Association Between Waist Circumference and Percentage Body Fat among Rural Thais

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Objective: *Determine the association between waist circumference (WC) and percentage body fat (%BF) and to develop cut-off values and evaluate the accuracy of WC in the definition of obesity in rural Thai population.*
Material and Method: *A cross-sectional, epidemiologic study in 181 men and 255 women aged 50 $\pm$ 16 yr (mean $\pm$ SD; range: 20-84 yr) sampled by stratified clustering sampling method, was designed. Percentage body fat was measured by dual energy X-ray absorptiometry (GE Lunar Corp, Madison, WI). The "golden standard" for defining obesity was%BF $\geq$ 25 in men and%BF $\geq$ 35 in women. Waist circumference in centimeter was measured.*
Results: *In this study, the %BF-based prevalence of obesity in men and women was 8.3% and 44%, respectively. However, using the WC cut-off (WHO) of 102 cm in men and 88 cm in women, only 1.7% of men and 24% of women were classified as obese. WC was a significant predictor of %BF, such that in men, a WC of 93 cm would predict a %BF of 25%, and in women a WC of 84 cm would correspond to a %BF of 35%. The area under the receiver operating characteristic curve was 0.87 and 0.88 in men and women, respectively. In conclusion, waist circumference is a reasonably useful indicator of obesity.*
Conclusion: *The cut-off values of WC for diagnosing obesity should be lower in Thailand than in Western countries.*

Keywords: *Obesity, Waist circumference, Percentage body fat, Rural, Thailand*

J Med Assoc Thai 2006; 89 (10): 1592-600
Full text. e-Journal: *http://www.medassocthai.org/journal*

The prevalence of obesity in both developed and developing countries has risen dramatically posing a threat to public health[1]. Obesity is a complex multifactorial condition characterized by excess body fat and requires on-going care, support, and follow-up. Obesity is associated with diabetes mellitus, hypertension, cardiovascular disease, gall bladder disease, and some types of cancer[2-6]. The increased health risk associated with obesity is a global problem imposing a heavy burden on the health care system and lowering the quality of life for the obese.

Most studies use body mass index (BMI) when evaluating the health effect and mortality associated with obesity[7-11]; however, the measurement of waist circumference (WC) alone may reflect the abdominal fat mass[12] and may indicate a need for weight management[13]. Years ago, WC alone or BMI and WC in combination was implemented in guidelines for the assessment and treatment of overweight and obesity in adults[14,15]. Thus, WC has been suggested as a simple clinical alternative to BMI for detecting adults with possible health risks due to obesity[16].

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In Western populations, the WC cut-off value for defining central obesity is 102 cm in men and 88 cm in women, which is associated with metabolic syndrome[16-18]. However, it seems that the Caucasian-based cut-off value is not necessarily applicable to Asian populations[18,19], Therefore, we investigated the appropriateness of the WHO anthropometric standards for assessing the prevalence of obesity in the rural, adult, Thai population compared with the measured value of body composition, to determine the relationship between WC and %BF and finally to determine the optimal WC cut-offs for defining obesity in Thais.

Material and Method

Setting and Study design

The study was designed as a cross-sectional community-based investigation. The setting was Khon Kaen province, a predominantly rural region located 445 km northeast of Bangkok, Thailand. The sampling technique has been described previously[20]. Briefly, subjects were recruited from 14 hamlets within two villages in Muang district of the Khon Kaen province. In each hamlet, a full list of subjects was obtained, from which 10 subjects were randomly selected by the village's administrator. We excluded participants with a history of recent acute illness (*e.g.* myocardial infarction or pneumonia), chronic conditions (*e.g.* cancer, chronic infection, collagen vascular disease, hepatic or renal impairment, diabetes), history taking of medication affecting body weight (*e.g.* thyroid hormone, prednisolone, diuretics) or involvement in weight training. The study was formally approved by the Ethics Committee of Khon Kaen University, and written informed consent was obtained from each subject. The study was performed in accordance with the Helsinki Declaration of 1975 as revised in Edinburgh (2000).

