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Optimal Cut-Off Points of Weight for Height, Waist Circumference and Waist-to-Height Ratio for Defining Overweight and Obesity in Thai School-Aged Children

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ABSTRACT

Background: The Body Mass Index (BMI) is widely used to diagnose overweight and obesity. However, there are limitations on the use of BMI and development of alternative measures can be of clinical importance. This study aimed to compare specificity and sensitivity of weight for height (W/H), waist circumference (WC) and waist-to-height ratio (WHTR) with BMI-for-age in diagnosing overweight and obesity in Thai school-age children.

Methods: This was a cross-sectional study. Children between the ages of 6 and 13 who attended elementary schools were potential participants of the study. BMI, W/H, WC, and WHTR were calculated for each participant. The optimal cut-off points for the diagnosis of overweight and obesity by W/H, WC and WHTR were generated by the receiver operating characteristic curves (ROC).

Results: Using BMI cut-off points introduced by WHO, the overall prevalence of overweight and obesity in the study population was 24.6% and 12.9% respectively. W/H, WC, and WHTR all showed acceptable sensitivity and specificity in diagnosing overweight and obesity when compared to BMI-for-age results. W/H had a particularly high correlation with BMI-for-age .

Conclusion: Cut-off points of 112% and 125% W/H are validated to determine overweight and obesity in Thai school-aged children.

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Introduction

Childhood obesity is a growing problem and has reached epidemic levels in many countries around the world [1, 2]. It is well established that an increase in the prevalence of childhood obesity contributes to a rise in the prevalence of some serious health problems such as diabetes, hypertension, dyslipidemia, polycystic ovary syndrome, gastro-esophageal reflux, iron deficiency, Vitamin D deficiency, etc [2].

Obesity is often defined as excess body fat [3]. The Body Mass Index (BMI) is not a direct measure of body fat but is generally considered the gold standard surrogate for measurement of body fat replacing the direct measures including density based, scanning, and bioelectrical methods that are often complex and hard to perform in clinical settings. In an attempt to optimize the use of BMI as an indicator of obesity in children, the WHO introduced BMI-for-age that also factors in child's sex.[4] However, without an access to specific software; this measure is relatively complex and time-consuming to calculate that can limit its use in practice [5].

BMI is the most frequently used measure for overweight and obesity. However, there are other measures available as well, most notably, weight for height (W/H), waist circumference (WC), and waist-to-height ratio (WHTR). W/H is defined as actual weight divided by the standard median weight for subject's sex and height. Based on the WHO recommendations, W/H of more than 120% of the standard weight indicates obesity [6]. However the validity of this cut-off point is not established in many populations including school-age children in Thailand. W/H is an easy and convenient assessment method for obesity, however, it has not been tested for it reliability and correlation with the standard method of BMI. WC and WHTR are recently proposed as alternative methods for defining obesity. It is suggested that these two methods may have advantages over BMI and W/H in that they include waist measurement that is believed to be correlated to risk of cardiovascular events. However, there are no standard cut-off points available for these two measures [7-9].

Thai population is a relatively homogeneous population ethnically where up to 90% of the population consists of Thai and Thai-Chinese ethnic groups. Nearly 20% of Thai population consists of children less than 15 years of age.

The present study is aimed to evaluate the optimal cut-off points of W/H, WC and WHTR for the diagnosis of overweight and obesity in Thai school-aged children and to compare these 3 methods to BMI standards of WHO to assess whether these measurements can potentially be an alternative for BMI-for-age in this population.

Methods

This was a cross-sectional study conducted in school children aged 6 to 13 years who attended 17 elementary schools in Ongkhaluck, Nakorn Nayok province in 2008 were the population of the study. A total number of 1874 participants were required to capture an obesity prevalence of 12% (accepted error at 0.01). Out of 38 primary schools (3483 students) in Ongkhaluck, 17 were randomly selected to meet the target sample size. Only those children who were present at school on the day of the study were approached to participate. Children who had major physical abnormality or dysmorphic features (syndromes) were not included.

All the anthropometry measurements were done by trained staff. Height was measured to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg by an electronic scale (Tanita BF 680W, Japan). Then, BMI was calculated using this formula: weight (kg)/height squared (m^2). Based on BMI-for-age standards of WHO, BMI scores of greater than 1 standard deviation (SD) and greater than 2 SD were defined as overweight and obese respectively [10].

