*Original Article*

# The Performance of Fat Mass Index and Percent Fat Mass in Predicting Metabolic Syndrome: A Study Based on The Healthy Aging Khon Kaen University Campus Project


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***Objective:*** Metabolic syndrome [MetS] is a deleterious complication related to obesity. Body mass index [BMI] is a practical parameter indicating obesity and associated conditions. However, the usefulness of BMI is limited since it does not truly reflect the amount of body fat a person has. This study aims to determine the performance of the fat mass index [FMI] and percent fat mass [PFM] in detecting MetS, and to identify the optimal cutoff points of these parameters among the elderly Thai population.

***Materials and Methods:*** Participants were subjects aged above 50 years who attended the Healthy Ageing Khon Kaen University Campus Project between March 2012 and April 2015. Baseline characteristics, anthropometric measures, body composition as measured by bioelectrical analysis [BIA], and metabolic profiles were collected. MetS was identified using the criteria of the International Diabetes Foundation [IDF].

***Results:*** There were 201 men and 385 women recruited for the present study. The prevalence of metabolic syndrome was approximately 40%. FMI and PFM were correlated with the prevalence of metabolic syndrome, particularly in women. The area under the ROC curve [AUC] of FMI to predict metabolic syndrome was 0.89 in men and 0.84 in women, while the AUC of PFM was 0.84 for men and 0.82 for women. We propose an FMI of 9.0 kg/m$^2$ or a PMF of 36.6% for women and an FMI of 5.8 kg/m$^2$ or PFM of 23.1% for men as cutoff points to indicate MetS.

***Conclusion:*** PFI and FMI are alternative reliable parameters in predicting MetS that can be measured using unsophisticated techniques.



***Keywords:*** Body mass index, Fat mass index, Metabolic syndrome, Percent fat mass, Waist circumference

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Metabolic syndrome [MetS], characterized by a cluster of cardiometabolic risk factors, is associated with several undesirable health outcomes, resulting in disability and death[1]. The prevalence of MetS is increasing worldwide, even in developing countries. Data from the National Health Examination Survey indicated that the prevalence of MetS in the Thai population was highest in subjects whose ages were between 50 to 79 years[2]. Moreover, the survey also found that the prevalence several components of MetS


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in the Thai population were rising between 2004 to 2009[3]. Obesity, defined as a state of excess fat storage, is one major component of MetS. It is practically determined using body mass index [BMI] and/or waist circumference [WC]. However, BMI does not always indicate the exact proportion of body fat since it cannot differentiate between fat mass and fat-free mass[4-7]. There has been considerable debate among researchers regarding the accuracy and validity of BMI in representing body fat mass and in predicting co-morbidities[8-15]. In addition, waist circumference is also discussed regarding the variation of the cut-off values among diverse racial/ethnic, gender, and age groups[16-21]. Thus, several techniques for body composition measurement have been introduced to minimize controversy regarding body fat measurement. Bioelectrical impedance analysis [BIA] is a non-invasive and convenient method which determines total body water indirectly. It can provide reliable estimates of fat-free mass [FFM], body fat, and body cell mass under various conditions[22-24]. Determination of body fat and FFM are found to be associated with MetS and cardiovascular risks[25-28]. Furthermore, the term 'fat mass index [FMI]' is proposed to reduce the bias related to absolute body fat and percent fat mass [PFM] since it is corrected for height[29,30]. However, body composition measurement parameters have been reported to vary among different race/ethnic and age groups[31-34]. Since there are limited data available from Asian populations, FMI and PFM are doubtful in terms of reliability and validity in the Thai population. This study aims to 1) determine the performance of PFM and FMI in detecting MetS using IDF criteria, and 2) identify the optimal cutoff points of the PFM and FMI among an elderly Thai population.

