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Receiver operating characteristic (ROC) curves to identify waist circumference cut-off points for predicting the overweight and obese school children

Wanphen Wimonpeerapattana[1] *and Uruwan Yamborisut*[2]

[1] *Division of Biostatistics and Computer Service,* [2] *Division of Human Nutrition,*
Institute of Nutrition, Mahidol University at Salaya, Phuttamonthon 4, Nakhon Pathom 73170, Thailand.
* *Correspondent author: wanphen.wim@mahidol.ac.th*

Abstract

Waist Circumference (WC) is used as an anthropometric index for central body fat distribution. Evidence shows that WC is one reliable index to predict abdominal obesity in children but an increased waist circumference is associated with the metabolic syndrome. However, data of WC is less available in Thai children. This study aims to identify WC cut-off points for predicting the overweight and obese school children. Subjects were one hundred and ninety-nine children (105 boys and 94 girls), aged 6-10 years, and were enrolled from primary schools in Nakhon Pathom province and Bangkok. WC was measured at midway between the lowest rib and the iliac crest. Nutritional status of children was categorized using two references; i) Thai Growth reference; using weight-for-height z-score (Thai-WHZ) to define the overweight WHZ >+1.5 SD and the obese WHZ >+2.0 SD, and ii) The International Obesity Task Force (IOTF) reference using body mass index (BMI)-for-age to define the overweight and obese that were equivalent to the adult's BMI of 25 kg/m^2 and 30 kg/m^2, respectively. Receiver operating characteristic (ROC) curves analysis was applied to determine WC cut-offs based on optimal combination of sensitivity (SN) and specificity (SP). Based on Thai-WHZ reference, the optimal WC cut-offs for predicting the overweight were 66.0 cm for boys and 65.5 cm for girls, whereas WC values to indicate the obesity were 67.5 cm for both gender. When IOTF-BMI reference was applied, WC cut-offs for predicting the overweight were 67.5 cm for boy and 65.5 cm for girls, for obese the cut-offs were 74.0 cm for boy and 72.0 cm for girls. For assessment of obesity, cut-offs based on IOTF-BMI reference were considered to be overestimate compared to those cut-offs based on Thai-WHZ reference. Future study needs to determine the relationship of WC and other adverse health outcomes in school-aged children.

Keywords: overweight, obese, waist circumference, Thai children, receiver operating characteristic

1. Introduction

Many studies have reported the risk factors for chronic diseases together with hypertension, diabetes, cardiovascular and cancer that caused by overweight and obese (1-3). The prevalence of overweight and obese has been increasingly in the many development countries include Thailand (4-6). The evidence demonstrated obesity prevalence in Thai children using weight for height criteria increased from 5.8% in 1977 to 6.7% in 2001 for the aged 6-12 year-olds (7-8). Whereas using the same adiposity indices to screen overweight and obese in urban school children increased from 15.1% in 2001 to 16.7% in 2005 (7-8). In the epidemiology studies have to define indicator as a simple measure for identify of overweight and obese, usually the index to classify of obesity often use body mass index (BMI) (9-10) but in Thailand have not yet validated BMI criterion. WC is considered as a simple and reliable to access abdominal adiposity (11-14). Recently, nutritional assessment in Thai children and adolescents were performed using Thai growth reference THAI-WHZ (15) and for the international comparison, the International Obesity Task Force IOTF (16) was applied to determine the magnitude of problem. Some studies have used receiver operating characteristic (ROC) techniques to identify the accuracy of adiposity cut-off points to predict percentage of body fat in children and adolescents (13, 17-18). Two-graph receiver operating characteristic (TG-ROC) analysis was used to examine the performance of WC cut-off points for detecting the overweight and obesity with maximized sensitivity (SN) and specificity (SP) (18-19). However, data of WC of Thai children and adolescents were less available. The objective of this study was to identify WC cut-off points for predicting the overweight and obese by ROC analysis on two references in primary school children.