W/H was calculated using the following formula: participant's weight (kg)/standard median weight for participant's sex and height. Standard median weight of Thai children for height and sex was obtained from the growth reference standards for weight and height published by the Department of Health, Ministry of Public Health, Thailand [11].

Waist circumference was measured to the nearest of 0.1 cm at the midpoint between lower margin of the last palpable rib and the top of iliac crest by a non-elastic tape. The measurement was taken at the end of a normal expiration. Waist to height ratio was the waist circumference (cm) divided by height (cm).

Sensitivity is defined as the proportion of obese (or overweight) children who are test positive for each cut-off value and method (W/H, WHTR and WC). [Sensitivity = number of true positive/ number of true positives+ number of false negatives]

Specificity is defined as the proportion of non-obese (or non-overweight) children who are test negative for the tests. [Specificity= number of true negatives/ number of true negative+ number of false positives]

Analysis

Demographic data were presented as frequencies, means, and standard deviations. The differences of demographic data between genders were tested by student's *t*-test and Chi-squared test as appropriate. A *P*-value of < 0.05 was considered as statistically significant. The optimal cut-off points for the diagnosis of overweight and obesity by W/H, WHTR and WC were generated by the receiver operating characteristic curves (ROC). Statistical analysis was performed using SPSS 11.0.

Ethical considerations

The study was approved by the Ethic Committee of Faculty of Medicine, Srinakharinwirot University. Each Participant provided assent prior to his/her participation. In addition, participants' parents signed an informed consent form before their children's participation in the study.

Results

In total, 1877 children including 964 boys (51.4%) and 913 girls (48.6%) participated in the study. Participants' age ranged from 6.0 to 12.9 years with mean age of 9.9 years. Table 1 shows demographic characteristics of the study population. There was no statistically significant difference between boys and girls in terms of age, body weight, WC and BMI; however, boys tend to be shorter than girls (*P*=0.022) and to have higher W/H (*P*=0.007) and WHTR (*P*=0.001) scores.

Table 1: Demographic data of the study population (964 boys and 913 girls)

Variables	Boys	Girls	*P* value
Age (yr)			
Mean (SD)	9.90 (1.90)	9.90 (1.90)	0.416
Weight (kg)			
Mean (SD)	32.00 (11.90)	32.60 (12.20)	0.283
Height (cm)			
Mean (SD)	133.10 (12.60)	134.50 (13.30)	0.022
Waist (cm)			
Mean (SD)	58.20 (10.63)	57.60 (9.50)	0.163
Body mass index (kg/m2)			
Mean (SD)	17.59 (4.03)	17.50 (3.94)	0.625
Weight for height			
Mean (SD)	108.40 (22.40)	105.70 (20.60)	0.007
Waist-to-height ratio			
Mean (SD)	0.4 (0.06)	0.43 (0.06)	0.001
Overweight			
Number (%)	255 (26.50)	206 (22.60)	0.053
Obesity			
Number (%)	143 (14.80)	99 (10.80)	0.011

Using BMI cut-off points introduced by WHO, the overall prevalence of overweight and obesity in the study population was 24.6% and 12.9% respectively. Based on the same cut-off points, obesity was more common in boys than girls (14.8% *vs.* 10.8% respectively; *P*=0.011).

ROC curves of W/H, WHTR and WC for diagnosis of overweight and obesity in Thai children are shown in Figures 1 and 2. The accuracy of W/H assessed by the area under the curve (AUC) to identify overweight and obesity was higher than that of WHTR or WC (W/H AUC for overweight = 0.993; 95% CI: 0.991,0.996; *P*<0.001 and W/H AUC for obesity = 0.996; 95% CI: 0.994,0.998; *P*<0.001). Table 2 presents AUC values for W/H, WHTR and WC in the study population according to participant's sex.

The calculated optimal cut-off points of W/H, WHTR and WC with their corresponding sensitivities and specificities to identify overweight and obesity are shown in Table 3.

