

Performance of Body Mass Index in Identifying Obesity Defined by Body Fat Percentage and Hypertension Among Malaysian Population: A Retrospective Study

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Purpose: Body mass index (BMI) is used universally to define obesity. Many studies have indicated that the current BMI cutoff value for obesity may be inaccurate in identifying individuals with excess body fat (BF) and at risk for cardiovascular diseases (CVD). This study aims to assess the performance of BMI in diagnosing obesity defined by BF percentage (BF%).

Patients and Methods: A total of 136 participants who attended an annual health screening programme were recruited. The subjects completed the health examinations, including BMI, BF% and blood pressure measurement. A receiver operating curve (ROC) analysis was conducted to determine the optimal cutoff value of BMI in classifying obesity based on BF% (>25%).

Results: The ROC analysis revealed that the optimal BMI cutoff value in classifying subjects with obesity based on BF% was 24.8 kg/m². The agreement between the classification scheme based on the new BMI cutoff (>24.8 kg/m²) and BF% was higher ($\kappa=0.722$) compared to the standard BMI cutoff (>27.5 kg/m²) ($\kappa=0.532$). BMI 24.8 kg/m² also had higher sensitivity (80.0%) than 27.5 kg/m² (56.0%) in detecting subjects with high adiposity. The new BMI cutoff also showed a sensitivity of 63.9% in identifying subjects with hypertension compared to the standard cutoff (36.1%).

Conclusion: The current definition of obesity based on BMI value needs to be reassessed by taking BF% into account. A new BMI cutoff point, 24.8 kg/m² for obesity, can identify a higher percentage of Malaysian at risk for CVD.

Keywords: body mass index, body fat percentage, hypertension

Introduction

The prevalence of cardiovascular disease (CVD), often known as the leading cause of death globally, is predicted to rise steadily over the next few years. Mortality due to coronary heart disease is expected to rise by 120% in women and 137% in men in low- and middle-income countries. This trend is generally attributed to urbanization and the adoption of lifestyles associated with low-energy expenditure but high-calorie intake.¹ In Southeast Asia countries experiencing progressive westernization of lifestyle, like Malaysia, obesity, diabetes and hypertension are among the most prevalent CVD risk factors. As evidence, the Malaysian National Health Morbidity Survey 2019 demonstrated that the prevalence of diabetes mellitus and hypertension among adults of 18 years and above was 18.3% and 30.0%, respectively.² Therefore, hypertension, diabetes mellitus and obesity form a triad of closely

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related metabolic derangements.^{3,4} In the coronavirus disease 2019 pandemic, these metabolic derangements are predictors of severe disease and may impair the efficacy of vaccines.⁵

Obesity and overweight are major public health issues with increasing prevalence worldwide. Notably, many Asian countries have high rates of obesity and overweight.¹ Malaysia is no exception, whereby the prevalence of obesity among adults aged 18 years and above increased from 15.1% in 2011 to 19.7% in 2019.^{2,6,7} The World Health Organization (WHO) defines obesity and overweight as abnormal or excessive fat accumulation, measured by body mass index (BMI), whereby a person's weight (in kilograms) is divided by the square of his/her height (in metres). In the Asian population, individuals with a BMI between 23 kg/m² and 27.5 kg/m² are considered overweight, and >27.5 kg/m² are obese.⁸ Obesity poses many adverse effects on haemodynamics and cardiovascular structure and function. Obesity increases total blood volume and cardiac output but reduces the total peripheral resistance at any given arterial pressure. As a result, obese and overweight individuals have increased filling pressure and volume, subsequently increasing the cardiac workload and negatively affecting systolic and diastolic ventricular function.⁹

Despite the well-established role of obesity as a CVD risk factor, many epidemiological studies failed to demonstrate a higher CVD risk among obese and overweight patients.^{10,11} This observation could be attributed to the inability of BMI to differentiate body fat from lean mass, particularly among the Asian populations. Other researchers have suggested that metabolic disorders are associated strongly with lipodystrophy in the general populations, particularly with low leg fat mass than the subcutaneous or visceral fat,^{12,13} and the presence of non-alcoholic liver disease.¹⁴ Over the years, several studies have analyzed the performance of BMI to detect body adiposity based on techniques that could estimate body composition.^{15,16} For instance, a study in Thailand showed that the obese population estimated by body fat percentage (BF%) was significantly higher than the values based on standard BMI cutoffs.¹⁵ Hence, BMI could underestimate the prevalence of obesity, leading to missed opportunities for obesity diagnosis and management.

