Optimal BMI cut-off values for predicting diabetes, hypertension and hypercholesterolaemia in a multi-ethnic population

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Abstract

Objective: To determine the optimal cut-offs of BMI for Malaysian adults.
Design: Population-based, cross-sectional study. Receiver operating characteristic curves were used to determine the cut-off values of BMI with optimum sensitivity and specificity for the detection of three cardiovascular risk factors: diabetes mellitus, hypertension and hypercholesterolaemia. Gender-specific logistic regression analyses were used to examine the association between BMI and these cardiovascular risk factors.
Setting: All fourteen states in Malaysia.
Subjects: Malaysian adults aged $\geq$18 years (*n* 32 703) who participated in the Third National Health and Morbidity Survey in 2006.
Results: The optimal BMI cut-off value for predicting the presence of diabetes mellitus, hypertension, hypercholesterolaemia or at least one of these cardiovascular risk factors varied from 23·3 to 24·1 kg/m² for men and from 24·0 to 25·4 kg/m² for women. In men and women, the odds ratio for having diabetes mellitus, hypertension, hypercholesterolaemia or at least one cardiovascular risk factor increased significantly as BMI cut-off point increased.
Conclusions: Our findings indicate that BMI cut-offs of 23·0 kg/m² in men and 24·0 kg/m² in women are appropriate for classification of overweight. We suggest that these cut-offs can be used by health professionals to identify individuals for cardiovascular risk screening and weight management programmes.

Keywords
BMI
Optimal cut-off
Diabetes
Hypertension
Hypercholesterolaemia

Overweight and obesity are associated with an increased risk of CVD, some cancers and all-cause mortality[1]. The WHO recommends the use of BMI $\geq$ 25·0 kg/m² and BMI $\geq$ 30·0 kg/m² for the definition of overweight and obesity, respectively[2]. These cut-off points were based on studies of associations between BMI and morbidity and mortality in Western populations. Subsequently, several studies have revealed that Asians have elevated risk of hypertension, type 2 diabetes and dyslipidaemia at lower BMI[3–8]. Thus, use of the WHO BMI cut-off values may fail to detect a significant proportion of those at risk of CVD in routine health screening in Asian populations. The WHO/International Association for the Study of Obesity (IASO)/International Obesity Task Force (IOTF)[9] have proposed BMI cut-off values of 23·0–24·9 kg/m² for classification of overweight and of $\geq$25·0 kg/m² for obesity

for adult Asians. However, some researchers have also suggested that country-specific and ethnic-specific BMI cut-offs for Asians are needed[10–12]. A recent study proposed, for Malaysian adults, BMI cut-off values of 23·3 to 25·5 kg/m² in men and 24·9 to 27·4 kg/m² in women for predicting dyslipidaemia, hypertension, diabetes or at least one cardiovascular risk factor (CRF)[13], but involved only a small sample size of patients who attended primary-care clinics. Thus, in order to determine more accurate optimal cut-off values of BMI for Malaysian adults, we analysed data from a nationally representative sample. We also sought to compare the sensitivity and specificity of the obtained BMI cut-off values with the WHO (1995)[2] and WHO/IASO/IOTF (2000)[9] cut-offs for predicting diabetes mellitus, hypertension and hypercholesterolaemia or at least one of these CRF.

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Methodology

Study population

The present analysis used data from the Third National Health and Morbidity Survey (NHMS III), which was carried out in 2006. The NHMS is a national population-based survey conducted every 10 years, beginning in 1986. The NHMS is a non-institutionalized, nationally representative, cross-sectional survey that assesses several aspects of population health, including burden of disease, health-care utilization and costs.

Sampling strategy

The NHMS III sampling plan was a two-stage stratified random sampling strategy proportional to the population size, as provided by the Department of Statistics. At the first stage, enumeration blocks formed the sampling unit with eighty to 120 living quarters in each. One living quarter was expected to contain 4·4 individuals. All households and persons in a selected living quarter were included in the survey. A total of 2150 enumeration blocks and 17 251 living quarters were randomly sampled and included in the NHMS[14].

