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Waist circumference and body fat distribution indexes as screening tools for the overweight and obesity in Thai preschool children

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KEYWORDS
Preschool children;
Thai;
Waist circumference;
Body mass index;
Total body fat;
Trunk skinfold

Summary
Background: Evidence shows that waist circumference (WC) is one reliable index to predict abdominal obesity in children. This study aims to examine the relationship of WC to other anthropometric indexes and to determine the ability of WC as obesity screening tool.
Subjects: 811, 5—6 years old children in Saraburi province, central region of Thailand.
Methods: Anthropometric measurements were performed in children; 406 boys and 405 girls. WC measurement was performed at the umbilicus level. Subcutaneous skinfold was measured on subscapular, suprailiac and abdominal regions. Total body fat was measured with bioelectrical impedance analyzer. Receiver operating characteristic (ROC) analysis was employed to determine WC cut-offs for predicting obesity in children.
Results: WC highly correlated with weight-for-height Z-score (WHZ) (r = 0.92—0.94, p = 0.01), body mass index (BMI) (r = 0.95—0.96, p = 0.01), trunk skinfold (r = 0.92—0.93, p = 0.01) and total body fat (r = 0.94—0.95, p = 0.01) for both genders. Based on Thai national reference, the optimal WC cut-offs for predicting obesity were 59.6 cm for boys and 60.5 cm for girls. When IOTF-BMI was employed as reference, WC thresholds were 64.4 cm for boys and 63.1 cm for girls. The latter WC cut-offs provided the slightly underestimated obesity prevalence compared with national reference.

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Conclusion: The strongly positive correlation between WC and weight—height based index and between WC and body fat in Thai preschool children suggests that WC should be the additional index for obesity screening in young children. Further study needs to explore the association between the increased WC and other adverse health outcomes.
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Introduction

Childhood overweight and obesity is known to be a critical public health problem due to the alarming prevalence rate in many countries [1,2]. Children who are obese will become great risk for developing of diabetes, dyslipidemia hypertension and cardiovascular disease in later life [3,4]. Studies also indicated that excess intra-abdominal obesity [IAAT] is associated with the increase in cardiovascular risk factors in children and adolescents [5—7]. The IAAT could be directly quantified using computed tomography [CT] and magnetic resonance imaging [MRI] which are considered as reference methods. However, such methods could not be practically applied for a large scale child population due to high cost and radiation exposure from CT. Attempts have been done to assess body fat distribution of children using simple and reliable anthropometric indexes. Studies have investigated the usefulness of waist circumference [WC] as an alternative index for abdominal obesity as that increase in WC predicts the risk for insulin resistance, adverse lipid profiles, high blood pressure and metabolic syndrome in children and adolescents [8—11]. WC, in addition, is found to be strongly associated with trunk and total body fat [12,13]. Biological factors that influence WC values in children include ethnicity, gender and pubertal development. Generally, WC value increase with age and boys tend to have greater WC than girls [14]. Results from one study suggested that the use of combination of WC and body mass index [BMI] provided more information regarding health risk than by BMI alone [15] for example; the overweight children with high WC would be 2 times more likely to have adverse lipid profiles and high insulin levels compared with the overweight children with low WC. While the waist-to-hip ratio [WHR] has been demonstrated as the reliable predictor of health-related measure in adults, this ratio index was poor proxy for central fatness in pre-pubertal children and adolescents [16,17]. Recently, the waist-to-height [WHtR] ratio has been proposed as another simple index to identify abdominal obesity and that WHtR value of $\geq$0.5 was applied for adults and children aged 5 years upwards [18]. This cut-off value was found to be strongly associated with cardiovascular risk factors [19—21]. Furthermore, the evidence showed that subcutaneous skinfold in some specific body surface areas was positively correlated with IAAT in children. Previous study in pre-pubertal children indicated positive correlation between subcutaneous abdominal skinfold and IAAT ($r = 0.88$) and between WC and subcutaneous abdominal adipose tissue (SAAT) ($R = 0.93$) assessed by CT [22].