Hence, this study aims to assess the performance of BMI in diagnosing obesity defined based on BF%. Secondly, we aim to validate the role of obesity (based on BMI standard and new cutoff) as a predictor of hypertension in the Malaysian urban population. We hypothesized that the new BMI cutoff could predict hypertension among subjects more effectively.

Materials and Methods

Subjects and Study Population

This is a retrospective study based on data derived from an annual health screening programme hosted by Asian Medical Students Association Malaysia, Universiti Kebangsaan Malaysia in 2018. The subjects were volunteers recruited conveniently at a shopping complex in Kuala Lumpur, Malaysia.

Methodology

Demographic data of the subjects, including sex, age, education level, working status, smoking habits, alcohol drinking, physical activity (per week), dietary profile and family history of hypertension, were recorded using a questionnaire. The clinical assessments conducted included blood pressure, BMI and body fat measurement. Body fat was estimated using the bioimpedance analysis (BIA) technique, which measures body composition using a small alternating current (HBF-306, Omron Japan). Informed consent was obtained from all participants in this study. This study was reviewed and approved by the Universiti Kebangsaan Malaysia Medical Centre Ethics Committee (Protocol No. FF-2020-416). The study was conducted in accordance with the Declaration of Helsinki.

Definition and Diagnostic Criteria Hypertension

Hypertension was defined based on Malaysia Clinical Practice Guidelines: Management of Hypertension, 5th edition (2018) as a persistent elevation of systolic blood pressure (SBP) of ≥ 140 mmHg and/or diastolic blood pressure (DBP) of ≥ 90 mmHg.¹⁷ In this study, blood pressure was measured on the non-dominant hand in a back supported, sitting position using Omron's blood pressure device (HEM-RML31, Omron United Kingdom). The patients refrained from smoking, caffeine intake or physical exercise for 30 minutes prior to measurement. If the first reading of the patients indicated hypertension (SBP >140 mmHg and/or DBP > 90 mmHg), a second reading was taken after 15 minutes of rest.

Obesity

Malaysia Clinical Practice Guidelines on Management of Obesity (2004) defines obesity as a complex multifactorial condition characterized by excess body fat for men and women with BF% >25% and >35%, respectively.¹⁸ WHO defines obesity based on BMI, which states the cutoff point for overweight lies between 23 and 27.5 kg/m² and obesity is >27.5 kg/m². Weight of consented participants

was measured using a weighing scale, while the height was measured in a standing position without shoes using a wall-mounted measuring tape. Body fat was measured using a portable Omron Body Fat Analyzer (HBF-306, Omron Japan) with 4 electrodes based on BIA.

Physical Activity

The subjects were classified into 3 groups based on the Malaysia National Strategic Plan for Active Living 2017. Subjects were categorized as active if they adopted 3 or more days of vigorous activity of at least 20 minutes per day. Individuals who did not meet the criteria for category 2 will be grouped as inactive. Subjects who have exceeded this criterion in terms of duration or days of physical activity were grouped as very active.²

Statistical Analyses

Data analysis of this study was performed using the Statistical Package for Social Science (SPSS) version 25. Categorical data were expressed as frequencies and percentages, while continuous data were expressed as means $\pm$ SD. The percentage of agreement between BMI and body fat % was analyzed using Cohen's Kappa. Receiver operating characteristic curve (ROC) analysis in SPSS was used to generate a list of BMI cutoff values based on BF% ($>25\%$ in men and $>35\%$ in women) with corresponding sensitivity and specificity. The judgement for the best BMI cutoff values was based on Youden's Index ($J = \text{sensitivity} + \text{specificity} - 1$). The cutoffs with the highest Youden's Index were selected as the optimal cutoffs. Chi-square test and binary logistic regression model was used to assess which BMI cutoff was better correlated with hypertension, a metabolic condition associated with obesity. A p-value less than 0.05 was considered statistically significant.