Data collection

Data were collected via face-to-face interview using a bilingual (Malay and English languages) pre-coded questionnaire. All interviewers were trained at the central level. Repeated visits of up to three times were carried out to ensure response, both at the household and individual level. A non-responder was classified as a household member who did not respond to any question in the questionnaire. A pilot study was carried out to test questionnaires, field logistics and central monitoring activities.

The study was funded by the Ministry of Health Malaysia and ethical approval was obtained from the Medical Research and Ethics Committee, Ministry of Health Malaysia. Written informed consent was obtained from all participants prior to the interview.

Measurement of variables of interest

Variables of interest were BMI, diabetes mellitus, hypertension and hypercholesterolaemia.

Anthropometric measurements

All participants had their height and weight measurements taken. Height was measured without shoes to the nearest 0·1 cm using a SECA 206 portable body meter (Seca, Hamburg, Germany). For elderly participants who could not stand upright or had kyphosis, half arm span was measured to the nearest 0·1 cm. This was then used to estimate standing height using a predictive equation[15]. Body weight was measured in light clothing without shoes to the nearest 0·1 kg using a Tanita digital lithium weighing scale (Tanita, Tokyo, Japan). BMI (kg/m^2) was calculated as weight (in kilograms) divided by the square of height (in metres).

Hypertension

Two readings of systolic and diastolic blood pressure were taken at rest, 15 min apart, using an Omron Digital Automatic Blood Pressure Monitor model HEM-907 (Omron Healthcare, Kyoto, Japan) with appropriate cuff size. The average reading was used. Hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg.

Hypercholesterolaemia

Total cholesterol level was measured after an overnight fast using a Roche Accutrend GC machine (Roche Diagnostics, Mannheim, Germany). Hypercholesterolaemia was defined as total cholesterol ≥5·2 mmol/l.

Diabetes mellitus

All participants who claimed to be non-diabetic had their blood glucose tested, after an overnight fast of 8 to 10 h, by a trained nurse using the finger-prick method and a Roche Accutrend GC glucometer. Those with fasting blood glucose ≥6·1 mmol/l were considered to be diabetic.

Statistical analyses

All statistical analyses were performed using the statistical software package PASW Statistics 18·0 for Windows (SPSS Inc.). All analyses took into account the complex survey design and unequal selection probabilities. Findings are reported as the weighted estimates of the prevalence with 95 % confidence intervals. An age-adjusted logistic regression model was used to determine the association between BMI and CRF (diabetes mellitus, hypertension, hypercholesterolaemia and at least one of these risk factors). The odds ratios of having these CRF were calculated at the different BMI cut-offs as compared with the lowest BMI. Receiver operating characteristic (ROC) curves were used to determine the optimal cut-off values of BMI with optimum sensitivity and specificity for the prediction of CRF. Sensitivity is defined as the probability of correctly identifying those with diabetes, hypertension, hypercholesterolaemia or at least one of these risk factors for a given BMI cut-off point. Specificity is defined as the probability of correctly identifying those without diabetes, hypertension, hypercholesterolaemia or at least one risk of these risk factors at a given BMI cut-off point. The optimal BMI cut-off value was determined by using the point with the highest Youden index (sensitivity+(specificity −1))[16]. The area under the curve (AUC) with 95 % confidence intervals was generated to indicate the diagnostic performance of BMI for identification of those having CRF. For all analyses, *P* values < 0·05 were considered statistically significant.

Results

The sample consisted of 32 703 respondents (14 980 men and 17 723 women), with an overall response rate of approximately 97 %. The median age was 41·0 years (interquartile range, 23·0 years). Fifty-nine per cent of the respondents were from urban areas and 41 % from rural areas. The ethnic distribution of the sample, comprising 54·9 % Malays, 20·3 % Chinese, 8·3 % Indians, 11·5 % indigenous non-Malay and 5·0 % other ethnic groups, approximates that in the general population.

The prevalence of overweight (BMI ≥ 25·0 kg/m^2) and obesity (BMI ≥ 30·0 kg/m^2) was 29·1 % and 14·1 %, respectively. The distribution of these sample characteristics by gender is presented in Table 1. There were significant associations between BMI and the presence of diabetes, hypertension, hypercholesterolaemia or at least one CRF. The age-adjusted odds ratio of diabetes, hypertension, hypercholesterolaemia or at least one CRF increased with increase in BMI for both men and women (Table 2).

