Original Article

Comparison of Body Adiposity Index and Body Mass Index in Defining Obesity in Rural Thais

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Background: Body adiposity index [BAI], which is based on the measurements of hip circumference and height, has been suggested as an alternative adiposity index to body mass index [BMI]. Previous studies have demonstrated that BAI exhibits good cross-sectional agreement with percent body fat [PBF].

Objective: To compare BAI with BMI and their correlations with PBF and to define the optimal BAI cut-offs for defining obesity in rural Thai adults using PBF as a gold standard.

Materials and Methods: A total of 180 men and 254 women aged 20 years or older were recruited using a stratified clustering sampling method. PBF was measured using dual energy x-ray absorptiometry, and the "gold standard" for defining obesity was PBF greater than 25% in men and greater than 35% in women. BMI was obtained by dividing weight (in kg) by height^2 (in meters), while BAI was calculated using the following equation: (hip circumference (in centimeters)/height$^{1.5}$ (in meters)) -18.

Results: The prevalence of PBF-based obesity in men and women was 7.8% and 42.1%, respectively. When using a BMI cut-off of greater than 25 kg/m^2, 13.9% of men and 37.4% of women were classified as obese. There was a strong correlation between BAI and BMI (r = 0.76 in men and 0.83 in women, $p<0.001$). A strong correlation was also found between BMI and PBF (r = 0.71 in men and 0.78 in women, $p<0.001$), which was comparable with the correlation between BAI and PBF (r = 0.65 in men and 0.73 in women, $p<0.001$). BAI was a significant predictor of PBF, such that in men, a BAI of at least 29.2 predicted a PBF of 25% (with sensitivity of 85.7% and specificity of 89.8%), while a BAI of at least 32.7 corresponded to a PBF of 35% (with sensitivity of 80.4% and specificity of 88.4%) in women. The area under the receiver operating characteristic curve for BAI in the diagnosis of obesity was approximately 0.85 in both men and women.

Conclusion: Both BMI and BAI are reasonably useful indicators of obesity. We proposed BAI cut-off values for diagnosing obesity of 29.2 in men and 32.7 in women.

Keywords: Body adiposity index, BAI, Body mass index, Obesity, Thai populations

J Med Assoc Thai 2018; 101 [Suppl. 7]: S71-S75
Website: http://www.jmatonline.com

Obesity is a common disease of public health importance in all age groups and in both developed and developing countries. It increases the risk of several chronic debilitating diseases including diabetes, hypertension, coronary artery disease, and stroke[1,2]. The prevalence of obesity has increased worldwide and is a burden on the health care system, accounting for 0.7 to 2.8% of countries' total healthcare expenditures[1].

According to a 1995 World Health Organization [WHO] report[2], percent body fat [PBF] greater than 25% for men and 35% for women is a criterion for diagnosing obesity[3-8]. PBF can be measured using a variety of methods including bioelectrical impedance analysis, magnetic resonance imaging, computed tomography, and dual energy x-ray absorptiometry [DXA]. Since the availability of the equipment necessary to carry out these techniques is limited, a more commonly used indicator for obesity is

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How to cite this article: Charoensri S, Kotruchin P, Khumyen A, Pongchaiyakul C. Comparison of Body Adiposity Index and Body Mass Index in Defining Obesity in Rural Thais. J Med Assoc Thai 2018;101;Suppl.7: S71-S75.

body mass index [BMI], which has been a standard measurement since 1972[9]. In Asian populations, a BMI of at least 25 kg/m^2 is considered obese, based on the Asia-Pacific criteria[10]. However, BMI is not an ideal indicator for obesity, as higher BMI can be due to excess weight from increased muscle mass rather than fat mass[8,11]. Moreover, there is still debate regarding different BMI cut-off points for different populations, as associations among BMI, PBF, and body fat distribution differ across populations, particularly Asian subjects[12].

Recently, BAI has been proposed as a new alternative to BMI. It is calculated solely based on hip circumference and height (hip circumference in cm/ (height (m)$^{1.5}$ - 18)[13]. One previous study suggested that BAI was strongly correlated with PBF in adults and was equally suitable in both genders and various ethnic groups[13]. However, there is a lack of data from the Thai population. Therefore, this study aimed to determine the correlations among BAI, BMI, and PBF measured using DXA in rural Thai populations and to establish the optimal BAI cut-off values for defining obesity.

