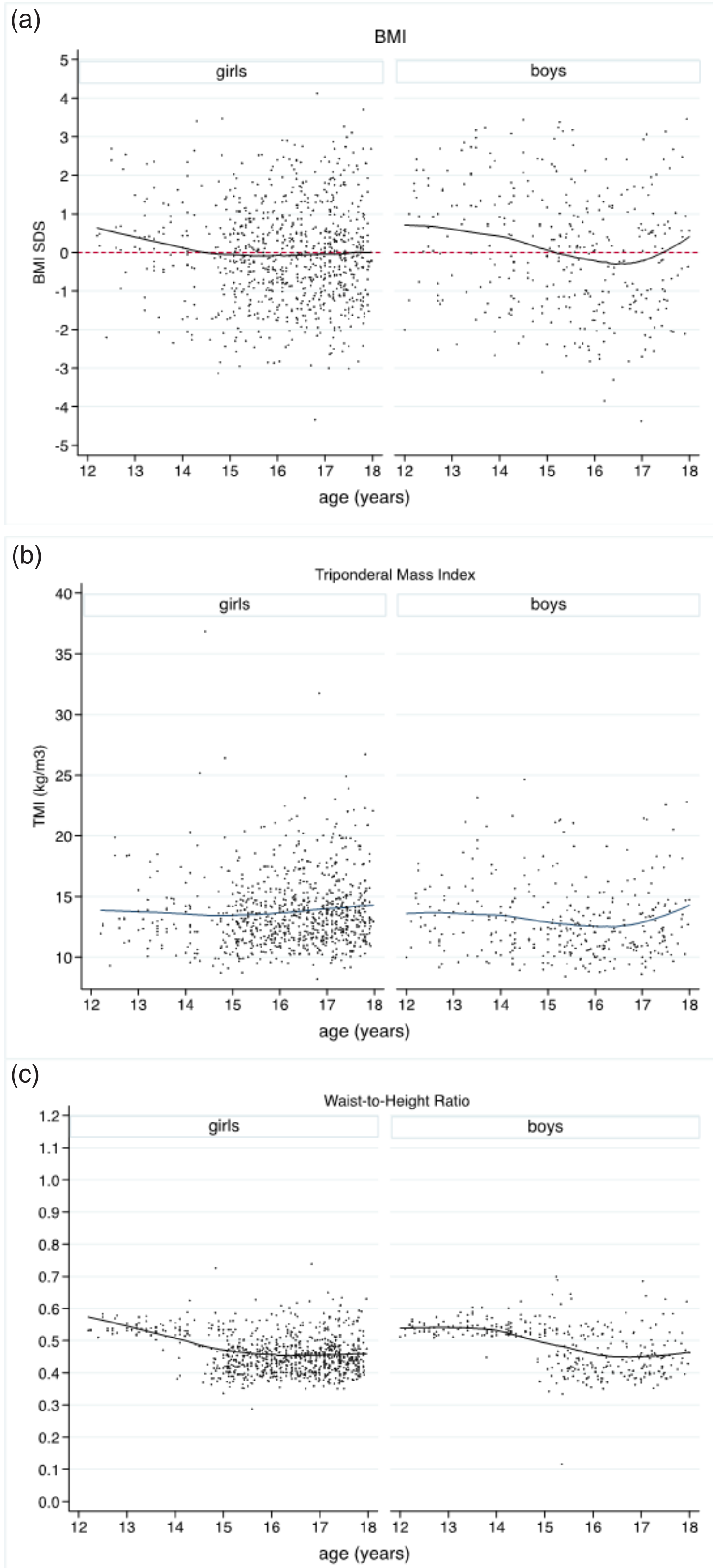

Figure 1. Scatterplots of BMI-SDS (a), TMI (b), and WtHR (c)

Table 3. Sensitivity, specificity, and AUC for TMI and BMI in adolescents with general obesity

Variables	Obese girls		Obese boys	
	BMI-WHO	TMI	BMI-WHO	TMI
Sensitivity, %	100.00	77.71	100.00	59.52
Specificity, %	98.24	99.56	98.84	100
AUC	0.99	0.89	0.97	0.80

Table 4. Sensitivity, specificity, and AUC for TMI and BMI in adolescents with central obesity, based on WtHR

Variables	Obese girls		Obese boys	
	BMI-WHO	TMI	BMI-WHO	TMI
Sensitivity, %	58.77	48.82	47.40	27.75
Specificity, %	92.81	96.49	90.80	98.77
AUC	0.76	0.73	0.69	0.63

Discussion

Our study revealed that the specificities of TMI were higher compared to BMI-WHO for general obesity in both girls (99.56%) and boys (100%). The TMI specificity for central obesity was better compared to that of BMI-WHO.