The optimal BMI cut-off value for predicting the presence of diabetes mellitus, hypertension, hypercholesterolaemia or at least one CRF varied from 23·3 to 24·1 kg/m^2 for men and from 23·9 to 25·4 kg/m^2 for the women (Table 3). The optimal BMI cut-off values for women were higher than for men for all risk factors. The BMI cut-off value for predicting diabetes, hypertension, hypercholesterolaemia or at least one CRF in men was 23·7, 24·1, 23·3 and 23·3 kg/m^2, respectively, and in women was 24·9, 25·4, 23·9 and 24·0 kg/m^2, respectively.

Comparison of three major ethnic groups in Malaysia showed that Indian men had the lowest BMI cut-off points compared with Malay and Chinese men for diabetes and hypercholesterolaemia (Table 3). The BMI cut-off point for diabetes for Indian men was 1·4 and 2·1 kg/m^2 lower than that for Malay and Chinese men, respectively; while for hypercholesterolaemia it was 1·1 and 1·7 kg/m^2 lower than that for Malay and Chinese men, respectively. However, Chinese women had the lowest BMI cut-off values compared with Malay and Indian women for all of the risk factors.

The BMI cut-off values for men obtained from the present study, which ranged from 23·3 kg/m^2 for hypercholesterolaemia and at least one CRF to 24·1 kg/m^2 for hypertension, were lower than the cut-off value (BMI ≥ 25·0 kg/m^2) recommended by WHO[2], but slightly higher than that (BMI ≥ 23·0 kg/m^2) recommended by IASO/IOTF/WHO[9] for classification of overweight (Table 3).

For women, the BMI cut-off values for predicting diabetes and hypertension in the present study were comparable with those of the WHO[2], but much higher than the IASO/IOTF/WHO[9] cut-off values. As for predicting

Table 1 Characteristics of respondents: Malaysian adults aged ≥18 years (n 32 703), Third National Health and Morbidity Survey, 2006

	Men			Women		
	n	%	95 % CI	n	%	95 % CI
Residential area						
Urban	8616	63·1	62·2, 63·9	10 811	66·4	65·7, 67·1
Rural	6364	36·9	36·1, 37·8	6912	33·6	32·9, 34·3
Ethnicity						
Malay	8267	54·6	53·0, 56·1	9692	54·1	52·6, 55·6
Chinese	3091	22·1	20·8, 23·5	3545	21·4	20·1, 22·7
Indian	1158	8·3	7·6, 9·0	1559	9·4	8·6, 10·2
Other Indigenous	1700	10·2	9·3, 11·0	2047	10·3	9·5, 11·1
Others	764	4·9	4·2, 5·7	880	4·8	4·3, 5·4
Age group (years)						
18–29	4116	27·4	26·5, 28·3	4660	26·4	25·6, 27·2
30–39	3052	20·4	19·6, 21·1	3755	21·1	20·5, 21·8
40–49	3189	21·3	20·6, 22·0	4062	23·0	22·3, 23·6
50–59	2534	17·1	16·4, 17·8	2940	16·7	16·1, 17·3
60–69	1404	9·3	8·8, 9·8	1526	8·5	8·1, 9·0
≥69	685	4·5	4·2, 4·9	780	4·3	4·0, 4·7
BMI (kg/m^2)						
<23·0	6363	41·7	40·8, 42·6	6843	38·6	37·8, 39·4
23·0–24·99	2713	18·3	17·6, 18·9	2648	15·1	14·5, 15·6
25·0–27·49	2723	18·4	17·8, 19·1	2816	15·8	15·3, 16·4
27·5–29·99	1678	11·4	10·9, 12·0	2297	12·9	12·4, 13·4
≥30·0	1503	10·2	9·7, 10·7	3119	17·6	17·0, 18·2
Diabetes*	1726	11·8	11·2, 12·4	2001	11·4	10·9, 11·9
Hypertension†	5785	38·4	37·6, 39·3	6752	37·6	36·9, 38·4
Hypercholesterolaemia‡	2726	19·8	19·0, 20·5	4046	24·4	23·6, 25·1
At least one CRF§	7265	52·5	51·6, 53·4	8520	51·1	50·2, 51·9

CRF, cardiovascular risk factor.
*Diabetes defined as fasting blood glucose ≥6·1 mmol/l or known diabetes.
†Hypertension defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg or known hypertension.
‡Hypercholesterolaemia defined as total cholesterol ≥5·2 mmol/l or known hypercholesterolaemia.
§Diabetes or hypertension or hypercholesterolaemia.