Anthropometric measurements

Body weight (including light indoor clothing) was measured using an electronic balance (accuracy 0.1 kg) and standing height (without shoes) with a stadiometer (nearest 0.1 cm). Circumferences were measured with a Harpenden anthropometric tape by a registered nurse who has been trained in technique of measurement. Waist circumference was taken midway between the inferior margin of the last rib and the crest of the ilium in a horizontal plane and hip circumference (HC) around the pelvis at the point of maximal protrusion of the buttocks (both to the nearest 0.1 cm). The measurements were done thrice and averaged. The waist to hip ratio (WHR) was then calculated.

Body composition

The DXA scanners (model DPX-IQ, Lunar Radiation Corp, USA) were used to measure body fat and lean tissue mass. Fat mass and lean tissue mass were expressed in kg and %BF was calculated by the ratio between fat mass and total body weight. These had CVs of 1.5% for bone mineral and 3-4% for body fat[21,22]. The onboard software estimated fat mass, lean tissue mass and %BF based on an extrapolation of fatness from the ratio of soft tissue attenuation of two x-ray energies in pixels not containing bone.

Statistical analysis

Data analysis was performed separately for men and women. By using the WHO recommended criteria[16], a man was classified as obese if his %BF was equal to or more than 25, while the criterion for women was 35. The prevalence of obesity was then estimated for each sex. The correlation between %BF and anthropometric measures was determined using the Pearson's product moment correlation coefficient. In considering the prediction of WC as a surrogate of obesity, a number of receiver operating characteristic curves were constructed. The area under the ROC curve (AUC) is the probability that a randomly drawn individual from the obese group (defined by %BF) has a greater WC value than a randomly drawn individual from the non-obese group. This probability is not affected by the prevalence of obesity in the population.

In the second analysis, the interest was in deriving an optimal cut-off value of WC for the diagnosis of obesity in the absence of%BF. In this analysis, %BF was considered the primary outcome variable, while WC were treated as predictor variables. In each sex, a polynomial regression equation for predicting %BF as a linear function of WC was developed, e.g., $\%BF = \beta_0 + \beta_1 BMI + \beta_2 BMI^2 + \beta_3 BMI^3 + \ldots + e$, where $\beta_0, \beta_1, \beta_2, \beta_3, \ldots$ are unknown parameters, the random error e is assumed to be normally distributed with mean 0 and a constant variance. The unknown parameters of the polynomial regression equation were estimated by the method of least squares. Because there are several possible polynomial equations, the selection of a "final" equation was based on measures of goodness-of-fit of the equation, such as coefficient of determination (which reflects the amount of variation in %BF that could be explained by WC, residual mean square error, and residual analyses (to make sure the assumptions of normality, homogeneity and independence were satisfied). Based on the parameter estimates of the final polynomial equation, a WC value was derived so that the predicted value of%BF is 25% for men and 35% for women. A p-value of less than 0.05 was considered significant.

Results

Characteristics of study participants

A total of 181 men and 255 women aged 50 ± 16 yr (mean ± SD; range: 20-84 yr) were included in this study. While the two sexes were comparable in terms of age, men had significantly greater stature, heavier weight, higher percentage of lean mass tissue, but lower %BF, and lower WC, than women (Table 1). There was no evidence of skewness in the distribution of the anthropometric variables.

Age was positively correlated with %BF in men ($r = 0.33$; $p < 0.001$), but not in women ($r = -0.01$; $p = 0.98$). Advancing age was associated with increase in WC in men ($r = 0.17$; $p = 0.06$) and women ($r = 0.18$; $p = 0.004$). WC was highly correlated with BMI and %BF in both men and women.

Relationships between%BF and WC

In men, the relationship between %BF and WC was significant at the third degree polynomial (cubic equation), (Fig. 1). It was estimated that 59% of variation in %BF was explained by WC. Using the estimated regression parameters (Table 2), a WC of 92.8 cm would predict a%BF of 25%.