2. Materials and Methods

2.1 Subjects and sample size

This was a cross-sectional study. Children were recruited from 39 primary schools in Nakhon Pathom province and Bangkok in 2004. Sample size was estimated based on the prevalence of obesity in primary schools children of approximately 4.4% (accepted error at 0.01). Therefore, subjects in this study were 199 school children; 105 boys and 94 girls, aged 6-10 years. They were from primary schools in 9 districts; namely Muaeng, Sampran, Nakhon-Chaisri, Phuttamonthon, Kampangsan, Banglane, Bangkae, Nongkaem and Talingchan. The study was approved by the Committee on Human Rights Related to Human Experimentation, Mahidol University.

2.2 Methods

For each child, body weight was measured using a beam balance scale (weighing capacity 5-150 kg, Soehnle-Waagen Co., Germany) to the nearest 100 g. Height was measured with stadiometer (Stanley-Mabo,France) to the nearest 0.1 cm. WC was measured midpoint between the lowest rib and the iliac crest using non-stretchable tape. Nutritional status of children was categorized using two references; i) Thai Growth reference using weight for height z-score (15, 20) to define THAI-WHZ >+1.5 SD for overweight and THAI-WHZ >+2.0 SD for obese ii) IOTF-BMI criterion used the adult's BMI of 25 kg/m^2 for defining overweight and the BMI of 30 kg/m^2 for obesity at 18-years of age (16).

2.3 Statistical analysis

Descriptive statistics of anthropometric data were computed by mean and standard deviation (SD). The anthropometric variables of boys were compared to that of girls using by t-test. ROC analysis (19) was used to determine WC cut-off points for defining the

overweight and obese by pointing the Y-axis; the sensitivity (true-positive value) against the X-axis; the 1- specificity (false-positive value) and a perfect test was shown when SN and SP closest to 1. The areas under the curve (AUC) were estimated by point and 95% confident interval (95% CI) which of 0.5 shows is not good discriminates, the values of 1 the represents is a perfect discriminate. Wald tests were performed to compare the areas under the curve between national and international growth references. Positive predictive value (PPV) indicates the probability of children who become overweight or obese when the test results are positive and the negative predictive value (NPV) indicates the probability of children who are non-overweight or non-obese when the test results are negative. Two-graph receiver operating characteristic (TG-ROC) were constructed to determine WC cut-off points (d_0) to predict overweight and obese which corresponded to the intersection between SN and SP curve which is at maximum as equal (Θ_0) (21-23). The statistical analysis was performed using Statistical Package for Social Science (SPSS, version 18, SPSS Inc., Chicago, IL, USA). TG-ROC was built in Microsoft-Excel program.

3. Results and Discussion

3.1 Results

The anthropometric characteristics (Table 1) presented mean and standard deviation of weight (kg), height (cm), weight for height z-score, body mass index (kg/m^2) and waist circumference (cm). There were slightly higher in boys than in girls. Compared the anthropometric data between boys and girls shown statistically significant different ($p<0.01$), except for height was not significant.

Table 1. The anthropometric data of primary schools children in aged 6-10 years

Anthropometric data	Boys	Girls	P-value
No. of subjects (%)	105 (52.8)	94 (47.2)	
Age (y)	8.2 $\pm$ 1.1	8.3 $\pm$ 1.0	0.518
Weight (kg)	36.8 $\pm$ 13.0	32.0 $\pm$ 12.1	0.008*
Height (cm)	130.2 $\pm$ 8.9	127.8 $\pm$ 8.5	0.056
Weight for height z-score	1.9 $\pm$ 2.5	1.0 $\pm$ 2.2	0.007*
Body mass index (kg/m^2)	21.3 $\pm$ 5.9	19.1 $\pm$ 5.5	0.009*
Waist circumference (cm)	70.6 $\pm$ 15.3	63.8 $\pm$ 13.4	0.001*

All value were mean $\pm$ standard deviation

* Significant mean difference compared with boy, by t-test ($p<0.01$).