Table 2 Association of BMI with CRF by gender: Malaysian adults aged ≥18 years (*n* 32 703), Third National Health and Morbidity Survey, 2006

CRF	Men				Women			
	BMI (kg/m²)	aOR	95 % CI	*P* value	BMI (kg/m²)	aOR	95 % CI	*P* value
Diabetes (*n* 3727)	<23·0	Ref.			<23·0	Ref.		
	23·0–24·99	1·79	1·51, 2·11	<0·001	23·0–24·99	1·96	1·64, 2·34	<0·001
	25·0–27·49	2·10	1·79, 2·46	<0·001	25·0–27·49	2·92	2·49, 3·42	<0·001
	27·5–29·99	2·94	2·48, 3·49	<0·001	27·5–29·99	3·16	2·67, 3·73	<0·001
	≥30·0	3·84	3·23, 4·57	<0·001	≥30·0	4·44	3·82, 5·16	<0·001
Hypertension (*n* 12 537)	<23·0	Ref.			<23·0	Ref.		
	23·0–24·99	1·48	1·34, 1·65	<0·001	23·0–24·99	1·65	1·47, 1·86	<0·001
	25·0–27·49	2·16	1·95, 2·40	<0·001	25·0–27·49	2·51	2·25, 2·80	<0·001
	27·5–29·99	3·11	2·77, 3·50	<0·001	27·5–29·99	3·84	3·42, 4·30	<0·001
	≥30·0	4·89	4·28, 5·59	<0·001	≥30·0	6·14	5·51, 6·85	<0·001
Hypercholesterolaemia (*n* 6772)	<23·0	Ref.			<23·0	Ref.		
	23·0–24·99	1·58	1·39, 1·79	<0·001	23·0–24·99	1·48	1·31, 1·66	<0·001
	25·0–27·49	1·80	1·60, 2·03	<0·001	25·0–27·49	1·75	1·55, 1·96	<0·001
	27·5–29·99	1·94	1·68, 2·23	<0·001	27·5–29·99	1·91	1·69, 2·15	<0·001
	≥30·0	1·99	1·72, 2·31	<0·001	≥30·0	2·12	1·91, 2·37	<0·001
At least one CRF§ (*n* 15 785)	<23·0	Ref.			<23·0	Ref.		
	23·0–24·99	1·62	1·46, 1·80	<0·001	23·0–24·99	1·66	1·48, 1·85	<0·001
	25·0–27·49	2·40	2·16, 2·68	<0·001	25·0–27·49	2·37	2·12, 2·65	<0·001
	27·5–29·99	3·48	3·07, 3·96	<0·001	27·5–29·99	3·30	2·93, 3·71	<0·001
	≥30·0	5·48	4·73, 6·35	<0·001	≥30·0	5·30	4·74, 5·92	<0·001

CRF, cardiovascular risk factor; aOR, age-adjusted odds ratio; Ref., reference category.

hypercholesterolaemia and at least one CRF, the cut-offs obtained in present study were much lower than those of the WHO[2] and much higher than the IASO/IOTF/WHO[9] cut-offs (Table 3).

In men, the sensitivity at the optimal cut-off for detecting diabetes, hypertension, hypercholesterolaemia or at least one CRF ranged from 62·1 to 71·3 % and the specificity ranged from 51·5 to 62·2 %. In women, the sensitivity ranged from 62·4 to 70·7 % and the specificity ranged from 51·1 to 67·6 % (Table 4).