At the cut-off point of 112.6748, W/H provided a sensitivity of 0.963 and a specificity of 0.962 in predicting overweight as calculated by WHO criteria of BMI-for-age. The sensitivity and specificity values for obesity were 1.000 and 0.995 respectively when the W/H cut-off point was set at 125.0638. The optimal cut-off points of W/H for overweight were relatively comparable between boys and girls (112.9776% *vs.* 112.6748%, respectively); however, the optimal cut-off point for obesity was higher in girls than boys (128.6921% *vs.* 125.6748%, respectively).

Table 2: Area under the curve (AUC) of weight for height, waist to height ratio and waist circumference for the diagnosis of overweight and obesity in Thai children as defined by body mass index for age and gender

	Boys			Girls			Total		
	AUC	**SD**	**95% CI**	**AUC**	**SD**	**95% CI**	**AUC**	**SD**	**95% CI**
Overweight									
Weight for height	0.995	0.002	0.992, 0.998	0.991	0.002	0.987, 0.996	0.993	0.001	0.991, 0.996
Waist to height ratio	0.917	0.011	0.894, 0.939	0.909	0.012	0.885, 0.933	0.913	0.008	0.897, 0.930
Waist circumference	0.887	0.014	0.859, 0.915	0.907	0.014	0.879, 0.934	0.896	0.010	0.876, 0.915
Obesity									
Weight for height	0.996	0.001	0.994, 0.998	0.996	0.001	0.994, 0.999	0.996	0.001	0.994, 0.998
Waist to height ratio	0.951	0.013	0.926, 0.976	0.954	0.015	0.925, 0.983	0.952	0.010	0.934, 0.971
Waist circumference	0.916	0.017	0.883, 0.948	0.942	0.014	0.915, 0.969	0.926	0.011	0.904, 0.948

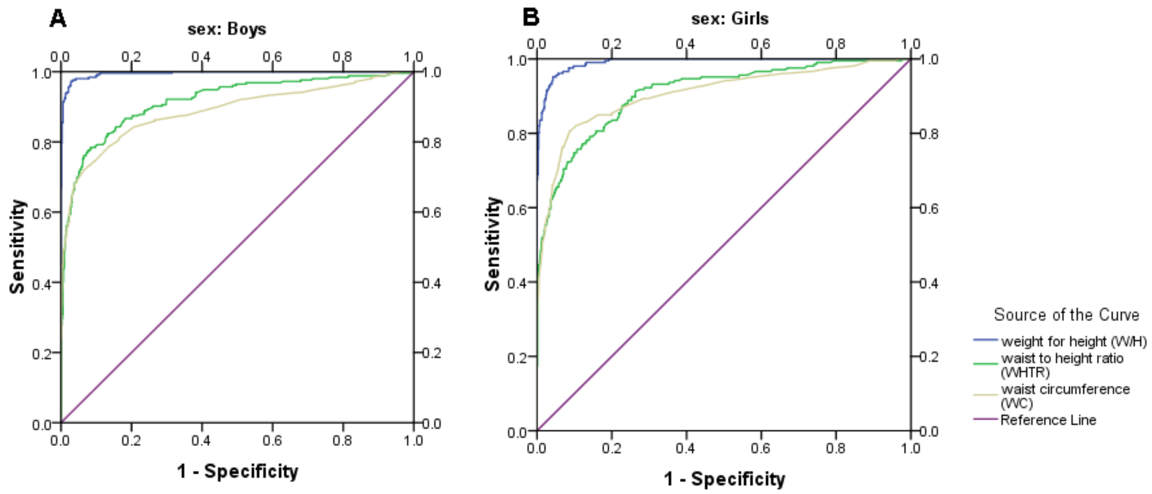

Figure 1: Comparison of 3 smooth ROC curves for defining overweight in boys (1A) and girls (1B)