Results

The subjects of this study comprised 136 individuals (45 men and 91 women), with ages ranging from 20 years to 65 years. In this study, 62.5% of the subjects were <40 years and 37.5% were ≥ 40 years old. The average BMI was 25.9 ± 6.0 kg/m², while the body fat percentage was $29.5 \pm 10.9\%$. The mean systolic blood pressure was 120.7 ± 18.6 mmHg. The clinical characteristics of the study population are summarized in Table 1.

Standard BMI cutoff (>27.5 kg/m²) showed a sensitivity value of 56%, specificity value of 98.4% and area under the curve (AUC) of 0.778 in ROC analysis (Figure 1). Based on Youden's Index, a new optimal BMI

Table 1 The Characteristics of the Study Population

Indicator	N (%)
Gender	
Male	45 (33.1)
Female	91 (66.9)
Age (years)	
< 40	85 (62.5)
> 40	51 (37.5)
Education	
Primary	7 (5.1)
Secondary	54 (39.7)
University	75 (55.2)
Smoking status	
Never	118 (86.8)
Former	5 (3.7)
Current	13 (9.6)
Physical activity	
Inactive	67 (49.3)
Active	47 (34.6)
Very active	22 (16.2)
Alcohol intake	
Never	117 (86.0)
1–3 unit a week	19 (13.9)
	Mean$\pm$SD
Weight (kg)	67.28 $\pm$ 16.3
Height (cm)	160.97 $\pm$ 7.8
BMI (kg/m²)	25.9 $\pm$ 6.0
Body fat (%)	29.5 $\pm$ 10.9
Systolic (mmHg)	120.7 $\pm$ 18.6
Diastolic (mmHg)	77.4 $\pm$ 11.2

cutoff value (>24.8 kg/m²) was selected. This cutoff value improved the sensitivity (80%), specificity (34%) and AUC value 0.867 of BMI in identifying obese individuals (Table 2).

The agreement between BMI and BF% in categorizing subjects with/without obesity was also compared. Using the standard BMI cutoff value, a κ -value of 0.532 was obtained, indicating low agreement. In contrast, the new BMI cutoff value increased the κ -value to 0.722, indicating acceptable agreement (Table 2). However, both agreement results were not statistically significant ($p > 0.05$).

Based on logistic regression, obese subjects based on the new cutoff values were 2.5 times more likely to have