The ROC curves analysis (Table 2) showed WC cut-off points for the optimal discrimination of overweight and obese bases on references for classily nutritional status in primary school children. The AUC for two references closed to 1 and there was no statistically significant difference between Thai growth reference and IOTF reference ($p > 0.05$) of overweight for both boys and girls. While obese was significant difference among IOTF reference with Thai growth reference ($p < 0.05$) in boys. According to ROC curves, WC cut-off points were equally maximal SN and SP. Based on Thai Growth reference indicate overweight

(THAI-WHZ >+1.5 SD) was as a positive reference test, the optimal WC cut-offs points for predicting the overweight children were 66.0 cm for boys (AUC 0.999; 95% CI 0.997 to 1.001; SN/SP 97.5%) and 65.5 cm for girls (AUC 1.000; 95% CI 1.000 to 1.000; SN/SP 99.9%). WC cut-offs to predicting the obese (THAI-WHZ >+2.0 SD) were 67.5 cm for both boys and girls (boys; AUC 0.996; 95% CI 0.987 to 1.004; SN/SP 97.5%, girls; AUC 0.981; 95% CI 0.953 to 1.008; SN/SP 96.5%). When IOTF-BMI criterion were equivalent to the adult's BMI of 25 kg/m^2 as a positive screening test for overweight, WC cut-offs points were 67.5 cm for boys (AUC 0.995; 95% CI 0.986 to 1.003; SN/SP 94.0%) and 65.5 cm for girls (AUC 1.000; 95% CI 1.000 to 1.000; SN/SP 99.9%). Whereas IOTF-BMI of 30 kg/m^2 defined a positive screening for obese WC cut-offs points were 74.0 cm for boys (AUC 0.953; 95% CI 0.913 to 0.992; SN/SP 86.0%) and 72.0 cm for girls (AUC 0.980; 95% CI 0.959 to 1.000; SN/SP 90.0%). As well as PPV and NPV were around 85% to 100%, on the order hand the prevalence percent of overweight and obese ranged from 56.2% to 64.8% for boys whereas was 37.2% to 46.8% for girls.

Table 2. Waist circumference (WC) cut-off points for predicting overweight and obese in primary school children.

Nutrition Status	AUC[a] (95% CI)	Cut-off[b] WC (cm)	SN[c] / SP[d] (%)	PPV[e] (%)	NPV[f] (%)	Prevalence (%)
Boys						
Overweight						
Thai reference WHZ >+1.5 SD	0.999 (0.997-1.001)	66.0	97.5	98.5	94.7	64.8
IOTF reference BMI $\geq$ 25 kg/m^2	0.995 (0.986-1.003)	67.5	94.0	96.9	90.0	63.8
Obese						
Thai reference WHZ >+2 SD	0.996 (0.987-1.004)*	67.5	97.5	98.5	95.0	62.9
IOTF reference BMI $\geq$ 30 kg/m^2	0.953 (0.913-0.992)*	74.0	86.0	89.5	83.0	56.2
Girls						
Overweight						
Thai reference WHZ >+1.5 SD	1.000 (1.000-1.000)	65.5	99.9	100.0	100.0	46.8
IOTF reference BMI $\geq$ 25 kg/m^2	1.000 (1.000-1.000)	65.5	99.9	100.0	100.0	46.8
Obese						
Thai reference WHZ >+2 SD	0.981 (0.953-1.008)	67.5	96.5	95.2	98.1	43.6
IOTF reference BMI $\geq$ 30 kg/m^2	0.980 (0.959-1.000)	72.0	90.0	84.2	94.6	37.2

[a] AUC: Area under the curve ; 95% confidence intervals were given within parentheses,

* Value in AUC was denoted with same superscript letters were significantly difference two references at $p<0.05$ by Wald test.