It is known that rapid growth, particularly high weight gain during early childhood could predispose to the development of obesity and fat deposition on trunk region is strongly associated with adverse health outcomes. The characteristic of fat distribution is relatively complex because change in anthropometric index value is affected by ethnicity, gender difference and the pubertal development.

In Thailand, 2006, the National Statistical Office conducted nutrition survey in 9404 children aged under five from 26 provinces and indicated that proportion of obesity in children was 7.0% for boys and 6.7% for girls, based on Thai national reference [23]. Since data of waist circumference and body fat distribution index for Thai children is less available, therefore, this study aims [a] to determine the relationship of waist circumference to weight—height based indexes, trunk skinfold and total body fat in Thai preschool children. [b] To compare the ability of waist circumference and various fat distribution indices measured by simple anthropometry as obesity screening tools and [c] to determine waist circumference cut-off points correlated with the existing weight-for-height and body mass index-for-age reference.

Subjects and methods

Study area

Saraburi is one province located in the central part of Thailand and is 113 km away from Bangkok. The provincial area covers 3576 squared kilometers with approximately total 605,701 inhabitants. Approxi-

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mately 98% of inhabitants are Buddhist. The study was conducted during July—September 2008. Two-stage stratified sampling technique was employed to recruit target children. Approximately 30% of total 13 districts in Saraburi province was sampled and the districts namely; Mueang, Phra Phuttabat, Kaeng Khoi and Nong Khae were included in this study. The primary schools were then randomly sampled from each district as target schools.

Subjects

Subjects were preschool children whose families were residing in the municipal areas of Saraburi province. Children aged 5—6 years and were studying in the kindergartens grade 1 and 2 of nine schools located in four districts. Children who were under-or over-nutrition resulting from pathological disease were excluded from the study.

Methods

The researchers sent the formal letter to both school directors and children's parent for asking permission. Written consent forms were also obtained from all parents. The study design was approved by the Mahidol University Institutional Review Board (MU-IRB) (COA. No. MU-IRB 2008/050.1507). On the school day, anthropometric measurements were performed on subjects by the same researcher throughout the study. For each child, subject with light-clothing and bare feet stood over the center of platform of weighing scale. Body weight was measured using digital weighing scale (CAMRY®; Model EB-6571, Nanjing; capacity of 0—150 kg) to the nearest 100 g. To obtain the reliable data, the weighing balance was calibrated with standard weight before measurement. Standing height was measured with stadiometer (Stanley-Mabo, France). Each subject stood without shoes and the hand positioned such that Frankfurt plane; a plane passing through the lower edge of the orbit and the upper margin of ear canal was horizontal, feet together, buttocks and shoulders in contact with the wall. The head-bar of stadiometer was lowered and attached the crown of subject's head. The height was measured to the nearest 0.1 cm. Body mass index (BMI) was calculated as body weight (kg) divided by height squared (m^2). Measurement of mid-upper arm circumference (MAC) was done using inelastic tape placed on the midway between spinous process of scapular and the tip of olecranon process of elbow. The tape was positioned perpendicular to the long axis of the arm at the marked mid-point and arm circumference value was recorded to the nearest 0.1 cm. WC was performed using an inelastic tape positioned horizontally at the umbilicus level. Hip circumference was measured at the level yielding the maximum circumference over the buttocks. Measurement of WC and hip circumference were to the nearest 0.1 cm. Weight-to-hip ratio (WHR) was calculated by waist circumference divided by hip circumference value and weight-to-height ratio (WHtR) by waist circumference divided by height value. Subcutaneous skinfold thickness was measured using skinfold calipers (Holtain, Crymych, UK.) to the nearest 0.2 mm. Subscapular skinfold was measured 1 cm inferior to the inferior angle of the scapular. Suprailiac skinfold was measured immediately superior to the iliac crest as the oblique skinfold. The abdominal skinfold site was at 3 cm lateral to the mid-point of the umbilicus and 1 cm inferior to it. All skinfold measurements were taken in duplicate and the average value was used as the data. Body fat measurement was performed using tetrapolar bioelectrical impedance analyzer (Tanita®; Inner Scan, Model BC-545, Tokyo, Japan). Measurement was initially done by entering the information of birth date, gender and height of each child in the software program of the instrument. After stepping on the platform, subject was instructed to hold the electrodes with both hand grips and arms straight down for ½—1 min until the total body fat was determined.

