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RESEARCH ARTICLE

OPTIMAL BMI CUT-OFF VALUES FOR PREDICTING DIABETES, HYPERTENSION AND HYPERCHOLESTEROLEMIA AMONG MALAYSIAN ADULTS' POPULATION: REVISITING A DECADE OF OLD VALUES

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ABSTRACT

Background: Body Mass Index (BMI) can be used to determine bodyweight categories. This study aimed to re-examine the previous optimal BMI cut-offs in identifying the Non-Communicable Diseases (NCDs) among the Malaysian adults' population. Data were obtained from the National Health and Morbidity Survey (NHMS) 2019. Methods: It was a cross-sectional, population-based survey that employed a two-stage stratified random sampling design. A total of 10,472 adults aged 18 years and above participated in this survey throughout Malaysia, with the majority aged between 31 to 59 years. Results: The optimal BMI cut-off values for identifying diabetes, hypertension, hypercholesterolemia, and at least one NCD ranged from 22.92 to 24.81 kg/m2 for males. The highest optimal BMI cut-off value for at least one NCD in females was 26.29 kg/m2, while the lowest optimal BMI cut-off value was for hypercholesterolemia in females, which was 22.63 kg/m2. Our study has produced a more reliable and revised BMI cut-off point that can detect NCD at a lower BMI compared to available BMI classification. Conclusion: The findings highlight the importance of recognizing the issue of BMI and obesity to tackle NCD. A new set of modified BMI which is very useful for tertiary care, demonstrates the potential benefit of early detection and intervention in preventing morbidity and mortality. Hence, it would lessen the length and impact of the disease on a person's quality of life and also reduce complications and lower the mortality rates of certain diseases because early treatment is often the most effective.

KEYWORDS

Optimal BMI cut-off, obesity, Diabetes, Hypertension, Hypercholesterolemia.

1. INTRODUCTION

Body Mass Index (BMI) has been used for decades to classify obesity. Obesity prevalence is set to increase drastically by 2030 to around one billion people worldwide(WHO, 2016). National Health Morbidity Survey (NHMS) Malaysia 2015 showed that the national prevalence of overweight, obesity, and abdominal obesity has increased by 0.6%, 2.6%, and 2.0%, respectively, compared to the previous findings (NHMS 2011; NHMS 2015). Obesity is known to cause major non-communicable diseases (NCD) such as type 2 diabetes mellitus, cardiovascular disease, and hypertension (Jastreboff et al., 2019; Malaysian Clinical, 2015).

A study have reported trends of increasing BMI among China population using the China Health and Nutrition Survey (CHNS) from 1991-2011 (Nie et al., 2019). The report from CHNS revealed that mean BMI increased by 2 kg/m^2 in 20 years period from 21.65 kg/m^2 in 1991 to 23.65 kg/m^2 in 2011. Data from the National Health and Nutrition Examination Survey (NHANES) United States from 1971-2012 also revealed an increase in BMI trends among adults. In 1971, the average BMI for adults aged 20 years and above was 25.66 kg/m^2. In the year 2012, the mean BMI increased to 28.71 kg/m^2(Kranjac et al., 2016).

The first BMI cut-off points to predict diabetes, hypertension, and high cholesterol among Malaysian adults. BMI cut-off points were also determined for major ethnic groups in Malaysia and gender (Cheong et al., 2013). This retrospective study used data from the National Health Morbidity Survey (NHMS) 2006 using the AsiaPacific Guidelines on Obesity 2000 BMI classification. Cheong et al. indicate that the optimalBMI cut-offs for predicting diabetes, hypertension, hypercholesterolemia, or at least one cardiovascular risk factor (CRF) ranged from 23.3 to 24.1kg/m^2 from 23.9 to 25.4kg/m^2 for women.

There are studies on the determination of BMI cut-offs and other anthropometric measurements to predict NCD and other diseases. Studies conducted in Asian countries have documented BMI cut-off value of 27kg/m^2 in Hong Kong, Indonesia, and Singapore; 28kg/m^2 in rural Thailand; and 29kg/m^2 in Japan for identifying chronic heart disease

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(Cheong et al., 2013). Others reported BMI 24kg/m^2 to identify metabolic syndrome amongthe rural Chinese population (Pan et al., 2016). BMI of 24.6kg/m^2 for women and 25.2kg/m^2 for men to identify metabolic syndrome among the Korean population (Yang et al., 2019). A study on the Ethiopian population found out that the optimal BMI cut-off for defining obesity in Ethiopian adults was 22.2 kg/m2 for malesand 24.5 kg/m^2 for females (Sinaga et al., 2018).