Discussion

Our data support the initiative to adopt lower BMI cut-off values for defining overweight instead of the WHO recommendation of BMI ≥ 25·0 kg/m² among Malaysian adults. Our results showed that the optimal BMI cut-off values for defining overweight are 23·0 kg/m² for men and 24·0 kg/m² for women. In 2005, a similar but smaller study involving 1833 adults from ninety-three primary-care clinics in Malaysia reported optimal BMI cut-off values of 23·5 kg/m² for men and 24·9 kg/m² for women for predicting hypertension, diabetes and dyslipidaemia[13]. Most of the studies in other Asian countries have also reported lower BMI cut-off values than the WHO recommendation (BMI ≥ 25·0 kg/m²) as more appropriate for defining overweight for their population. Similar findings were reported by studies conducted in Thailand (23·0 kg/m²)[8], Japan (23·0–24·9 kg/m²)[5], China (23·0–24·0 kg/m²)[3,17], India (23·0 kg/m²)[18], Taiwan (24·5–25·0 kg/m²)[4], Pakistan (21·0–23·0 kg/m²)[6] and Singapore (22·0–24·0 kg/m²)[7]. The slight variations in the optimal BMI cut-offs

among these Asian populations were most probably due to differences in sample size, age group, health risk factors or the methods used in determining the 'optimal' cut-off. However, all of these findings support the WHO/IASO/IOTF recommendation to use BMI = 23·0–24·9 kg/m² for classification of overweight and BMI ≥ 25·0 kg/m² for classification of obesity among adult Asians.

Our study showed that there are gender and ethnic variations in the optimal BMI cut-off values in relation to the CRF studied. The optimal cut-off values for men were lower than those for women regardless of ethnicity for all of the risk factors investigated. This implies that men are at greater risk for CVD than women at a given BMI value[4–6,12].

Optimal cut-off values for predicting a disease outcome increase with mean BMI when other factors (age, ethnicity, sex, socio-economic status, lifestyle) remain constant. Therefore, a population with a high mean BMI will have a high BMI cut-off value[12]. Our findings showed that Chinese women had the lowest mean BMI (24·0 kg/m²) compared with Malay (26·0 kg/m²) and Indian women (26·3 kg/m²), and their optimal BMI cut-off points were also the lowest compared with Malay and Indian women for all of the risk factors. This means that Chinese women's risk for CVD is greater at a given BMI value than for women of other ethnicities. Similar results were revealed by another Malaysian study[13]. However, difference in mean BMI alone does not account for all of the variation in optimal cut-off value. Some researchers have suggested that the differences in genetic and environmental factors (dietary preferences and patterns, health risk behaviours, culture, sociodemographic characteristics) among different ethnic groups may play an important role in the different patterns

Table 3 AUC, sensitivities and specificities of optimal BMI cut-offs associated with CRF by gender and ethnicity: Malaysian adults aged ≥18 years (n 32 703), Third National Health and Morbidity Survey, 2006

CRF	Ethnicity	Men					Women				
		AUC	95 % CI	BMI cut-off (kg/m²)	Sens. (%)	Spec. (%)	BMI cut-off (kg/m²)	95 % CI	AUC	Sens. (%)	Spec. (%)
Diabetes (n 3727)	All*	0·650	0·637, 0·663	23·7	71·3	51·8	24·9	0·656, 0·679	0·668	70·7	55·6
	Malay	0·660	0·643, 0·677	23·7	74·4	51·1	24·9	0·644, 0·674	0·659	74·1	51·3
	Chinese	0·606	0·577, 0·635	24·4	60·0	55·0	23·9	0·636, 0·692	0·664	66·2	59·2
	Indian	0·591	0·553, 0·629	22·3	82·7	31·6	24·6	0·610, 0·675	0·643	77·6	48·0
Hypertension (n 12 537)	All*	0·662	0·653, 0·671	24·1	62·1	62·2	25·4	0·685, 0·701	0·693	62·4	67·6
	Malay	0·674	0·662, 0·686	23·7	74·2	51·4	24·6	0·681, 0·702	0·692	71·9	58·0
	Chinese	0·641	0·622, 0·661	23·6	66·8	53·7	24·0	0·674, 0·710	0·692	60·7	67·6
	Indians	0·632	0·599, 0·666	24·4	64·7	56·3	24·6	0·645, 0·701	0·673	75·2	52·7
Hypercholesterolaemia (n 6772)	All*	0·600	0·589, 0·611	23·3	67·6	51·5	23·9	0·598, 0·615	0·607	65·9	51·1
	Malay	0·605	0·590, 0·619	23·2	69·7	47·7	24·0	0·590, 0·615	0·603	67·4	50·4
	Chinese	0·539	0·512, 0·565	23·8	59·2	48·4	22·5	0·567, 0·613	0·590	70·5	41·0
	Indian	0·565	0·523, 0·608	22·1	84·5	29·2	23·3	0·545, 0·614	0·580	75·7	37·0
At least one CRF (n 15 785)	All*	0·677	0·668, 0·686	23·3	67·2	59·6	24·0	0·686, 0·702	0·694	65·0	62·8
	Malay	0·693	0·681, 0·705	23·3	68·9	61·0	24·4	0·684, 0·706	0·695	65·1	64·8
	Chinese	0·639	0·619, 0·660	23·7	63·7	57·6	23·6	0·670, 0·706	0·688	62·5	61·5
	Indian	0·636	0·602, 0·669	22·2	81·6	38·1	24·3	0·645, 0·701	0·673	68·8	53·9