Materials and Methods

This was a cross-sectional analytical study performed according to the Declaration of Helsinki. The study was approved by the Khon Kaen University Ethics Committee, and all the subjects who participated gave a written informed consent prior to the study being conducted.

Study populations

Previously-healthy Thai subjects, age 20 years old or older, were recruited using a stratified clustering sampling method from local villages in Khon Kaen province in Thailand between January 2010 and September 2011. Patients with significant comorbidities, including coronary artery disease, cerebrovascular disease, active malignancy, chronic liver disease, chronic kidney disease, diabetes mellitus, and those currently undergoing treatment for chronic infection were excluded from the study. Moreover, patients who were in a weight-reduction program or currently taking medications that might influence body weight (i.e, thyroxine, steroid hormone, diuretics) were also excluded. Each patient underwent a thorough medical history interview.

Based on the 35% obesity prevalence in Thailand ($p = 0.35$)[14] and the acceptable deviation from the real value in the population (d = 0.005) with the standard normal deviation with a confidence of 95% (Z = 1.96), the calculated sample size in the study was 350.

Measurements

An anthropometric assessment was performed in each patient. Waist circumference was measured at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest. Hip circumference was measured around the widest portion of the buttocks over the greater trochanters, with the tape parallel to the floor. For both measurements, the subject stood with feet close together, arms at the side, and body weight evenly distributed. Both measurements were taken at the end of a normal expiration[15]. BMI was calculated as the weight in kilograms divided by the square of the height in meters (kg/m^2), and BAI was calculated using the following equation: (hip circumference (in centimeters)/height$^{1.5}$ (in meters)) -18. According to the Asia-Pacific criteria, a BMI of at least 25 kg/m^2 is considered obese[10]. After the anthropometric measurements were obtained, fat mass and muscle mass measurements were obtained using DXA. PBF was calculated as fat mass divided by body weight of each patient. Obesity was defined according to the 1995 WHO criteria as percent body fat greater than 25% for men and greater than 35% for women[2].

Statistical analysis

The statistical analyses were performed using Stata, version 10.1 (Stata, College Station, TX). Mean and standard deviation were used to analyze the descriptive data. The correlations among BAI, BMI, and PBF were analyzed by the Pearson's correlation coefficients. Receiver operating characteristic [ROC] curves were plotted for optimal diagnostic cut-offs for BAI, using PBF as the gold standard.

Results

Characteristics of the study sample

A total of 434 patients were included in the study, 254 of whom were female (58.5%). While the two sexes were comparable in terms of age and body weight, men had significantly greater stature and more lean mass tissue, but smaller waist circumference, hip circumference, amounts of fat mass tissue, and PBF. The average BMI of men was significantly lower than that of women (22.3 vs. 24.0 kg/m^2, respectively, $p<0.001$), as was the average BAI (26.5 vs. 32.1 kg/m^2, respectively, $p<0.001$; Table 1).

Table 1. Patient characteristics categorized by gender

Patient characteristics	Men (n = 180)	Women (n = 254)	Mean difference	*p*-value
Age (years)	49.0±17.0	50.6±15.9	1.6	0.085
Weight (kg)	58.2±8.7	55.8±10.5	2.4	0.012
Height (cm)	161.2±5.8	152.1±5.2	9.1	<0.001
Body mass index (kg/m^2)	22.4±2.8	24.0±4.0	1.7	<0.001
Waist circumference (cm)	78.0±8.0	80.3±10.1	2.3	<0.001
Hip circumference (cm)	91.0±6.0	93.9±7.9	3.0	<0.001
Body adiposity index	26.5±2.9	32.1±4.2	5.6	<0.001
Fat mass (kg)	7.99±4.57	17.58±7.21	9.59	<0.001
Lean mass (kg)	46.85±5.48	35.07±4.01	11.78	<0.001
Percent body fat (%)	14.02±6.36	32.11±8.26	18.09	<0.001

The data are represented as the mean ± standard deviation

Prevalence of obesity

When BMI of at least 25 kg/m^2 was used as the definition of obesity, the prevalence of obesity was 27.7% (13.9% and 37.4% in men and women, respectively). When excess PBF (greater than 25% for men and greater than 35% for women) was used, the prevalence of obesity was 27.9% (7.8% and 42.1% in men and women, respectively).