Since it has been more than a decade since the last study on optimal BMI cut-off points was conducted in Malaysia which was in 2012 while using 2006 data, adding on to the rise of obesity and non-communicable diseases in Malaysia, it's important to revisit the BMI cut-off points. This paper's main objective is to re-examine the previous optimal BMI cut-offs for adults determined in 2012 by using data from NMHS 2019. We would also like to investigate whether there are any changes to BMI's optimal cut-off points for predicting diabetes mellitus, hypertension, and hypercholesterolemia established in 2012.

The expected new cut-off points for adults will also be established according to major ethnic groups in Malaysia (Malay, Chinese, and Indian). The new set of BMIs will then be used for predicting the major NCD in Malaysia, which we hope will be very useful for early health screening among patients and weight management programs in tertiary care and hospitals all over Malaysia. Early detection of NCD will be very useful for early treatment. This can mitigate possible socioeconomic and other health effects.

2. Methodology

2.1 Sample and design

Data from the Malaysia National Health and Morbidity Survey (NHMS) 2019 was used for this study. The NHMS 2019 was a population-based, nationally representative cross-sectional survey. The sampling frame of NHMS 2019 was provided by the Departmentof Statistics Malaysia, which was updated in 2014 before the sampling process. Basedon the sampling frame, Malaysia was geographically divided into enumeration blocks (EB). The sampling design used two-staged stratified random sampling. The primary stratum was made up of Malaysia's states, while the second stratum was made up of urban and rural strata. Sampling involved two stages; the Primary Sampling Unit (PSU),which was Enumeration Blocks (EBs), and the second sampling Unit (SSU), which wasLiving Quarters (LQs) within the selected EBs. A total of 10,428 LQs were selected fromthe total EBs in Malaysia. Twelve LQs were randomly selected from each selected EBs.This study's exclusion criteria include pregnant women, post-natal women (less than 60 days at the time of visit), and bedridden individuals. Also, a physically disabled person who cannot stand up-right (including those in a wheelchair), individual with body deformities such as no hand or leg, or individual with spondylolysis were excluded as well. Individual who were deaf, blind or mute were included in this study. Data collectionwas carried out from July-October 2019.

2.2 Study Instrument

Structured questionnaires were used to collect data. There were two types of questionnaires; face-to-face interview and self-administered. The face-to-face interview questionnaire was programmed into an application, and the data collection was done using a tablet. The self-administrated questionnaire was prepared in hardcopies. Before data collection, a training course was conducted for all data collectors.

Clinical assessment (weight, height, waist circumference, blood pressure measurement,fasting blood sugar, and fasting cholesterol) was done by trained nurses. For anthropometric assessment, the trained research assistants measured weight and height using the Tanita Personal Scale HD319 and SECA Stadiometer 213 that had been validated and calibrated. Bodyweight was measured to the nearest 0.1 kg, while height was measured to the nearest 0.1 cm. BMI was defined as weight in kilograms divided by the square of the heights (kg/m^2) (Asia Pacific Guidelines on Obesity, 2000). All measurements were taken twice, and the average of two readings was computed. Variables of interest for this study were BMI, diabetes, hypertension, and hypercholesterolemia status.

2.3 Statistical Analysis

Data were analyzed using SPSS statistical package version 23.0. The data were cleaned by checking for outliers and missing values. Descriptive analysis of the background characteristic was performed. Normality was checked for continuous variables. Continuous variables were expressed as mean and standard deviation (SD), and categorical variables were expressed as percentages. An age-adjusted logistic regression model was used to determine the associations between BMI and NCDs (diabetes mellitus, hypertension, hypercholesterolemia, and at least one of these risk factors). The odds ratios of having these NCDs were calculated at the different BMI categories compared to the lowest BMI. Receiver operating characteristic (ROC) curveswere used to plot sensitivity (true positive) against specificity (false positive) rates.

$$\frac{[\text{ True positive / (True positive + False negative) }]}{1 - [\text{ True negative / (True negative +False positive) }]}$$

The ROC analysis was used to quantify how accurately medical diagnostic tests (or systems) might discriminate between a diseased and "no disease" patient state. The area under the curve (AUC) indicates how well a parameter distinguishes a diagnostic state (presence or absence of diabetes, hypertension, and hypercholesterolemia in thiscase). The Youden index, a commonly used measure of overall diagnostic effectiveness, which is the maximum vertical distance or difference between the ROC curve and the diagonal or chance line, was calculated to determine BMI's optimal cut-off values. A *p*- value of less than 0.05 was used as the level of significance. Incomplete data were excluded from the analysis. Data with a refuse answer or questions not answered by the respondents were coded as missing values and were excluded from the analysis.