## Materials and Methods

### *Participants and setting*

This was a cross-sectional study. It was a part of the Healthy Aging Khon Kaen University Campus Project, which was a cohort study in that the end point was specified to encompass common atherosclerotic-related conditions and major geriatric syndromes. The population of this study consisted of urban middle class adults 50 years old and older who worked for Khon Kaen University (KKU; Khon Kaen, Thailand), as well as their elderly relatives. The inclusion criteria were that participants were aged 50 years old or over, that their medical records were eligible for the study, that either they or proxies who were willing to participate in the study resided in Khon Kaen, and that their physicians had allowed the participants to take part. Participants who could not follow-up according to study protocol were excluded. The complete details of the study population have been described elsewhere[20].

### *Definition of metabolic syndrome [MetS]*

Metabolic syndrome [MetS] was identified using the criteria from the International Diabetes Foundation [IDF][35], which requires central obesity as waist circumference [WC] ≥90 cm in men and ≥80 cm in women plus any two of the following four conditions: (1) high blood pressure: blood pressure ≥130/85 mmHg or known treatment for hypertension, (2) hypertrigly ceridemia: fasting plasma triglycerides ≥150 mg/dl, (3) low HDL: fasting HDL cholesterol <40 mg/dl in men and <50 mg/dl in women, (4) a hyperglycemic fasting glucose level of ≥100 mg/dl or known treatment for diabetes.

### *Data collection*

Baseline data were collected including age, sex, comorbid diseases, blood pressure. Blood pressure was measured after each participant had been lying down for 10 min. Anthropometric measures were taken while subjects were lightly clothed and wore no shoes. Fasting blood samples were collected including blood sugar, uric acid, lipid profiles, and liver function tests. Body composition statistics, including fat mass [FM], percent body fat [PBF], free fat mass [FFM], and total body water [TBW] estimation, were determined using the Omron bioelectrical impedance analysis [BIA] system. Body mass index [BMI] was calculated as weight (kg) divided by height squared ($m^2$). Fat mass index [FMI] was derived from fat mass (kg) divided by height square ($m^2$)[29].

### *Procedure*

The study was conducted in the special outpatient clinic at Srinagarind Hospital in Khon Kaen, Thailand. All KKU personnel and their relatives who were aged 50 or older were sent a letter inviting them to participate. All volunteer participants in this cohort were provided required informed consent forms and given an appointment to undergo a checkup at Srinagarind hospital. Baseline descriptive data were collected from March 21st, 2012 to April 28th, 2015. Participants underwent a physical examination by physicians, blood pressure and systemic physical examination, measurement of body composition, and provided blood samples for fasting blood sugar, uric acid, lipid profiles, and liver function tests. The study flowchart is shown in Figure 1.

### *Sample size*

Sample size calculations were based on the areas under the receiver operating characteristic [ROC] curves and areas under the curves [AUC] according to the methodology of Hanley and McNeil (1983)[36]. Receiver operating characteristic curves were used to summarize the accuracy of diagnostic tests. This method varies the sample size until a sufficiently small standard error [SE] of the area under the ROC curve is achieved. Because of the complexity of the formula, a web-based calculator (www.anaesthetist.com/mnm/stats/roc/#stderr) was used to determine the standard error. Finally, a sample size of at least 500 participants, consisting of both men and women was found to be adequate and feasible to conduct the trial in clinical practice at an AUC of 0.8 and SE of 0.02.

### *Statistical analysis*

Demographic data and anthropometric variables were analyzed using descriptive statistics. Univariate analysis, the Chi-square test, or Fisher's exact test was used to examine all categorical variables. Student t-tests were used to compare all continuous variables between men and women. The ROC curve was used to summarize the overall accuracy of the anthropometric indices (fat mass index and percent fat mass) for MetS detection. Then optimal cut-off points were determined. The performance of the tests was summarized as sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV], and likelihood ratios [LR]. All of the data analysis was performed using STATA version 10.0 (StataCorp, College Station, TX, USA).

Ethics approval was provided by the Khon Kaen University Faculty of Medicine ethics committee as instituted by the Helsinki Declaration.