Relationships between BAI and BMI

BAI and BMI were well correlated in both genders (r = 0.76 in men and 0.83 in women, respectively, *p*<0.001). Moreover, BAI and BMI showed comparable correlations with PBF. In men, the correlation coefficients for BAI and PBF, BMI and PBF were 0.65 and 0.73, respectively (*p*<0.001). In women, the correlation coefficients for BAI and PBF, BMI and PBF were 0.729 and 0.78, respectively (*p*<0.001).

BAI and BMI cut-offs for obesity

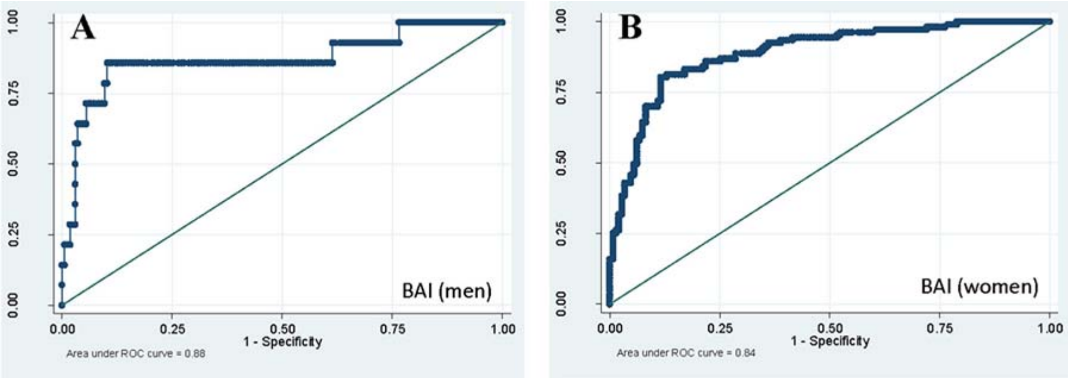
ROC curve analysis was performed using excess PBF as a gold standard for determining obesity. The BAI cut-off in men was 29.2 with an area under the ROC curve of 0.88 (95% CI: 0.78 to 0.97; Figure 1A), sensitivity of 85.7, specificity of 89.8, positive predictive value [PPV] of 41.4, negative predictive value [NPV] of 98.7, and likelihood ratio [LR] of 8.4. The BAI cut-off in women was 32.7 with an area under the ROC curve of 0.84 (95% CI: 0.798 to 0.890; Figure 1B), sensitivity of 80.4, specificity of 88.4, PPV of 83.5, NPV of 86.1, and LR of 6.9. ROC curve analysis was also performed to define BMI cut-offs using excess PBF as a gold standard for determining obesity. The BMI cut-off in men was 24.9 with an area under the ROC curve of 0.85 (95% CI: 0.73 to 0.96; Figure 2A), sensitivity of 78.6, specificity of 91, PPV of 42.3, NPV of 98.1, and LR of 8.7. The BMI cut-off in women was 24.3 with an area under the ROC curve of 0.86 (95% CI: 0.82 to 0.90; Figure 2B), sensitivity of 84.1, specificity of 87.8, PPV of 83.3, NPV 0f 88.4 and LR of 6.9.

A comparison between the conventional BMI cut-off of at least 25 kg/m^2 and the proposed BAI cut-offs revealed comparable performance when excess PBF was used as the gold standard for determining obesity. The sensitivity and specificity of a BMI cut-off of at least 25 kg/m^2 for obesity were 76% and 91.1%, respectively (PPV of 76.7, NPV of 90.8, and LR of 8.5), while the sensitivity and specificity of the new BAI cut-off values were 81% and 89.1%, respectively (PPV of 74.2, NPV of 92.4, and LR of 7.46).