This higher TMI specificity for general obesity supports the use of TMI instead of BMI in adolescence, since BMI may lead to over-detection.[1] Tri-ponderal mass index was found to be as effective as BMI in determining overweight and obesity in Turkish children aged 6-17 years.[5] Other research indicated that TMI was more accurate for estimating body fat percentage in non-Hispanic white adolescents (aged 8-17 years) compared to BMI.[8] Tri-ponderal mass index remains relatively constant during adolescence compared to BMI, which requires adopting age-specific percentiles and is thought to provide specific cut-off values.[8,11] Other studies also showed TMI stability in Canadians aged 6-19 years in both sex and Koreans aged 10-20 years.[11,23] A previous study recommended using TMI cut-offs of 85th and 95th percentile readings to predict excessive adiposity and obesity.[8] By employing a specific TMI value, clinicians can identify obesity in children and adolescents and associated comorbidities that require early care during the development of height and weight and even during periods of rapid growth.[11]

Tri-ponderal mass index appeared to function on par with or even better than BMI as a predictor of central fat.[9] A study suggested that TMI was a more reliable measure of central obesity in adolescents, particularly in males, than BMI and BMI *z*-score. Their conclusion was based on a strong association between WtHR and TMI in examining the relationship between abdominal adiposity and weight status.[7] Similarly, another study showed that TMI significantly predicted adiposity in both survivors of pediatric brain tumors and non-cancer controls, and showed high associations with markers of total and central obesity.[16] Detection of central obesity is important as it is linked to higher morbidity of chronic illness. Regardless of BMI, higher levels of abdominal fat were substantially linked to cardiometabolic risk factors in children.[11] Tri-ponderal mass index, comparable to BMI *z*-score, was able to identify insulin resistance in children and adolescents. It is related to the role of fat mass distribution as part of insulin resistance.[24] Therefore, TMI may offer more accurate information without the need for specialized instruments like DXA for children and adolescents with obesity and its complications who need early identification and intervention. It also has the advantage of simple anthropometrical measurements and intuitive interpretation in the primary clinical setting.[11]

Because of the need to adjust body weight for height, BMI was created to assess obesity and overweight.[5] BMI provides reliable information for adults whose height is stable. However, during the peripubertal stages, adiposity rises with age. Compared to less mature children of the same height, children with rapid growth due to pubertal development typically have greater levels of adiposity.[11] Age- and sex-specific BMI cut-offs are necessary because body fat content and distribution differ significantly during childhood and adolescence. Although BMI is used for clinical judgment, it cannot be used to elucidate the proportion of fat and lean content.[5] The next promising anthropometric measure appears to be TMI. TMI was found to estimate body fat levels more accurately, misclassify overweight status less frequently than BMI z-scores, perform as well as an updated set of BMI percentiles, and remain relatively constant throughout adolescence.[8]

Depending on the measurement method, the overall prevalence of obesity in our study varied from 14.92 to 32.74%. It was higher compared to a previous study in 514 Indonesian districts across 34 provinces in Indonesia using BMI-WHO, which reported an overall obesity rate of 7.0%.[25] This discrepancy might have been related to the study population. Our study was conducted in Surakarta City, an urban district in Central Java, Indonesia. Environmental factors include the urban nature of the area and the habits of certain ethnicities, such as Chinese and Javanese communities, who often consume and use sweets and desserts as gifts or rewards for children.[26] Similar to general obesity, central obesity is also influenced by poor lifestyle choices that support a surplus energy balance. Children who eat breakfast regularly and who have a high total meal frequency had lower total and abdominal adiposity indices compared to those who skipped breakfast or ate fewer but larger meals throughout the day. This may be explained by the positive effects of more frequent meals on regulating appetite, postprandial metabolic and endocrine responses, and non-exercise physical activity.[27]

The prevalence of obesity based on WtHR was higher (32.74%) compared to other parameters. The WtHR is a recently proposed alternative anthropometric indicator for detecting central obesity, which is straightforward and can be interpreted without using age- or gender-specific charts.[28] A recent systematic review and meta-analysis supported the idea that children and adolescents of different racial, age, and gender backgrounds can have their central obesity accurately predicted using WtHR with a cut-off value of 0.5.[6] The higher percentage of WtHR measurements should raise awareness of the possibility of higher prevalence of abdominal or central obesity. Visceral fat deposition is mostly linked to central obesity. Visceral and subcutaneous fat have both been linked to cardiometabolic comorbidities.[3,29] Furthermore, central obesity throughout adolescence is associated with a possible risk for autoimmune disorders.[30] Adipose tissue has pro-inflammatory properties, and an accumulation of this tissue may lead to persistent low-grade inflammation.[31,32]

We also found a higher mean WtHR in boys compared to girls, indicating a higher prevalence of central obesity in boys, which is supported by previous studies.[27,33] A pervious study demonstrated that the odds of having abdominal obesity increased by 36% in Brazilian adolescent boys aged 14-17 years.[33] The gender disparity in obesity may be partially explained by the nutritional and sedentary behaviors that distinguish boys and girls. A study in China showed the customary preference in society for sons, especially in rural areas, where boys are expected to receive a greater share of the family's resources. It could also be connected to the gender disparity in body image satisfaction, as body image dissatisfaction is more common in girls than in boys. In addition, boys tend to spend more time watching screens compared to girls.[3] A systematic review and meta-analysis showed that individuals with the highest screen time had a higher waist circumference than those with the lowest screen time.[34]

Our study is the first to compare sensitivity and specificity of TMI and BMI in identifying central and general obesity in Indonesian children and adolescents. However, the findings might not be applicable to adolescents nationwide, as they were from only one district in Indonesia. We need a body fat measurement to be used as a gold standard for obesity determination.

In conclusion, TMI consistently showed higher specificity and lower sensitivity than BMI for assessing general and central obesity. Further study with a larger sample size that represents Indonesian children is needed.

Conflict of interest

None declared.

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