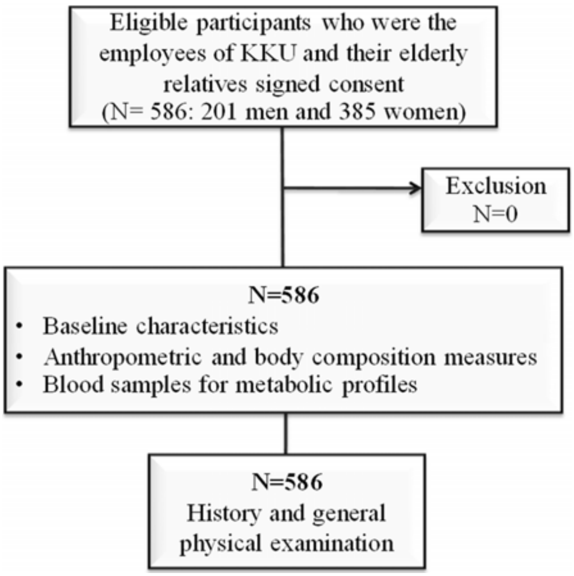



**Figure 1.** Study flowchart.

## Results

### *Baseline characteristics*

There were 201 men and 385 women recruited to participate this study. Baseline data of studied populations are shown in Table 1. The prevalence of metabolic syndrome in men and women was similar at about 40%. Women had significantly higher percent fat mass and fat mass index. Figure 1 demonstrates the prevalence of metabolic syndrome based on FMI and PFM quartiles. It was found that FMI and PFM correlated more closely with the prevalence of metabolic syndrome in women than in men.

### *The comparison of FMI and PFM in predicting metabolic syndrome*

The areas under the ROC curve [AUC] of FMI and PFM to predict metabolic syndrome based on the IDF criteria in men were 0.89 (95% CI 0.84, 0.93) and 0.87 (95% CI 0.82, 0.92), respectively. For women, they were 0.84 (95% CI 0.80, 0.88) and 0.82 (95% CI 0.77, 0.86), respectively. Table 2 demonstrates the performance of the FMI and PFM at the optimal cutoff points to detect metabolic syndrome according to the IDF criteria.

## Discussion

The deleterious sequelae of obesity are widely reported, especially the cardiometabolic risk factors. The World Health Organization [WHO] suggested using BMI to classify the severity of obesity[37] since BMI is strongly associated with mortality[38]. However, BMI cut-off points for obesity classification vary according to ethnicity and gender. Furthermore, certain studies have revealed metabolically healthy obesity in some subgroup populations[39-44]. Thus, we attempted to verify additional parameters to be used as better predictors of obesity-related morbidity.

Since adipose tissue releases adipokines and free fatty acid, which are both involved in pathogenesis of obesity-associated metabolic abnormalities[45], body fat measurement would be valuable in predicting

**Table 1.** Baseline characteristics of the studied populations

| Parameter | Men n = 201 (34.3%) | Women n = 385 (65.7%) |
|---|---|---|
| Age; years (mean, SD) | 60.7 (7.2) | 57.7 (6.6) |
| DM; n (%) | 27 (13.4) | 27 (7) |
| HTN; n (%) | 63 (43.1) | 83 (56.9) |
| Dyslipidemia; n (%) | 60 (29.9) | 111 (28.8) |
| CHD; n (%) | 10 (5) | 5 (1.3) |
| Weight; kg (mean, SD) | 68.1 (9.4) | 58.8 (8.9) |
| Height; m (mean, SD) | 1.65 (0.1) | 1.5 (0.1) |
| BMI; kg/m$^2$ (mean, SD) | 24.9 (3.3) | 24.5 (3.5) |
| WC; cm (mean, SD) | 88.5 (8.8) | 80 (9) |
| PFM; % (mean, SD) | 22.0 (5.8) | 36.1 (6.4) |
| FMI; kg/m$^2$ (mean, SD) | 5.7 (2.1) | 9.0 (2.8) |
| SBP, mmHg (mean, SD) | 129.4 (18.3) | 124.1 (19) |
| DBP, mmHg (mean, SD) | 75.5 (10.4) | 71.4 (10.6) |
| TC; mg/dl (mean, SD) | 206.4 (39) | 220.7 (40.6) |
| TG; mg/dl (mean, SD) | 146.1 (96.1) | 121.4 (72.5) |
| HDL; mg/dl (mean, SD) | 53.1 (13.5) | 63.7 (17.2) |
| LDL; mg/dl (mean, SD) | 132.7 (36.4) | 139.6 (37.1) |
| FPG; mg/dl (mean, SD) | 99.8 (36.9) | 94.6 (22.9) |
| Uric; mg/dl (mean, SD) | 6.5 (1.3) | 5.1 (1.1) |
| ALT; U/L (mean, SD) | 27.7 (16.4) | 23.1 (14.6) |
| AST; U/L (mean, SD) | 24.7 (12.6) | 22.2 (7.9) |
| Prevalence of MetS; % | 79 (39.3) | 156 (40.5) |