Categorization of child's nutritional status

Nutritional status of each child was categorized using weight-for height *Z*-score (WHZ), Thai national reference [24]. An obese child was defined as WHZ > +2SD, overweight by WHZ > +1.5SD to +2SD, normal weight by WHZ between −1.5 SD and +1.5 SD of median of growth reference. Nutritional status of children were also categorized using IOTF-BMI criteria and that the overweight and obesity were defined by gender specific BMI for age values that pass through adult BMI of $\geq$25 kg/m^2 and BMI of $\geq$30 kg/m^2, respectively [25].

Statistical analysis

All anthropometric data were analyzed using Statistical Package for Social Science (SPSS version 17, Chicago, IL, USA). Descriptive statistics of anthropometric variables of the subjects were computed as mean ± standard deviation (SD). Significant mean difference between boys and girls in anthropometric variables was compared using Student's *t*-test. The relationship between waist circumference and other anthropometric indexes was analyzed using Pearson correlation coefficient. Receiver operating

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Table 1 Anthropometric characteristic of Thai preschool children.

Anthropometric index	Boys	Girls
No. of subjects	406	405
Age (years)	5.5 ± 0.4	5.6 ± 0.4
Weight (kg)	20.4 ± 4.9	19.8 ± 5.3
Height (cm)	111.9 ± 5.3	111.4 ± 5.6
Thai WHZ	0.33 ± 1.7	0.13 ± 1.5
No. of obese children by Thai WHZ *n* (%)	60 (14.8)	38 (9.4%)
BMI (kg/m^2)	16.2 ± 2.9	15.7 ± 2.8*
No. of obese children by IOTF-BMI *n* (%)	48 (11.8)	36 (8.9)
Mid-upper arm circumference (cm)	17.5 ± 2.6	17.2 ± 2.6
Waist circumference (cm)	54.2 ± 7.6	53.8 ± 7.4
Hip circumference (cm)	57.3 ± 6.5	57.3 ± 6.6
WHR	0.94 ± 0.04	0.94 ± 0.04
WHtR	0.48 ± 0.06	0.48 ± 0.05
Trunk skinfolds (mm)[a]	19.4 ± 12.5	20.8 ± 11.4
% Total body fat	14.0 ± 8.2	14.4 ± 6.4

Values were mean ± SD. Obese child was defined by Thai weight-for-height Z-score (WHZ) > +2SD and by IOTF-BMI ≥ 30 kg/m^2. WHR = waist-to-hip ratio, WHtR = waist-to-height ratio.
[a] Trunk skinfold = sum of subscacpular, suprailiac and abdominal skinfolds.
* Significant mean difference from boys at $p < 0.05$.

characteristics (ROC) curve was applied to determine the ability of WC and various anthropometric indexes as screening tools for the overweight and obesity in children. The area under curve (AUC) with 95% confidence interval (CI) values provided the indication of how performance of anthropometric indexes as the predictors of health risk. The proposed WC cut-offs defining child's nutritional status was derived based on the optimal sensitivity (the true-positive rate) and specificity (the true negative rate) values.

Results

Data on anthropometric indexes and total body fat were completed for 811 children; 406 boys and 405 girls. The anthropometric characteristics of subjects are shown in Table 1. The mean age of children were 5.5 ± 0.4 years for boys and 5.6 ± 0.4 years for girls. The mean value for body weight, height, WHZ were similar in both gender except for mean BMI of girls that was slightly lower than that of boys ($p < 0.05$). There was no significant mean difference in arm circumference, WC, hip circumference and WHtR between boys and girls. Mean trunk skinfold defined by sums of subscapulr, suprailiac and abdominal skinfolds of girls were not different from that of boys. Mean percentage total body fat of girls was also similar to that of boys.