In women, the relationship between %BF and WC followed a quadratic function (Fig. 1). According to these equations, 48% of variation in %BF was explained by WC. On solving the quadratic equations, it was estimated that a WC of 84.2 cm would predict a %BF of 35% (Table 2).

These data, therefore, suggest that in the absence of %BF measurement, the cut-off WC criteria are 93 cm for men and 84 cm for women.

Table 1. Demographic, anthropometric and body composition data according to sex

Variables	Men (n = 181)	Women (n = 255)	Difference (95%CI)
Age (yr)	49.1 ± 17.1	50.6 ± 15.9	-1.5 (-4.7, 1.6)
Body Weight (kg)	58.2 ± 8.8	55.9 ± 10.5	2.3 (0.52, 4.3)[b]
Height (cm)	161.2 ± 5.9	152.1 ± 5.2	9.1 (8.0, 10.1)[a]
BMI (kg/m^2)	22.4 ± 2.8	24.1 ± 4.0	-1.7 (-2.4, -1.0)[a]
Waist circumference (cm)	78.0 ± 8.0	80.3 ± 10.1	-2.3 (-4.1, -0.5)[a]
Hip circumference (cm)	90.8 ± 6.6	94.0 ± 7.9	-3.2 (-4.6, -1.8)[a]
Waist to hip ratio	0.86 ± 0.06	0.85 ± 0.06	0.01 (-0.07, 0.01)
Fat mass (kg)	8.1 ± 4.6	17.5 ± 7.3	-9.4 (-10.7, -8.3)[a]
Lean mass (kg)	46.9 ± 5.5	34.9 ± 4.6	12.0 (10.9, 12.7)[a]
Percentage Body Fat	14.1 ± 6.4	32.0 ± 8.5	-17.9 (-19.5, -16.6)[a]

All values are mean and SD. Others are specifed
Statistical significant at [a]p <0.001 and [b]p < 0.05

Table 2. Prediction of percentage body fat by waist circumference: Estimates of regression parameters and associated statistics

Parameter	Men	Women
Intercept	598.99 ± 86.00	64.82 ± 21.02
WC	-21.889 ± 3.10	1.83 ± 0.52
WC^2	0.263 ± 0.037	-0.008 ± 0.003
WC^3	-0.001 ± 0.0001	
R^2	0.59	0.48
Residual mean square	17.12	37.55
Estimated WC so that %BF is 25 for men and 35 for women	92.8	84.2

Predictor: Waist circumference (WC)