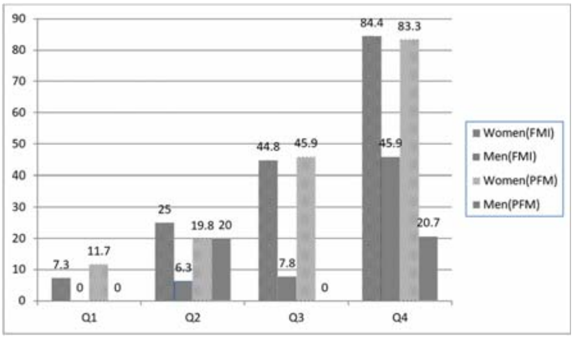
The *p*-value were significant at 0.05
SD = standard deviation; DM = diabetes mellitus; HTN = hypertension; CHD = coronary heart disease; BMI = body mass index; WC = waist circumference; PFM = percent fat mass (%); FMI = fat mass index (kg/m$^2$); SBP = systolic blood pressure; DBP = diastolic blood pressure; TC = total cholesterol; TG = triglyceride; HDL = high density lipoprotein cholesterol; LDL = low density lipoprotein cholesterol; FPG = fasting plasma glucose; ALT = alanine aminotransferase; AST = aspartate aminotransferase

metabolic syndrome. Body fat can be measured by several different methods, e.g. BIA, dual-energy absorptiometry [DXA], etc. The present study used the BIA since it was safe and widely available in numerous health institutes in Thailand. Since measurements of total body fat may be imprecise due to variation in body frame size, percent fat mass [PFM] and fat mass index [FMI] were used. Previous studies indicated that high PFM was related to greater cardiometabolic risks in Caucasian[11] and Asian populations[46-48]. Data from the Thai population revealed that PFM increased with age, but BMI remained steady[49]. Our study found that PFM and FMI body fat measurements were related to the prevalence of metabolic syndrome in middle-aged Thai adults. Although PFM and FMI were not criteria of metabolic syndrome, the highest quartiles of both PFM and FMI were strongly associated with metabolic syndrome, especially in women.

Numerous studies reported body fat determined by BIA or DXA could be correlated with increased BIA or increased cardiovascular risks[34,50-55]. The findings from our study reveals that both PFM and FMI were shown to be significant predictors of metabolic syndrome. We proposed the cut-off points of PFM measured by BIA at 36.6% in women and 23.1% in men for predicting MetS. These cut-off points have been shown correspond to the predicted percentage body fat determined by DXA for obese Asian Americans in a previous study, which suggested the PFM cut-off points for BMI of 25.0 kg/m$^2$ were 34.9% for women and 23.8% for men[50]. According to previous research conducted in Asian countries (i.e., China, Korea, India, and Thailand) the PFM cut-off points for predicting cardiovascular disease are between 20.3% and 25.5% in males, and

**Table 2.** The performance of the FMI and PFM at the optimal cutoff points

| Indices | Women | | Men | |
|---|---|---|---|---|
| | FMI | PFM | FMI | PFM |
| Cutoff-point | 9.0 kg/m$^2$ | 36.6% | 5.8 kg/m$^2$ | 23.1% |
| AUC (95% CI) | 76.2 (71.9, 80.6) | 75.3 (71.0, 79.7) | 83.7 (78.5, 88.9) | 80.3 (74.7, 85.9) |
| Sensitivity | 78.7 | 80 | 85.1 | 83.5 |
| Specificity | 75.5 | 70.7 | 81.4 | 77.1 |
| PPV | 68.5 | 64.9 | 75.6 | 71.0 |
| NPV | 84 | 83.9 | 89.7 | 87.5 |
| LR+ | 4.1 | 2.7 | 4.6 | 3.6 |
| LR- | 0.3 | 0.3 | 0.2 | 0.2 |