3. Result

A total of 10,472 adults aged 18 years and above participated in this survey throughout Malaysia, with the majority aged between 31 to 59 years. The ethnic groups were 51.0% Malays, 21.5% Chinese, 11.1% Other Bumiputras, 10.6% other ethnicities, and 5.8% Indians. The prevalence of BMI more than 23.00 kg/m^2 was 66.0%. Table 1 shows the distribution of these sample characteristics by gender.

Table 1: Distribution of respondent's characteristics by gender: adults aged ≥ 18 years old

		National (n=10472)				Male (n=4785)				Female (n=5687)			
		n	%	95% CI		n	%	95% CI		n	%	95% CI	
Residential Area	Urban	6380	78.1	76.7,	79.4	2926	77.9	76.0,	79.7	3454	78.3	76.8,	79.6
	Rural	4092	21.9	20.6,	23.3	1859	22.1	20.3,	24.0	2233	21.7	20.4,	23.2
Ethnicity	Malay	6751	51.0	47.3,	54.7	3060	49.4	45.3,	53.5	3691	52.7	48.8,	56.5
	Chinese	1327	21.5	18.0,	25.5	617	21.5	17.5,	26.1	710	21.5	18.1,	25.3
	Indian	662	5.8	4.7,	7.3	299	5.4	4.2,	7.0	363	6.3	5.0,	7.8
	Other Bumiputras	1114	11.1	9.3,	13.2	494	10.8	8.8,	13.2	620	11.4	9.5,	13.6
	Others	618	10.6	8.4,	13.2	315	12.8	9.8,	16.6	303	8.2	6.4,	10.5
Age	18-30	2411	34.2	32.3,	36.1	1161	35.5	32.7,	38.3	1250	32.8	30.9,	34.8
	31-59	5608	51.2	49.4,	53.0	2509	50.8	48.2,	53.3	3099	51.7	49.8,	53.6
	60 and above	2438	14.6	13.4,	15.9	1111	13.8	12.4,	15.2	1327	15.5	14.1,	17.0
BMI (kg/m^2)	<18.50	523	6.4	5.6,	7.3	271	7.1	5.9,	8.6	252	5.6	4.7,	6.7
	18.50 - 22.99	2335	27.6	25.9,	29.4	1156	28.8	26.3,	31.5	1179	26.2	24.3,	28.2
	23.00 - 24.99	1535	15.9	14.8,	17.0	799	18.1	16.5,	19.8	736	13.4	12.1,	14.9
	25.00 - 29.99	3266	30.5	29.1	32.0	1559	30.8	28.9,	32.9	1707	30.1	28.3,	31.9
	≥30.00	2128	19.6	18.3,	21.0	747	15.1	13.5,	16.8	1381	24.6	22.8,	26.5
Diabetes	No	7835	81.7	80.4,	82.9	3592	81.8	80.1,	83.4	4243	81.6	80.1,	83.0
	Yes	2629	18.3	17.1,	19.6	1191	18.2	16.6,	19.9	1438	18.4	17.0,	19.9
Hypertension	No	6407	70.0	68.5,	71.4	2959	69.7	67.5,	71.8	3448	70.3	68.5,	72.0
	Yes	4056	30.0	28.6,	31.5	1823	30.3	28.2,	32.5	2233	29.7	28.0,	31.5
Hypercholesterolemia	No	5657	61.9	60.0,	63.9	2924	68.0	65.6,	70.3	2733	55.5	53.2,	57.8
	Yes	4809	38.1	36.1,	40.0	1860	32.0	29.7,	34.4	2949	44.5	42.2	46.8

n = frequency ; % = percentage ; C.I = Confidence Interval

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Table 2 shows the associations between all the NCDs with BMI categories for bothmale and female. There were significant associations between increasing BMI and all the diseases except for hypercholesterolemia in a female. The highest odds with increasing BMI were among males with hypertension having: 3.22 (p=0.001), 4.49 (p=0.001) and 8.38 (p=0.001) for respective BMI of 23.00-24.99 kg/m^2, 25.00-29.99 kg/m^2 and more than 30.00 kg/m^2 compared to those with BMI less than 18.59 kg/m^2.