Discussion

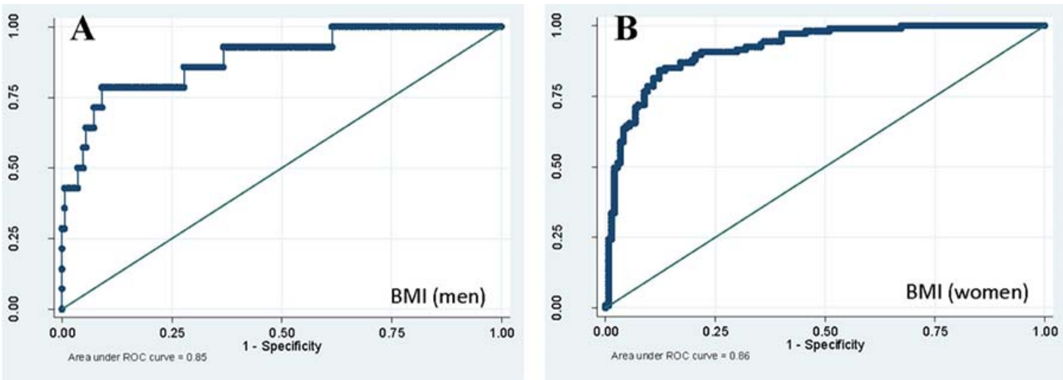
In the present study, we evaluated whether BMI or BAI, a new index of body adiposity, correlates with the standard reference method of body fat estimation, DXA, in rural Thai populations. Our results showed that using BAI or BMI as an indicator for obesity yields similar diagnostic value. However, BMI exhibited a slightly stronger correlation with PBF compared to BAI in our populations. This finding is consistent with those of a previous study by Okorodudu et al[16]. In contrast, a study conducted in the US by Bergman et al reported that BAI is a better indicator of PBF than BMI[13]. Smaller hip circumference in Thai subjects, resulting in lower BAI, may explain this difference.

In the present study, we proposed new optimal BAI cut-off values for defining obesity: 29.2 in men and 32.7 in women. These cut-off points yielded more than 80% sensitivity in diagnosis when compared with



BAI = body adiposity index

Figure 1. Receiver operating characteristic curve for BAI in detecting obesity in men (A) and in women (B).



BMI = body mass index

Figure 2. Receiver operating characteristic curve for BMI in detecting obesity in men (A) and in women (B).

the gold standard PBF measurement. Similar cut-off values have been proposed in another report, which suggested that BAI greater than 27.2 in men and greater than 36.4 in women should be used for the determination of obesity(17). We also define BMI cut-off values in our study as 24.9 and 24.3 in men and women, respectively. This finding affirms the use of conventional BMI cut-off of at least 25 kg/m^2 to determine obesity(10). Compared to BMI, BAI demonstrated greater sensitivity (81% vs 76.6%) but lesser specificity (91.9% vs 89.1%) in defining obesity.

The strength of our study is the availability of DXA to be used as a gold standard to determine PBF. However, DXA estimates of PBF can also vary systematically, with DXA underestimating the amount of body fat of leaner subjects and overestimating the amount of body fat of obese subjects(18). Despite the large number of subjects in the present study, the authors included participants only in the rural areas of northeast Thailand, which may not be a good representation of the whole country's population. Moreover, we did not analyze the correlation of BAI with other cardiometabolic indices that may indicate the risk of debilitating diseases or death. Further study addressing these issues is warranted.

In conclusion, in addition to BMI, BAI is a good indicator of body adiposity, which can be used in the diagnosis of obesity. A BAI value of greater than 29.2 in men and 32.7 in women is a suitable cut-off value for the diagnosis of obesity in the Thai population, and has a sensitivity and specificity comparable with BMI.

What is already known on this topic?

Despite being a standard measurement for obesity, BMI is not an ideal indicator, as higher BMI from excess weight can be due to increased muscle mass rather than fat mass.

What this study adds?

BAI is a good indicator of body adiposity, which can be used in the diagnosis of obesity. The proposed BAI cut-off value is 29.2 in men and 32.7 in women.

Acknowledgements

The authors thank to the technicians at the Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine, Khon Kaen University, who helped facilitate the measurement of fat mass using DXA.

Potential conflicts of interest

The authors declare no conflict of interest.

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