AUC, area under the ROC curve; ROC, receiver operating characteristic; CRF, cardiovascular risk factor; Sens., sensitivity; Spec., specificity.
*All ethnic groups (Malay, Chinese, Indian, Other Indigenous and Others).

for prevalence of CRF and hence the BMI cut-off values[12,19]. This probably explains why Indian men had the lowest BMI cut-off values compared with Chinese and Malay men for predicting diabetes, hypercholesterolaemia and at least one CRF even though they had the highest mean BMI (25·1 kg/m²) compared with Malay (24·6 kg/m²) and Chinese (24·5 kg/m²) men[14]. In Indian men, higher prevalences of diabetes and hypercholesterolaemia at lower BMI levels led to lower optimal BMI cut-off values[14]. This strengthens the argument for ethnic- and country-specific BMI cut-off values for defining overweight and obesity in Asian countries[10–12].

Our study revealed that the age-adjusted odds ratios of diabetes mellitus, hypertension, hypercholesterolaemia and at least one CRF increased significantly for those with BMI ≥ 23·0 kg/m² compared with those with BMI < 23·0 kg/m² in both men and women. Although the cause-and-effect relationship between overweight and/or obesity and CRF cannot be drawn in the present study, numerous prospective studies have documented that cardiovascular risk, cancer and all-cause mortality are attributed to overweight and obesity[1,20]. It is worth noting that individuals in the category BMI = 23·0–24·99 kg/m² had more than 50 % increased risk for diabetes, hypertension and hypercholesterolaemia than those in the category BMI < 23·0 kg/m². Therefore, those with BMI of 23·0 kg/m² or greater are prime candidates for cardiovascular risk screening and for weight management and lifestyle modifications[21,22].

The diagnostic performance of a BMI cut-off value is assessed by calculating its sensitivity and specificity for predicting the CRF. Ideally, good diagnostic performance of a BMI cut-off value should demonstrate 100 % sensitivity (i.e. predict all those who have CRF as having CRF) and 100 % specificity (i.e. not predict anyone without CRF as having CRF). However, 100 % sensitivity and specificity is usually not achieved in medical diagnostics; there is generally a trade-off between the sensitivity and specificity. Our results showed that the optimal BMI cut-offs (23·3 to 24·1 kg/m² for men and 24·0 to 25·4 kg/m² for women) determined in the present study correctly identified more than 60 % of those with CRF and correctly identified more than 50 % of those without. Use of the BMI cut-offs of 25·0 kg/m² and 30·0 kg/m², however, had lower sensitivities and higher specificities compared with the optimal cut-offs presented in our study. A BMI cut-off of ≥25·0 kg/m² will miss almost half those with CVD risks in men. While the BMI cut-off of ≥30·0 kg/m² had good specificity, it failed to identify approximately 80 % of individuals with CVD risks in both sexes. Adoption of a BMI cut-off point having a higher sensitivity (which also means a higher false-positive rate), while minimizing the false-negative rate, is needed in clinical and public health practice. This is because there is relatively less harm and cost in recommending the false-positive group for weight management and CRF screening compared with medical cost incurred for treatment of those with obesity-related