Table 2: BMI Association with NCDs by gender

Disease	BMI	Male				Female			
		aOR	95%CI		p-value	aOR	95%CI		p-value[a]
Diabetes	<18.50	1.00(ref.)							
	18.50 - 22.99	0.87	0.46	1.67	0.675	1.73	0.81	3.68	0.153
	23.00 - 24.99	1.32	0.68	2.57	0.410	2.20	1.08	4.52	0.031
	25.00 - 29.99	1.56	0.84	2.89	0.157	3.16	1.58	6.29	0.001
	≥30.00	2.83	1.52	5.24	0.001	5.01	2.50	10.06	0.001
Hypertension	<18.50	1.00(ref.)							
	18.50 - 22.99	1.77	0.98	3.18	0.058	1.37	0.70	2.70	0.364
	23.00 - 24.99	3.22	1.82	5.71	0.001	1.99	0.99	3.97	0.052
	25.00 - 29.99	4.49	2.57	7.84	0.001	4.30	2.22	8.33	0.001
	≥30.00	8.38	4.65	15.11	0.001	8.45	4.34	16.48	0.001
Hypercholesterolemia	<18.50	1.00(ref.)							
	18.50 - 22.99	1.29	0.71	2.34	0.401	1.02	0.64	1.63	0.923
	23.00 - 24.99	2.20	1.22	3.96	0.009	1.05	0.65	1.68	0.853
	25.00 - 29.99	2.59	1.45	4.62	0.001	1.34	0.86	2.11	0.198
	≥30.00	3.21	1.76	5.86	0.001	1.32	0.84	2.07	0.234
at least one NCD	<18.50	1.00(ref.)							
	18.50 - 22.99	1.05	0.63	1.77	0.843	1.05	0.64	1.72	0.857
	23.00 - 24.99	1.86	1.12	3.08	0.016	1.06	0.64	1.76	0.829
	25.00 - 29.99	2.45	1.49	4.02	0.001	1.54	0.95	2.50	0.083
	≥30.00	3.88	2.31	6.52	0.001	2.257	1.386	3.676	0.001

a Complex Samples Logistic Regression adjusted for age; aOR = adjusted Odds Ratio; C.I = Confidence Interval;Ref. = reference category

Table 3 shows the optimal BMI cut-off values for identifying diabetes, hypertension, hypercholesterolemia, and at least one NCD ranged from 22.92 to 24.81 kg/m^2 for males.The highest optimal BMI cut-off value was at least one NCD for females, which was 26.29 kg/m^{2,} while the lowest optimal BMI cut-off value was hypercholesterolemia for females, which is 22.63 kg/m^2. BMI performed poorly in predicting hypercholesterolemiain both males (AUC=0.58) and female (AUC=0.57). BMI cut-off point for diabetes in females was varied between races, with the lowest was among the Chinese (24.98 kg/m^2) while the highest was among the Indians respectively (28.20 kg/m^2). The BMI cut-off values for hypertension disease were similar for both genders (24.30 kg/m^2).

Table 3: Optimal BMI Cut-offs Associated with cardiovascular risk factor (CRF) by Gender and Ethnicity