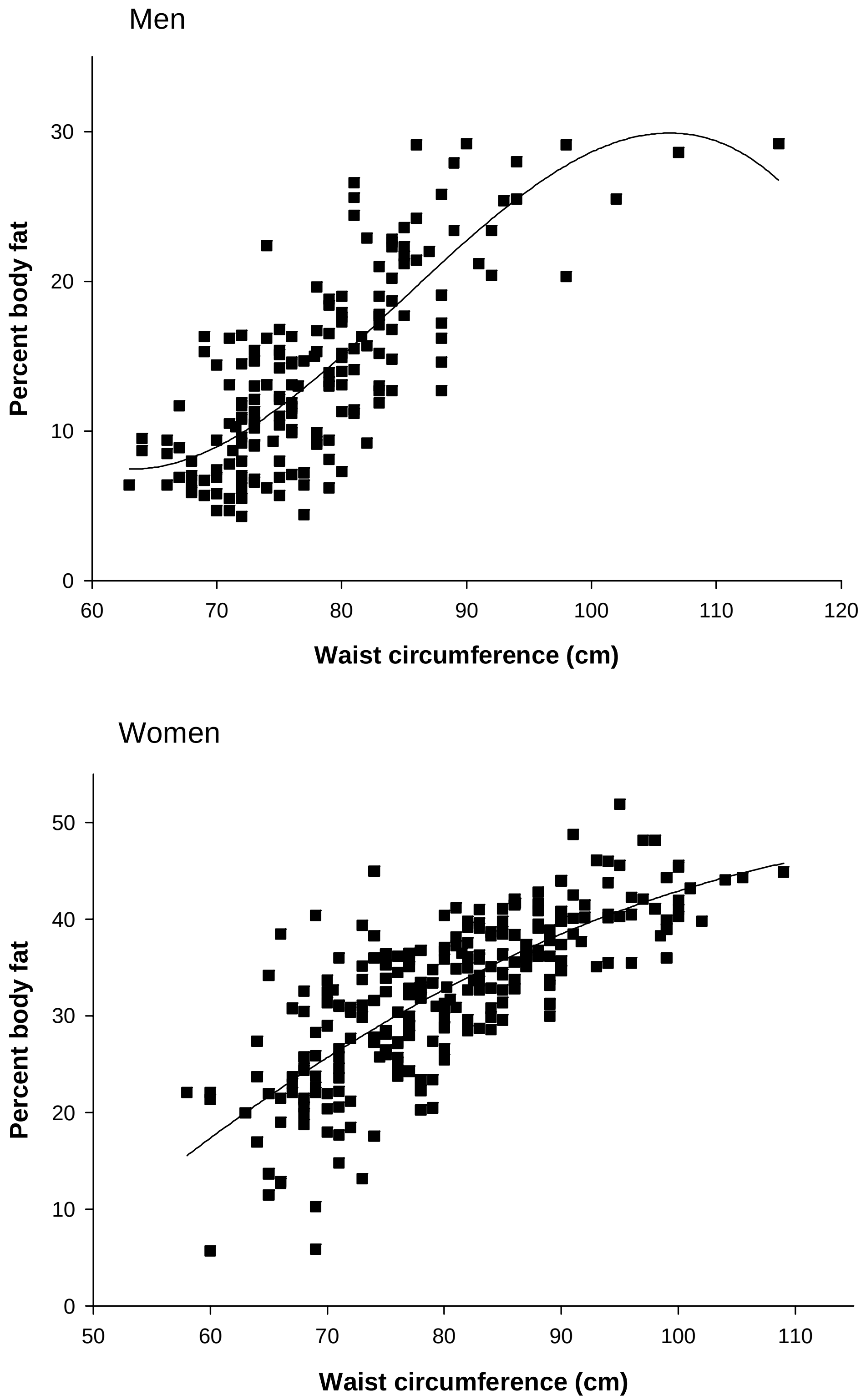

Fig. 1 Scatter plot between percentage body fat and waist circumference in men and women