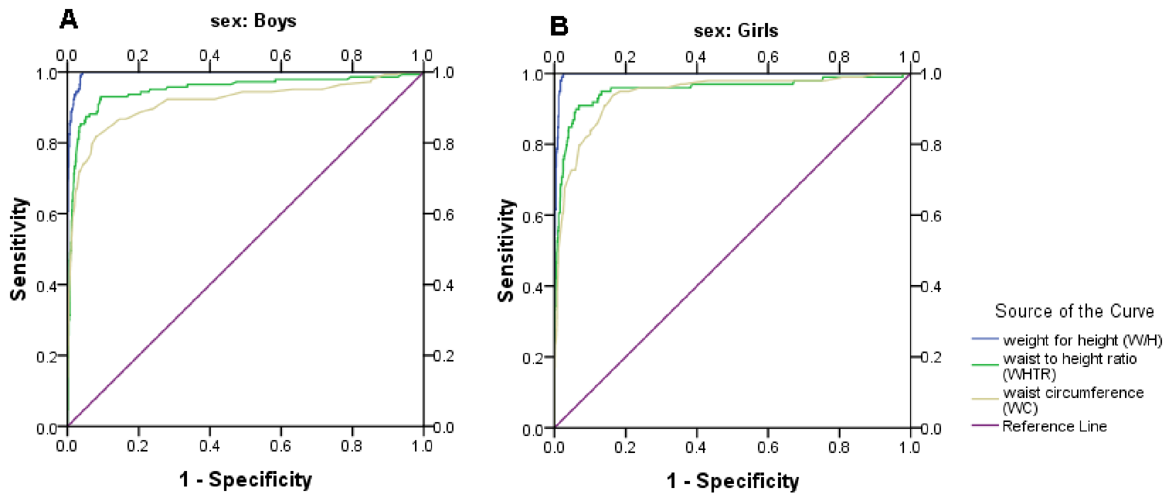

Figure 2: Comparison of 3 smooth ROC curves for defining obesity in boys (2A) and girls (2B)

The optimal cut-off points of WHTR for overweight in both genders were 0.4530 (sensitivity 0.770, specificity 0.950) and the optimal cut-off points for obesity was 0.4678 (sensitivity 0.926, specificity 0.899).

The optimal cut-off points of WC for overweight in both genders were 62.15 (sensitivity 0.757, specificity 0.924) and the optimal cut-off points for obesity was 63.7 (sensitivity 0.864, specificity 0.879).

Table 3: Optimal thresholds, sensitivities and specificities of weight for height, waist to height ratio and waist circumference for the diagnosis of overweight and obesity in Thai schoolchildren aged 6-13 years old

	Index	Boys	Girls	Total
Weight for height	**Overweight**			
	Optimal threshold	112.675	112.978	112.675
	Sensitivity	0.973	0.951	0.963
	Specificity	0.972	0.958	0.962
	Obesity			
	Optimal threshold	125.675	128.692	125.064
	Sensitivity	1.000	1.000	1.000
	Specificity	0.957	0.975	0.995
Waist-to-height ratio	**Overweight**			
	Optimal threshold	0.453	0.453	0.453
	Sensitivity	0.784	0.757	0.770
	Specificity	0.915	0.893	0.905
	Obesity			
	Optimal threshold	0.471	0.478	0.468
	Sensitivity	0.909	0.909	0.926
	Specificity	0.914	0.931	0.899
Waist circumference	**Overweight**			
	Optimal threshold	58.250	62.650	62.150
	Sensitivity	0.812	0.806	0.757
	Specificity	0.835	0.912	0.924
	Obesity			
	Optimal threshold	64.900	62.650	63.700
	Sensitivity	0.818	0.939	0.864
	Specificity	0.920	0.834	0.879

Discussion

The results of this study demonstrate that W/H is a reliable valid measure of overweight and obesity in Thai school-aged children with a very high correlation to the standard measure – BMI-for-age. The high sensitivity and specificity shown in this study for W/H suggest that W/H can be considered as a reliable alternative to BMI-for-age in this population.

Although not a direct measure of body fat, BMI remains the gold standard measure of overweight and obesity. WHO recommends using BMI-for-age in order to assess overweight and obesity in children; however the cut-off points are age and sex dependent. Without having access to specific software, this may make the use of BMI-for-age in practice slightly inconvenient. Therefore, developing other valid measures with acceptable sensitivity and specificity to measure overweight and obesity is important and of clinical use.

One important step in the process of developing a measurement tool is to determine its validity. Validity is the process by which one ensures that the measure is actually measuring what it is expected to measure. One aspect of measurement validation is the assessment of its convergent validity that is the extent to which the new scale is related to other measures that are theoretically measuring the same construct and if available to the gold standard [12]. One method to test the validations of each parameters (W/H, WHTR and WC), is that to test the sensitivity and specificity values of each parameter in comparison with the gold standard (BMI) as we used in this study. Sensitivity and specificity have an inverse relationship to each other in that as sensitivity increases, specificity decreases and vice versa. ROC curve is a visualization of such trade-off between sensitivity and specificity. The use of ROC curve helps researchers to identify cut-off points at which sensitivity and specificity values are optimal[13].