Table 4 Sensitivities and specificities of different BMI cut-offs associated with CRF: Malaysian adults aged ≥18 years (*n* 32 703), Third National Health and Morbidity Survey, 2006

	Men			Women		
CRF	BMI cut-off (kg/m^2)	Sens. (%)	Spec. (%)	BMI cut-off (kg/m^2)	Sens. (%)	Spec. (%)
Diabetes (*n* 3727)	23·7*	71·3	51·8	24·9*	70·7	55·6
	25·00†	57·8	63·1	25·00†	69·5	56·6
	30·00†	17·8	91·0	30·00†	30·4	84·1
	23·00‡	76·6	45·0	23·00‡	83·2	41·1
Hypertension (*n* 12 537)	24·1*	62·1	62·2	25·4*	62·4	67·6
	25·00†	53·8	69·8	25·00†	64·8	64·9
	30·00†	16·0	93·7	30·00†	28·0	88·8
	23·00‡	71·5	51·3	23·00‡	78·2	49·0
Hypercholesterolaemia (*n* 6772)	23·3*	67·6	51·5	23·9*	65·9	51·1
	25·00†	50·1	63·3	25·00†	55·5	60·0
	30·00†	12·7	90·6	30·00†	19·1	87·1
	23·00‡	70·2	45·6	23·00‡	72·7	43·8
At least one CRF (*n* 15 785)	23·3*	67·2	59·6	24·0*	65·0	62·8
	25·00†	51·4	26·1	25·00†	56·9	70·2
	30·00†	14·5	94·5	30·00†	20·5	91·9
	23·00‡	69·8	56·0	23·00‡	73·1	53·5

CRF, cardiovascular risk factor; Sens., sensitivity; Spec., specificity.
*Optimal cut-off proposed by the present study.
†WHO (1995) classification[2].
‡WHO/International Association for the Study of Obesity/International Obesity Task Force (2000) classification[9].

diseases[23]. Furthermore, it will create awareness about the potential risks of further weight gain among those classified as overweight but not having any cardiovascular risks as yet[24].

The present study is the first nationally representative one to determine the optimal BMI cut-off points for predicting CRF among the Malaysian adult population. The major strength of our study is its representativeness of the Malaysian population. It is population-based, with a larger sample size than the previous studies conducted in this country. There are several limitations. Our study design is cross-sectional; therefore, causal inference cannot be drawn because the associations of BMI and CRF (diabetes mellitus, hypertension and hypercholesterolaemia) are probably not stable over time. A prospective study should be conducted to investigate the association between the duration of overweight and obesity and the incidence of CVD and its risk factors. The study reported age-adjusted odds ratios to assess the strength of association between BMI status and CRF by gender using multivariable logistic regression analysis. However, other confounders including smoking status, alcohol consumption, family history and physical activity were not controlled for during the statistical analysis. The point on the ROC curve closest to (0,1), the Youden index and equal sensitivity and specificity are methods commonly used for determining the 'optimal' cut-off point using two criteria based on ROC curves. There is an ongoing debate about which method should be used for identifying the 'optimal' cut-off point. However, the Youden index has been shown to be better in overall correct classification rates compared with the point on the ROC curve closest to (0,1) method[16]. Furthermore, comparisons among studies over the optimal BMI cut-off points may be difficult and inappropriate since different studies apply different methods in their analysis.

Conclusions

Our findings indicate that the optimal BMI cut-off for predicting diabetes, hypertension, hypercholesterolaemia or at least one CRF ranged from 23·3 to 24·1 kg/m^2 for men and from 23·9 to 25·4 kg/m^2 for women. These BMI cut-offs demonstrated higher sensitivities and specificities than the WHO recommendation but are compatible with the WHO/IASO/IOTF classification. The age-adjusted odds ratio for having diabetes, hypertension, hypercholesterolaemia or at least one CRF increased in those with BMI < 23·0 kg/m^2 *v.* those with BMI ≥ 23·0 kg/m^2. Therefore, we propose the use of BMI cut-offs of 23·0 kg/m^2 in men and 24·0 kg/m^2 in women for defining overweight among Malaysian adults. We suggest that these cut-offs can be used by health professionals to identify individuals for cardiovascular risk screening and weight management programmes.

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