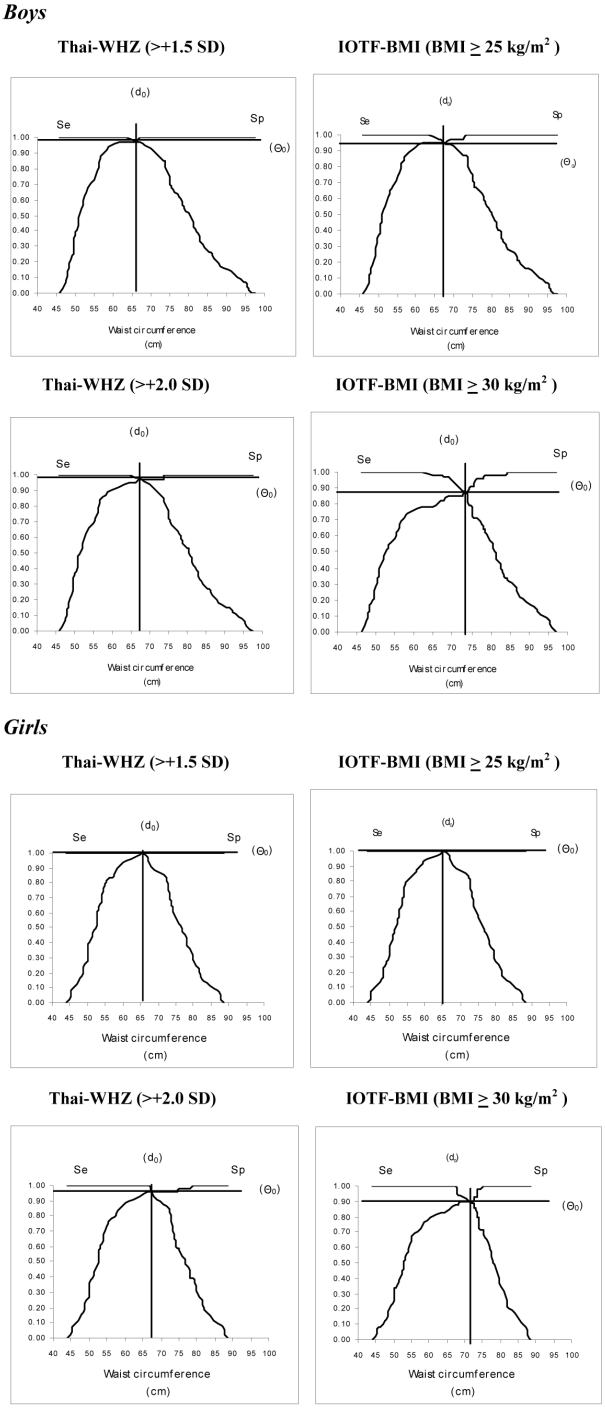
[b] Cut-off points for WC equal values of sensitivity and specificity,

[c] Sensitivity (SN) = true positive rate [d] Specificity (SP) = 1-false positive rate,

[e] Positive predictive value (PPV), [f] Negative predictive value (NPV)

TG-ROC curves (Figure 1) plotted to observe cut-off points for WC that the estimate to identify overweight and obese (d_0) and intersections (Θ_0) value in each graph get level ranged from 90.0% to 99.9% for SN/SP, But IOTF-BMI reference for obese had only 86.0% for boys.

Figure 1. Two-graph receiver operating characteristic (TG-ROC) curves for waist circumference (WC) cut-off points the overweight and obese in primary school children.



3.2 Discussion

The results of this study demonstrated that the WC can be used to predict the overweight and obese in primary school children as indicated by the high sensitivity and high specificity values. This was consistent with previous studies (12-13, 24). The assessment of overweight children, the cut-off points for WC based on two references was not significantly different. For obese children, the cut-off points based on IOTF-BMI reference was considered to be overestimated in boys when compared to cut-offs based on Thai-WHZ reference. This implied that the use of IOTF-BMI reference provide the late detection of the obese children, particularly among boys.

The WC cut-off points demonstrated a high PPV, this identify that these cut-off points could accurately predict the overweight and obese. While the high NPV could be effectively screened out signify the non-overweight and non-obese. The AUC estimated all most the areas reached to 1 and the narrowest for 95% CI, hence the present is a good discriminate power to detect in overweight and obese (25).

Regarding the diagnostic test using TG-ROC curves identified WC cut-off points with the maximum sensitivity and specificity for detecting overweight and obese children. The advantage of TG-ROC could help to determine the intersection of maximum sensitivity and specificity values for WC cut-offs (21-23). Thus TG-ROC curve helps the study to identify cut-off points at which sensitivity and specificity values are maximized (25).

WC is considered as one reliable anthropometric index for screening the overweight and obesity in primary school children. It is recommended that age and gender-specific WC reference for each country should be established and that WC cut-offs should be validated against other health outcomes. Additional study needs to determine the association between the increased WC and total body fat in children (17).

4. Conclusion

Waist circumference is considered as a simple anthropometric index for assessment abdominal obesity in school children. It is recommended that waist circumference should be used as another anthropometric indicator in nutrition surveillance system. Future study needs to determine the relationship of WC and other adverse health outcomes in school-aged children.

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