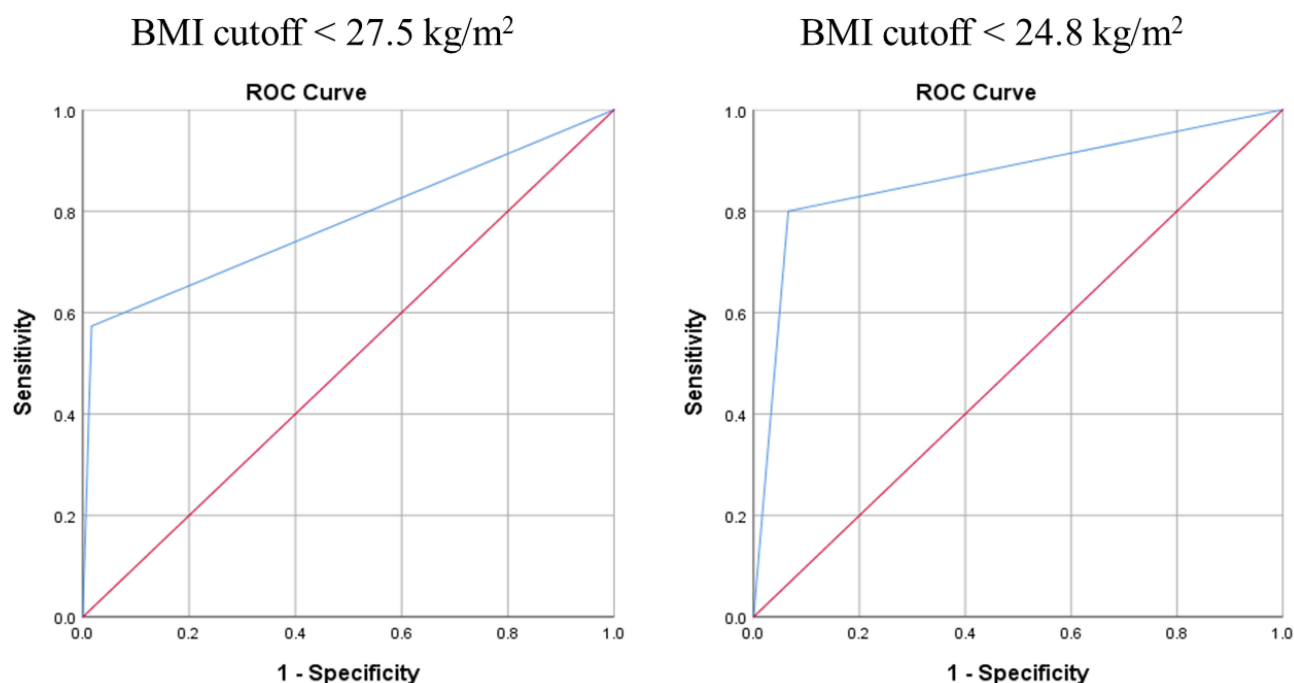


Figure 1 ROC analysis using body mass index (BMI) at two different cutoff values (standard $<27.5 \text{ kg/m}^2$; optimal $<24.8 \text{ kg/m}^2$). The area under the curve is larger for BMI $<24.8 \text{ kg/m}^2$ compared to $<27.5 \text{ kg/m}^2$.

hypertension (OR=2.546, 95% CI 1.158–5.600). In contrast, the standard BMI cutoff did not predict hypertension risk among the subjects (Table 3).

Discussion

This study revealed that the standard BMI cutoff did not predict obesity defined by BF%. However, after optimizing the cutoff value ($>24.8 \text{ kg/m}^2$), BMI showed high sensitivity in identifying subjects with obesity defined by

BF%. The new BMI cutoff also predicted hypertension risk among the subjects.

This study found a poor agreement between obesity defined by BF% and standard BMI cutoff. Okorodudu and co-workers conducted a study on the diagnostic performance of BMI to identify excessive adiposity. Similar to our results, they found that standard BMI cutoff ($>27.5 \text{ kg/m}^2$) showed a good specificity but poor sensitivity to identify adiposity. The current definition of obesity based on body weight has

Table 2 Agreement and ROC Analysis Between Standard (27.5 kg/m^2) and New BMI (24.8 kg/m^2) Cutoffs and BF% in Categorizing Obesity

BMI Cut-off Point (kg/m^2)	Body Fat Percentage		Kappa Value	p-value ^a	Specificity ^b (%)	Sensitivity ^b (%)	Area Under the Curve ^b
	Normal N (%)	Obese N (%)					
24.8							
Normal	57 (93.4)	15 (20.0)					
Obese	4 (6.3)	60 (80.0)	0.722	0.058	34.0	80.0	0.778
27.5							
Normal	60 (98.4)	29 (42.7)					
Obese	1 (1.6)	43 (57.3)	0.532	0.064	98.4	56.0	0.867

Notes: ^a indicates p-value of kappa analysis; ^b indicates results from receiver-operating characteristic curve.

Table 3 The Association Between Hypertension and Obesity Defined Using Standard (27.5 kg/m²) and New Cutoff Values (24.8 kg/m²)

BMI Cut-Off Point (kg/m ²)	Normotensive (n = 100)	Hypertensive (n=36)	χ^2 value ^a	p-value ^a	OR ^b	95% CI ^b
BMI (>24.8)			5.566	0.018*	2.546	1.158–5.600
Normal n (%)	59 (59.0)	13 (36.1)				
Obese n (%)	41 (41.0)	23 (63.9)				
BMI (>27.5)			0.316	0.574	1.258	0.565–2.804
Normal n (%)	69 (69.0)	23 (63.9)				
Obese n (%)	31 (31.0)	13 (36.1)				

Notes: *Significant level at $p < 0.05$; ^a indicates results from Chi-square analysis; ^b indicates results from binary logistic regression analysis.