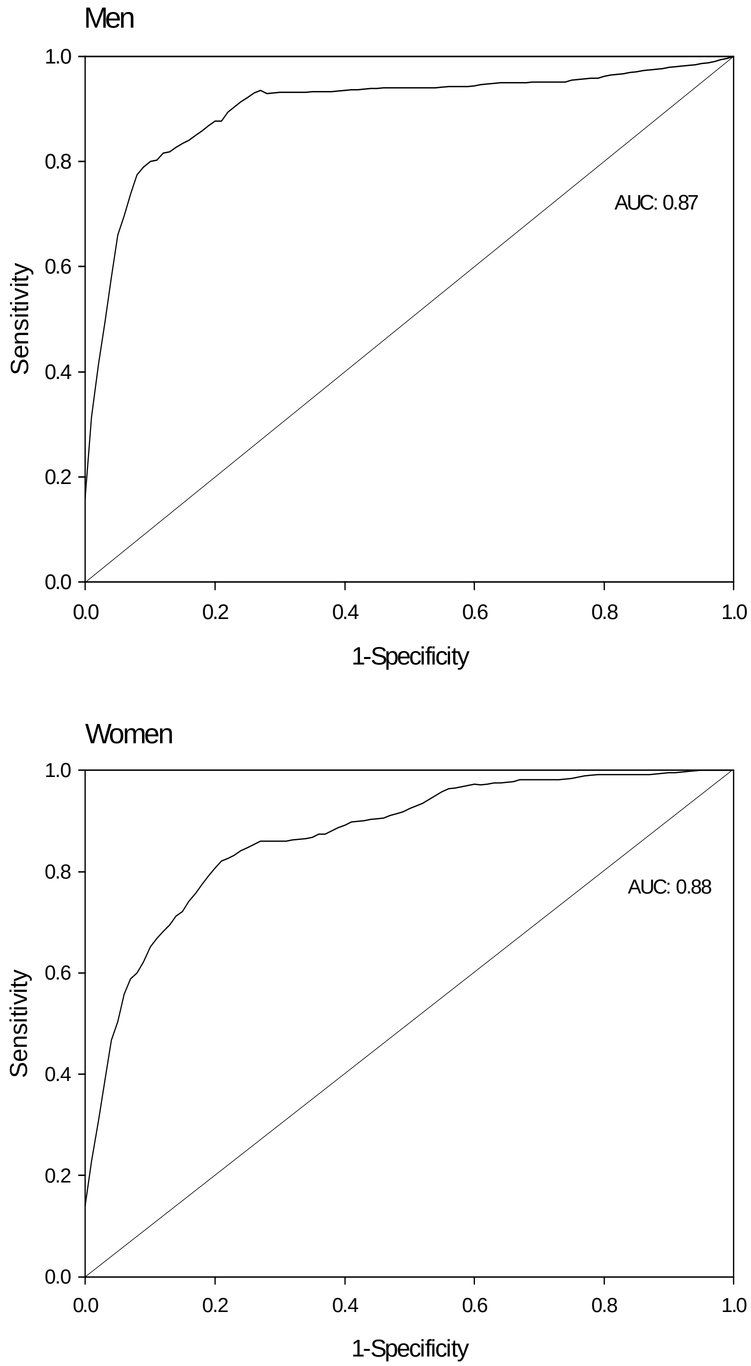

Fig. 2 ROC curve of percentage body fat and waist circumference in men and women

Sensitivity and specificity of WC

In men, using the%BF-based criteria of ≥ 25% the prevalence of obesity was estimated to be 8.3% (15/181). On the other hand, if WC measurements of ≥ 102 cm were applied, the prevalence of obesity was 1.7% (or 3/181). Therefore, the sensitivity of the WC criteria was low (20%), even with an absolute specificity of 100%. However, using the present study proposed cut-off criteria, the sensitivity of WC was 47%, while the specificity was 98% and the positive

Table 3. Cut-off values for waist circumference for the diagnosis of obesity (%BF $\geq$ 25% for men and $\geq$ 35% for women) and associated diagnostic indices

Sex	WHO cut-off	Proposed cut-off
Men	102 cm	93 cm
Prevalence (%)	1.7	4.4
Sensitivity (%)	20	47
Specificity (%)	100	98
PPV (%)	100	70
Women	88 cm	84 cm
Prevalence (%)	24	36
Sensitivity (%)	49	67
Specificity (%)	95	87
PPV (%)	88	81

PPV: Positive predictive value

predictive value was around 70% (Table 3). The AUC estimates for WC were 0.87, (Fig. 2).

In women, the prevalence of obesity, using the criteria of %BF $\geq$ 35%, was 44% (112/255). In the same sample, 24% (62/255) of women with their WC measurements being equal or greater than 88 cm. The sensitivity and specificity for WC were 49% and 95%, respectively. However, using the present study proposed cut-off criteria, the sensitivity increased to 67%, while the specificity was 87% with the predictive value being 81% (Table 3). The AUC estimates were 0.88, (Fig. 2).