Table 2 shows the relationship of WC to other anthropometric indexes. Results indicated that WC strongly positive correlated with body weight, WHZ, BMI, mid-upper arm circumference, hip circumference, trunk skinfolds and percentage total body fat for both genders.

Table 3 presents mean AUC values of WC and various body fat distribution indexes categorized by Thai national reference. Results showed that WC, WHtR and trunk skinfold provided higher AUC values than WHR indicator for boys and girls. Similarly, using IOTF-BMI as criteria, it was found that WC, WHtR and trunk skinfold indexes also provided the greater AUC values compared with that of WHR. The determination of WC cut-offs were performed using ROC analysis. Table 4 demonstrates that, when defining the overweight child

Table 2 Pearson correlation coefficient between waist circumference and other anthropometric variables.

Variables	Waist circumference	
	Boys (*n* = 406)	Girls (*n* = 405)
Weight	0.961*	0.964*
WHZ	0.941*	0.922*
BMI	0.961*	0.956*
Mid-upper arm circumference	0.925*	0.943*
Hip circumference	0.953*	0.951*
Trunk skinfold[a]	0.930*	0.922*
%Total body fat	0.955*	0.940*

WHZ = weight-for-height Z-score, BMI = body mass index.
[a] Trunk skinfold = sum of subscapular, suprailiac and abdominal skinfolds.
* Significant at $p = 0.01$.

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Table 3 The area under curve (AUC) values of various anthropometric indexes for overweight and obesity screening in preschool children.

References	Anthropometric index	Boys (n = 406) AUC[a] (95% CI)[b]	Girls (n = 405) AUC[a] (95% CI)[b]
Thai WHZ > +1.5SD			
	Waist circumference	0.995 (0.990–0.999)	0.990 (0.981–1.000)
	WHR	0.856 (0.807–0.904)	0.803 (0.736–0.871)
	WHtR	0.995 (0.991–1.000)	0.990 (0.976–1.000)
	Trunk skinfold	0.993 (0.988–0.998)	0.994 (0.989–0.999)
Thai WHZ > +2SD			
	Waist circumference	0.992 (0.986–0.999)	0.994 (0.988–1.000)
	WHR	0.899 (0.855–0.943)	0.801 (0.720–0.883)
	WHtR	0.997 (0.993–1.000)	0.995 (0.990–1.000)
	Trunk skinfold	0.993 (0.987–0.998)	0.990 (0.981–0.999)
IOTF-BMI ≥ 25			
	Waist circumference	0.992 (0.987–0.998)	0.988 (0.978–0.997)
	WHR	0.823 (0.771–0.875)	0.786 (0.725–0.848)
	WHtR	0.989 (0.981–0.997)	0.988 (0.977–0.999)
	Trunk skinfold	0.987 (0.976–0.998)	0.981 (0.966–0.997)
IOTF-BMI ≥ 30			
	Waist circumference	0.998 (0.996–1.000)	0.996 (0.991–1.002)
	WHR	0.930 (0.900–0.961)	0.821 (0.743–0.900)
	WHtR	0.995 (0.991–0.999)	0.996 (0.992–1.000)
	Trunk skinfold	0.995 (0.990–1.000)	0.996 (0.992–1.000)

WHR = waist-to-hip ratio, WHtR = waist-to-height ratio. Trunk skinfold = sum of subscapular, suprailiac and abdominal skinfolds.
[a] Area under the curve.
[b] 95% Confidence interval.

by WHZ > +1.5SD, Thai reference, the proposed WC cut-offs were 57.9 cm for boys and 58.3 cm for girls. WC threshold increased to 59.6 cm for boys and to 60.5 cm for girls to predict obesity as defined by WHZ > +2SD. When the IOTF-BMI was employed as reference, WC cut-off points to detect the overweight child were 57.1 cm for boys and 56.3 cm for girls. For defining the obese child, WC thresholds increased to 64.4 cm for boys and 63.1 cm for girls. The higher boundary of WC based on IOTF-BMI

Table 4 Proposed waist circumference cut-offs for the overweight and obesity screening in children defined by Thai national reference and IOTF-BMI reference.