Abbreviations: CI, confidence interval; OR, odds ratio; χ^2 , chi-square.

neglected the individual's body composition, particularly body fat. Their study concluded that current BMI cutoff values underdiagnose excess adiposity in many individuals. Their findings agree with our results, in which 42.7% of subjects with high BF% individuals were misclassified as non-obese.^{16,19} Our findings were also consistent with a study involving 7221 Koreans by Lee et al, which reported that 21.6% of individuals were misclassified as non-obese by standard BMI cutoff (>27.5 kg/m²), but they had central obesity defined by weight–height ratio (>0.5).²⁰ Therefore, the standard BMI cutoff for obesity is imperfect since it misinterprets low body weight as low body fat percentage. Therefore, a new cutoff value is necessary to identify subjects with high adiposity. Hence, our study suggested that a cutoff point of 24.8 kg/m² gives a good sensitivity (80%) and specificity (34%), in agreement with many studies which suggest lowering the Asian obesity cutoff values to below 25 kg/m².^{20,21}

The association between obesity and hypertension has been well documented. Many studies cited that obesity increased total blood volume, stroke volume, cardiac output, and increased peripheral vascular resistance, leading to increased blood pressure.²² This study showed that a lower BMI cutoff (24.8 kg/m²) could better identify hypertensive individuals. At BMI >24.8 kg/m², a stronger association between obesity and hypertension was shown. Asians have a higher body fat percentage at lower BMI compared to Caucasians.²² Substantiating this idea, they might also suffer from the complication of high adiposity at lower BMI. Our new proposed BMI cutoff was consistent with findings from 2 studies. The first study led by Cai and co-workers involving 5720 Chinese individuals showed a more significant association of obesity to hypertension when body fat was taken into account, measured by weight–height ratio. They concluded that the cutoff between 23.9 kg/m² to 25.6 kg/m² for men and 24.4 kg/m² to

25.4 kg/m² for women showed higher specificity and sensitivity in detecting hypertensive individuals.²³ This finding was supported by Lashkardoost et al via a cross-sectional study involving 230 Iran women, which showed that hypertension risk was greater in BMI above 25.6 kg/m².²⁴ Hence, an optimal BMI value will help to identify populations with metabolic derangements like hypertension so early intervention could be implemented.¹⁵

Proposing a new BMI cutoff requires a large, representative sample size. For example, in a recent study using electronic health records in England (n=1,472,819), Caleyachetty et al showed that BMI cutoff to identify type II diabetes was significantly different across subjects of different ethnicity. While the cutoff value was 30.0 kg/m² for Caucasians, South Asians (28.1 kg/m²), Arabians (26.6 kg/m²) and Chinese (26.9 kg/m²) experienced type II diabetes at a lower cutoff.²⁵ In line with this, the current study suggests that a new BMI cutoff may be needed to identify Malaysians with excess body fat and hypertension. However, the new cutoff suggested may not be valid for the general Malaysian population due to the small sample size. Instead, it needs to be validated in a larger, more representative cohort.

This study is also limited by the convenient sampling method, undermining its generalization to the Malaysian population. The subjects were not randomly selected from the general population. Instead, they volunteered for a health screening programme conducted in a shopping mall in Kuala Lumpur. Therefore, the study is subjected to selection and volunteer bias. The subjects could be more health-conscious and of better socioeconomic background than the general Malaysian population. The subjects' detailed medical and medication history was not available to the researchers during the health screening programme. BMI and BF% were only measured once at its baseline for all participants. It is worth noting that there is still no consensus on the accurate BF%

range for obesity even though the current definition by WHO (>25% for men and >35% for women) is adopted as a diagnostic measurement in this study. Unlike many studies, our study did not measure waist-circumference of all participants recommended by Malaysia Clinical Practice Guidelines on Management of Obesity (2004) which correlates well with abdominal fat irrespective of BMI. Thirdly, our sample size for obese individuals is small. This limitation may occur due to our health-conscious respondents who adopt a healthy lifestyle and undergo regular health screening.

Conclusion

In conclusion, this study suggests that the use of standard BMI cutoff for obesity (27.5 kg/m^2) should be reassessed by taking BF% into account. BMI is an indirect and imperfect measurement of adiposity. The new BMI cutoff, 24.8 kg/m^2 , performed better in detecting individuals with obesity defined by BF% and hypertension. Hence, further studies on the relationship between obesity and non-communicable diseases such as diabetes and dyslipidaemia can also be explored using the new cutoff value.

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Disclosure

The authors report no conflicts of interest in this work.

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