Discussion

Despite the recognition that obesity is a public health threat in Asian countries, the definition of obesity is still controversial. It has been recognized that the current Caucasian-based WC criteria for classifying obesity may not be appropriated in Asian populations, because the relationships between BMI or WC and the degree of fatness are not the same between ethnic populations[23-26]. The use of BMI for classification of obesity is not perfect, and has been subject to criticisms. One criticism articulates that BMI does not measure the *distribution* of fat, particularly abdominal fat, which may be a critical characteristic of obesity[27-30]. One way to assess abdominal fat is by measuring the waist circumference. The present study represents a contribution toward that research endeavor. By using the DXA methodology, this study shows that the use of the WHO obesity criteria of WC ($\geq$ 102 cm in men and $\geq$ 88 cm in women) is likely to underestimate the prevalence of obesity in the Thai population. Moreover, the magnitude of correlation between WC and%BF was good. In fact, judging from the sensitivity, specificity, and positive predictive value, the performance of WC as an indicator of obesity was as good as BMI. This suggests that WC could be a useful index of obesity in Thai men and women. Furthermore, results of this study suggest that a WC of 93 (in men) and 84 (in women) should be considered obese in rural Thai population. These proposed WC cut-off values are lower than those of the WHO's criteria[31], but are a bit higher than WC cut-off values recommended by WHO/IASO/IOTF for Asians[32]. The similar study in Hong Kong Chinese has been reported that WC cut-off values of 86 and 73.5cm in men and women were corresponded to %BF of $\geq$ 25 and 35 in men and women, respectively, which was lower than the values of this present study[33].

Ideally, optimal cut-off values should be derived based on health-related criteria, and this has been the basis of the WHO's BMI-based classification of obesity[31]. However, there have been no long-term prospective studies examining the relationship between body fat and WC and health complications in Asian populations; therefore, an indirect derivation is the only choice. Nevertheless, a recent study in elderly Taiwanese reported that cardiovascular disease (CVD) risk factors increased significantly with increment of WC, WHR, and BMI; and WC was related to CVD risk factors to a greater extent than BMI and WHR. In Taiwanese study, the cut-off values of WC corresponding to the highest sensitivity and the highest specificity in predicting various CVD risk factors were 86.2-88.0 cm in men and 82.0-84.0 cm in women, respectively[34]. Similar results from Hong Kong Chinese, reported that there were significantly increasing trends between obesity indexes (BMI or WC) and the severity of cardiovascular risk factors. Men and women who had a WC of $\geq$ 85 and 75 cm, had 3.2 to 4.4-fold increase risk in at least one morbidity condition. Patients with a greater number of comorbidities also had higher BMI and WC measurements[35]. Furthermore, the association between WC and cardiovascular risks in Singaporean Chinese, Malays, and Indians also supported the lowering of the WC cut-off values for obesity in these populations, which are reasonably consistent with our proposed cut-off values. Furthermore, our proposed cut-off values were built on the fact that BMI was a reasonable indicator of obesity in this population. Indeed, the area under the ROC curve for WC (as a predictor of %BF obesity) was around 0.9, which represents a very good trade-off between true positive and false positive rates(34-36). The lowering of WC cut-off values will result in an increase in the prevalence of obesity in Thai population. Indeed, in this study, the prevalence of obesity as defined by WHO's recommended criteria (WC $\geq$102 cm in men and $\geq$ 88 cm in women) was only 1.7% in men and 24% in women; this prevalence would increase to 4.4% in men and 36% in women by using the study's suggested cut-offs. It is difficult to know whether this prevalence is clinically sensible, because there is currently no data to assess the medical consequences in Thai population with this range of WC; however, the prevalence in women as estimated by the proposed cut-off is consistent with the %BF-based prevalence (viz%BF > 35%).

The present findings must be interpreted within the context of a number of potential strengths and weaknesses. A major strength of this study lies in the validity of its sampling scheme. The measurement of body fat and fat-free mass in this study was based on the DXA instrument, considered one of the most accurate and valid methods of measurement. The sample size was reasonably large to allow for a stable estimation of relations between body fat and WC. Even though the subjects in this study were randomly selected, they were well characterized vis-   -vis region and nationality. Their body size, lifestyle, cultural background and environmental living conditions are relatively homogeneous with respect to (and significantly different from) Caucasian populations on whom obesity standards are predicated.