Criteria	AUC[a] (95%CI)	Proposed WC cut-off[b] (cm)	WC percentile threshold	Sensitivity[c] (%)	Specificity[d] (%)	Total body fat (%)	Prevalence (%)
Overweight by Thai WHZ > +1.5SD							
Boys	0.995 (0.990–0.999)	57.9	78.5	98.7	96.4	17.9	18.7
Girls	0.990 (0.981–1.000)	58.3	82.0	98.2	95.1	17.6	14.1
Obesity by Thai WHZ > +2SD							
Boys	0.992 (0.986–0.999)	59.6	82.2	96.7	96.0	20.4	14.8
Girls	0.994 (0.988–1.000)	60.5	87.0	97.4	95.9	19.8	9.4
Overweight by IOTF-BMI 25 kg/m^2							
Boys	0.992 (0.987–0.998)	57.1	76.8	95.3	96.2	16.9	21.2
Girls	0.988 (0.978–0.997)	56.3	77.0	97.2	92.8	16.6	17.5
Obesity by IOTF-BMI 30 kg/m^2							
Boys	0.998 (0.996–1.001)	64.4	87.2	97.9	98.9	23.8	11.8
Girls	0.996 (0.991–1.002)	63.1	89.5	94.4	97.8	22.2	8.9

[a] AUC: Area under curve indicated the probability that a child who was overweight or obese had waist circumference value greater than indicated WC cut-off points.; 95% confidence intervals were given within parentheses.
[b] Cut-off point producing equal values of sensitivity and specificity.
[c] Sensitivity = True positive rate.
[d] Specificity = True negative rate.

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compared with WC cut-offs derived from Thai reference, led to the underestimation of prevalence of obesity in children.

Discussion

Obesity is an alarming public health problem among Thai children and adolescents. Our study explores the performance of waist circumference and other body fat distribution indexes as the obesity screening tools for Thai preschool children. Results show that WC and WHtR were the better indicators than WHR for child screening. Regarding the effect of gender, our results from Table 1 reveal no significant difference in mean percentage total body fat between boys and girls of this age group. Study by Malina et al. [26] demonstrated that gender difference in fat mass is negligible before 5–6 years old, but after that there will be the increasing body fat in both genders and girls tend to have more total body fat than boys.

The strongly positive correlation found between WC and WHZ, BMI, trunk skinfold and between WC and total body fat in children suggested that WC could be one useful indicator for defining obesity problem. The correlation between WC and IAAT was not determined in this study as because we did not directly measure IAAT of children using advanced technique. However, significantly positive correlation between WC and trunk skinfold was found suggesting that trunk skinfold would reflect the accumulation of abdominal adiposity and this should be further investigated. Goran et al. [22] study in children aged 4–10 y demonstrated that abdominal skinfold was highly correlated with IAAT [$r = 0.88$] assessed by CT and results from multiple regression showed that, in the absence of trunk fat data by dual-energy X-ray absorptiometry [DEXA], IAAT could be best predicted by abdominal skinfold, subscapular skinfold and ethnicity [$R^2 = 0.82$]

Given findings from our results from ROC analysis, Table 3 indicated that AUC derived from WC was comparable to that of WHtR and trunk skinfolds and the AUC values of these indexes were higher than that of WHR. The work done by Taylor et al. [17] denoted the higher performance of WC as the predictor for trunk fat with AUC value of 0.97 in both genders of 3–19 y children when compared with conicity index and WHR. For our study, we could not evaluate trunk fat of children using simple bioelectrical impedance analyzer except for percentage of total body fat which gave the strong correlation with WC index. Generally, total body fat mass is one determinant of visceral adipose tissue but it is unclear on whether increasing total body fat was related to the increasing visceral or subcutaneous adipose tissue in children [27]. Since WC measurement in combination of height will correct the effect of height on WC, WHtR would provide the advantage in case that the same boundary value of 0.5, has been defined as the cut-off applied across various children age groups [28,29].