FMI = fat mass index; PFM = percent fat mass; Q1-4 = quartile 1-4

**Figure 2.** Prevalence of metabolic syndrome based on FMI and PFM quartiles.

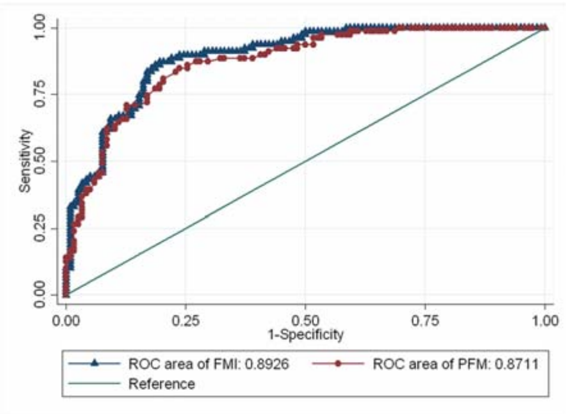



**Figure 3.** ROC curves of FMI and PFM in men.

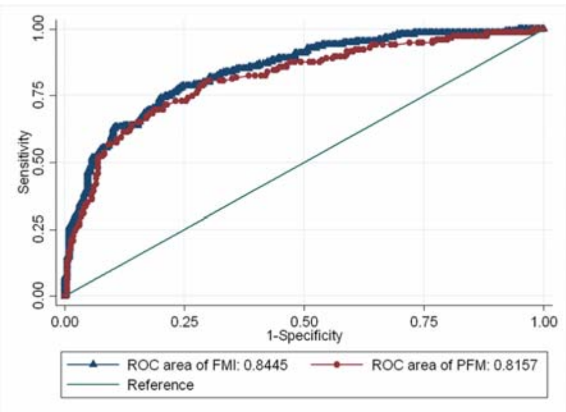



**Figure 4.** ROC curves of FMI and PFM in women.

between 31.4% and 38% in females[28,34,51-54]. Additionally, our study also revealed that FMI had a slightly higher AUC than PFM. We propose that the FMI cut-off points for predicting MetS be 9.0 kg/m$^2$ in women and 5.8 kg/m$^2$ in men. These cut-off values are different from those used in a study of a Caucasian population, which FMI determined by DXA at the cut-off values at 7.0 kg/m$^2$ in women and 6.4 kg/m$^2$ in men could predict cardiovascular complications[55]. Thus, our data might support the use of different obesity cut-off points for patients of different ethnicity or gender. The strength of the present study is that it was conducted in a population with a high prevalence of metabolic syndrome. However, BIA as a tool of body composition measurement, participant selection and the cross-sectional study design may be limitations. The gold standard for body composition measurement is underwater weighing, but it is not feasible fore daily practice. BIA is an alternative technique, but may require further validation. The urban middle-class population might not be representative of the general population of Thai adults. Moreover, participants in the present study were self-selecting, which could lead to selection bias. Finally, this was a cross-sectional study, which means that it was not able to predict exactly certain clinical outcomes (e.g., mortality).

## Conclusion

PFM and FMI are reliable alternative parameters to predict MetS that can be measured using unsophisticated techniques. We recommend an FMI of 9.0 kg/m$^2$ or a PMF of 36.6% for women and a FMI of 5.8 kg/m$^2$ or PFM of 23.1% for men as cutoff points to indicate MetS.

## What is already known on this topic?

Body fat and fat free mass are associated with metabolic syndrome and cardiovascular risks. However, body composition measurement parameters are varied among different racial/ethnic and age group.

## What this study adds?

The present study showed that PFM and FMI in Thai middle-aged population could predict metabolic syndrome. We also proposed the cutoff points of both parameters in indicating metabolic syndrome.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## Potential conflicts of interest

The authors declare no conflict of interest.

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