Care should be taken when extrapolating these results for other populations because 1) a measurement error of body fat result in misclassification of obesity and 2) body weight measured at a single time point may not reflect the true long-term weight of a subject. These two types of measurement errors, albeit inevitable, could have affected our results. We did not propose BMI cut-off values in this study, since these have been reported previously.

The authors do not have morbidity and mortality data to validate our proposed cut-off values; this needs to be done in urban, other rural Thai population, or with other Asian samples since life style and activities may not be the same even in the same ethic group. Additionally, since age is positively correlated with %BF and with WC in both men and women, the cut-off WC may differ with age and this, too, needs to be assessed in a further study.

In summary, the prevalence of obesity based on WC that corresponds to %BF previously defined in Caucasian populations was lower in Thai population. The results of this study suggest that optimal cut-off values using WC to define obesity should be lower in Thailand than in Western countries. The present study's results suggest that the optimal cut-off values for men are WC of 93 cm and 84 cm for women. However, its use in the general population requires further research and validation in other Thai population before being recommended for the community at large.

Acknowledgement

The authors would like to acknowledge the support of the Thailand Research Fund for funding the study.

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ความสัมพันธ์ระหว่างเส้นรอบเอวกับปริมาณร้อยละไขมันในร่างกายในประชากรไทยที่อาศัยในเขตชนบท

ฉัตรเลิศ พงษ์ไชยกุล, ชูวงศ์ พงษ์ไชยกุล, เอกลักษณ์ วโนทยาโรจน์, ทวน วี เหงี่ยน, รัชตะ รัชตะนาวิน

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างเส้นรอบเอวกับปริมาณร้อยละไขมันของร่างกายและเพื่อหาค่าที่เหมาะสมของเส้นรอบเอวในการบ่งชี้ถึงภาวะอ้วนรวมทั้งประเมินความถูกต้องในคนไทย การศึกษานี้เป็นการศึกษาแบบตัดขวางในผู้ชายจำนวน 181 คนและในผู้หญิงจำนวน 255 คน อายุเฉลี่ย 50 ± 16 ปี (อายุ ระหว่าง 20-84 ปี) ปริมาณร้อยละของไขมันในร่างกายวัดโดยใช้เครื่อง dual energy X-ray absorptiometry (GE Lunar Corp, Madison, WI) เกณฑ์มาตรฐานของปริมาณร้อยละของไขมันในร่างกายในการบ่งชี้ถึงภาวะอ้วนในผู้ชายและผู้หญิงใช้เกณฑ์ตั้งแต่ร้อยละ 25 และ 35 ตามลำดับ เส้นรอบเอวใช้หน่วยวัดเป็นเซนติเมตร ผลการศึกษาพบว่าร้อยละ 8.3 ในผู้ชายและร้อยละ 44 ในผู้หญิงได้รับการวินิจฉัยโรคอ้วนเมื่อใช้ปริมาณร้อยละของไขมันในร่างกายเป็นเกณฑ์ เมื่อใช้เกณฑ์ขององค์การอนามัยโลก (102 เซนติเมตรในผู้ชายและ 88 เซนติเมตรในผู้หญิง) ร้อยละ 1.7 และร้อยละ 24 ได้รับการวินิจฉัยโรคอ้วนตามลำดับ โดยพบค่าของเส้นรอบเอวที่ 93 และ 84 เซนติเมตรจะสัมพันธ์กับปริมาณร้อยละของไขมันในร่างกายที่ร้อยละ 25 ในผู้ชายและร้อยละ 35 ในผู้หญิงตามลำดับ โดยมีพื้นที่ใต้กราฟเท่ากับ 0.87 ในผู้ชายและ 0.88 ในผู้หญิง โดยสรุปผลการศึกษานี้พบว่าเส้นรอบเอวเป็นตัวบ่งชี้ที่ดีและมีประโยชน์ในการวินิจฉัยโรคอ้วน สำหรับค่าที่เหมาะสมของเส้นรอบเอวในการวินิจฉัยโรคอ้วนในคนไทยควรมีค่าต่ำกว่าประเทศตะวันตก