Results from Table 4 show the ability of different purposed WC cut-offs derived from maximum AUC values with combination of the optimal sensitivity and specificity. To define the overweight children, it was found that WC cut-off values, based on Thai national reference, were greater than WC values derived from IOTF-BMI 25 reference. This contributed to the slightly lower estimation of prevalence of the overweight children from our national reference. To define the obese children based on Thai reference, the WC cut-off values were lower than WC values categorized by IOTF-BMI 30 in both genders, thereby leading to the higher estimation of prevalence of the obese children. This findings have been subjected to discuss that WC cut-points would vary based on difference in anthropometric reference which in turn could reflect the different magnitude of problem. Study by Fu et al. [30] in Singapore Chinese pre-pubertal children also demonstrated the lower sensitivity of IOTF-BMI cut-offs criteria than by national reference for defining prevalence of childhood obesity. Studies in several countries have proposed different WC cut-off points in children and adolescents. Freedman et al. [31] showed that WC corresponding to 90th percentile; 59–61 cm for boys and 57–64 cm for girls whose aged ranged between 5 and 7 years predicted the high concentration of LDL-cholesterol, triglycerides and insulin. Higgins et al. [32] found children aged 4–11 years with $\geq$33% body fat and children with WC $\geq$ 71 cm were likely to have more cardiovascular risk factors. Study in Hong Kong Chinese, 6–12 years old children, revealed that WC corresponding to 85th percentile value; 58–76 cm for boys and 57–71 cm for girls, predicted high levels of insulin, lipid profiles and blood pressure [33]. Our results showed that, when applying our national reference, the predicting WC of 59.6 cm for boys and 60.5 cm for girls were derived and these values were corresponding to total body fat of 20.4% and 19.8%, respectively. Alternatively, when IOTF-BMI30 was set as reference, the WC cut-offs were 64.4 cm that was corresponding to body fat of 23.8% for boys and 63.1 cm that was corresponding to body fat of 22.2% for girls. These amounts of body fat of obese children were relatively high and positioned in the rank of >85th percentile of this population.

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The limitation of our study was that we had no biochemical data, thereby, whether these body fat of children were associated with other adverse health consequences have yet to be further determined. Previous studies have reported the relationship of total body fat to adverse health outcomes in children and adolescents. Washino et al. [34] study in 9 and 10 years old Japanese children demonstrated the amount body fat of 23% measured by bioelectrical impedance analyzer was associated with high ratio of total cholesterol to HDL-cholesterol. Study in Caucasian children, 4–11 year old, indicated the body fat of 33% as determined by DEXA [32] and body fat of 25% for boys and 35% for girls determined by sum of skinfolds in another study predicted the adverse lipid profiles and elevated blood pressure [35].

Even though body weight is one simple indicator for fatness, children of the same age but having different height could have wide variation of adiposity. The limitation of weight–height based reference is that it reflects both fat mass and fat free mass components of body weight. The child who has high body weight accompanied by a large lean mass may be misclassified as obese child. Additional concern is that BMI is influenced by child's age, gender difference and ethnicity. One study in 4175, 7-year-old children showed marked difference in sensitivity of IOTF-BMI in defining the problem and that low sensitivity for obesity cut-off was detected in boys, only 46%, compared with 72% for girls [36]. The influence of ethnicity on BMI was shown in one study that white children had more body fat than black children even though the same BMI [37].

Conclusion

This study demonstrated the usefulness of WC as one screening tool for defining obesity in Thai young children. Measurement of WC could be easily performed and measurement of WC in addition to body weight and height index could provide more meaningful information in terms of adiposity in children. Future study needs to investigate the association of waist circumference cut-offs and other adverse health outcomes in this child population.

Conflict of interest

The authors declare that they have no ownership of beneficial interest of any kind and any product or service that could influence the position presented in article.

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