The prevalence of overweight and obesity varies from one country to another and from one age group to another. A large study on prevalence of overweight and obesity in 12 European countries was recently published in which using WHO definitions, the prevalence of overweight in children ranged from 19.3 to 49.0% in boys and from 18.4 to 42.5% in girls[14]. Consistent with our study, Wijnhoven et al. (2012) showed that using WHO definitions, obesity is more prevalent in boys than girls. Variations in the prevalence of childhood overweight and obesity based on different variables such as age-group, race, sex, and country in which the study was done can be seen across many studies [14-17]. Our study however is not primarily aimed at comparing the prevalence of childhood overweight and obesity in Thailand with other countries nor has the power to provide a detailed analysis of all possible subgroups. Further studies are needed to do such comparisons.

In our study, BMI-for-age - the gold standard of obesity and overweight measurement in children - was used as the reference and three potential alternative measures were tested against BMI-for-age. The results of this study shows that using optimal cut-off points, W/H is a highly sensitive and specific measure in Thai school-aged children for the diagnosis of overweight and obesity as defined by WHO BMI-for-age standards. The cut-off point for obesity based on W/H (125.0638% median weight-for-height) in this population is higher than what has often been used as a general guideline (120% median weight-for-height).

WC and WHTR are two other measures that have been studied as measures of body fat in recent years. Weili et al suggests that WHTR is a better index for the diagnosis of overweight and obesity than WC [18]. A WHTR cut-off point of 0.445 for both genders was purposed for the diagnosis of overweight which yielded sensitivity and specificity values of over 0.80. WHTR at 0.485 in boys and 0.475 in girls were also set for the diagnosis of obesity which resulted in sensitivity and specificity values of over 0.90. Similar to a study by Weili, our study also showed that WHTR is a better index to define overweight and obesity in children than WC. Using WHTR cut-off points at 0.453 for a sensitivity of 0.77 and a specificity of 0.90 could be demonstrated. We purpose a cut-off point of 0.47 for WHTR for the diagnosis of obesity in Thai children which can yield sensitivity and specificity values of over 0.90. The difference between the proposed cut-off points and cut-off points introduced by previous studies may be explained by the ethnic differences. While WHTR and WC are known to be acceptable measures of overweight and obesity, our study shows that WC and WHTR have less sensitivity and specificity than W/H to capture overweight and obesity; nevertheless, both still show highly acceptable sensitivity and specificity at optimal cut-off points in this population. The higher accuracy of W/H may be due to the fact that W/H is less varied by age compared to WC and WHTR (R square of W/H= 1.357E-5 to 2.505E-5; of WC=0.113 to 0.144 and of WHTR=0.011 to 0.025).

The fact that BMI and W/H both are calculated from weight and height can very well be the reason for higher correlation of the two. W/H however, may be a more feasible method when compared to BMI-for-age because it is not age dependent. With cut-off points of 112% and 125%, W/H can yield very high sensitivity and specificity values in diagnosing overweight and obesity. W/H is also easy to calculate by using the National standard growth references.

While BMI is widely used to measure overweight and obesity, it is not a perfect measure of the two constructs. BMI is not a direct method of measuring body fat which defines obesity. BMI is also sex-, age- and level of maturity-dependent, it cannot discriminate between fat and fat free mass, and is also affected by leg length.[19] Altogether, these limitations contribute to a debate on validity of BMI as a measure of body fat. This study was designed based on the assumption that BMI is in fact an acceptable measure of body fat; however, one may still argue that less correlation between WC and WHTR with BMI should not be seen as flaws in WC and WHTR; rather, it shows that WC and WHTR are able to capture other aspects of body fat measurement that BMI is unable to address by bringing in another important yet independent factor: waist circumference.

Conclusion

At cut-off points of 112% and 125%, W/H is a valid method of assessing overweight and obesity in Thai school-aged children which has clear clinical implications as well as research implications. Further studies with larger sample sizes and a broader geographical coverage can use the findings of this study as stepping stones and further refine these results.

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Conflict of interest statement

The authors have no conflict of interest to report.

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