Disease	Ethnicity	MALE								FEMALE							
		BMI cut-off (kg/m²)	Sens	spec	AUC	SE	p-value	95% CI		BMI cut-off (kg/m²)	Sens	spec	AUC	SE	p-value	95% CI	
Diabetes	All	24.81	0.63	0.51	0.59	0.01	<0.001	0.58	0.61	24.38	0.77	0.42	0.62	0.01	<0.001	0.60	0.64
	Malay	22.89	0.80	0.34	0.59	0.01	<0.001	0.57	0.62	25.64	0.69	0.50	0.61	0.01	<0.001	0.59	0.63
	Chinese	26.49	0.49	0.71	0.60	0.03	0.001	0.54	0.66	24.98	0.60	0.60	0.60	0.03	0.002	0.54	0.66
	Indian	25.10	0.68	0.50	0.55	0.04	0.15	0.48	0.62	28.20	0.57	0.61	0.60	0.03	0.001	0.54	0.66
Hypertension	All	24.29	0.68	0.50	0.62	0.01	<0.001	0.60	0.63	24.30	0.77	0.45	0.65	0.01	<0.001	0.63	0.66
	Malay	24.23	0.71	0.49	0.63	0.01	<0.001	0.61	0.65	25.10	0.74	0.50	0.66	0.01	<0.001	0.64	0.67
	Chinese	24.73	0.59	0.59	0.60	0.02	<0.001	0.55	0.65	24.21	0.59	0.56	0.60	0.02	<0.001	0.55	0.64
	Indian	28.06	0.42	0.76	0.58	0.04	0.025	0.51	0.65	26.05	0.70	0.47	0.59	0.03	0.005	0.53	0.65
Hypercholesterolemia	All	23.19	0.75	0.38	0.58	0.01	<0.001	0.56	0.59	22.63	0.81	0.31	0.57	0.01	<0.001	0.55	0.58
	Malay	23.04	0.77	0.37	0.58	0.01	<0.001	0.56	0.60	22.69	0.82	0.31	0.57	0.01	<0.001	0.56	0.59
	Chinese	23.00	0.73	0.37	0.53	0.03	0.182	0.49	0.58	21.82	0.77	0.32	0.54	0.02	0.107	0.49	0.58
	Indian	22.77	0.83	0.24	0.50	0.04	0.977	0.43	0.57	23.05	0.84	0.25	0.51	0.03	0.644	0.45	0.58
At least one NCD	All	22.92	0.76	0.42	0.62	0.01	<0.001	0.60	0.63	26.29	0.56	0.64	0.63	0.01	<0.001	0.61	0.65
	Malay	22.87	0.77	0.42	0.62	0.01	<0.001	0.60	0.64	25.72	0.62	0.60	0.64	0.01	<0.001	0.62	0.66
	Chinese	22.91	0.74	0.42	0.58	0.03	0.001	0.54	0.63	22.38	0.71	0.41	0.57	0.02	0.002	0.53	0.62
	Indian	25.08	0.65	0.57	0.58	0.04	0.029	0.51	0.65	22.47	0.88	0.26	0.58	0.03	0.014	0.52	0.65

Sens = Sensitivity; spec = specificity ; AUC = Area Under the Curve ; C.I = Confidence Interval

4. Discussions

This study identified BMI cut-off points and its predictive ability in predicting the occurrence of NCDs among the Malaysian population. In general, BMI showed a good predictive ability in predicting the occurrence of diabetes, hypertension, and hypercholesterolemia. The BMI cut-off points for male and female in predicting the occurrence of diabetes were 24.81 kg/m^2 and 24.38 kg/m^2 respectively. For hypertension, the BMI cut-off points for males and females were 24.29 kg/m^2 and 24.3 kg/m^2, respectively. Meanwhile, for hypercholesterolemia, the BMI cut-off points were 23.19 kg/m^2 for male and 22.63 kg/m^2 for female. Lastly, in occurrence of at least one NCD, the BMI cut-off points were 22.92 kg/m^2 for male and 26.29 kg/m^2 for female. All of the cut-off points from this study were below the WHO cut-off points in defining overweight which is more than 25.0 kg/m^2. A lower BMI cut-off points was also found in a previous study among Malaysians in which the cut-off points was in a range of 23.3 to 24.1 kg/m^2 among male Malaysians and 23.9 to 25.4 kg/m^2 among female Malaysians (Cheong et al, 2013).

There are many researches in Asian countries that were conducted showed that Asians have higher percentage of body fat at lower BMI (London, England, 2004). There are also studies from Singapore and Hong Kong that revealed the risk of having cardiovascular diseaseor diabetes is high at lower BMIs (He et al., 2001; Deurenberg et al., 2001). A research on association between BMI status and morbidity among 6 countries with pooled sample. This study revealed higher significant likelihood of having morbidities among obese menand women compared to normal weight

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category (Agrawal et al., 2016). Has reported similar findings that suggests that overweight and obese women ageing above 35 years had significantly higher odds of having diabetes and hypertension (Bishwajit et al., 2017). Findings from this study also revealed similar results except for Indian ethnicity in terms of having morbidities at a lower BMI.

The reducing BMI cut-off points increased the sensitivity andspecificity of predicting body fat percentage. In their study, 20% of males and 30%of females were found to have a high body fat percentage but normal weight accordingto their BMI. Prevalence of obesity increased from 14.0% to 41.1% in men and 25.6% to 36.4% in women after lowering the BMI cut-off points. A lower BMI cut-off pointssuggested that an increase in BMI would results in a higher risk for having cardiovascular diseases (Hastuti et al., 2017; Tsai et al., 2011).

Malay males were found to have the lowest BMI cut-off points for diabetes and hypertension. In contrast, Chinese females had the lowest BMI cut-off points fordiabetes, hypertension, and hypocholesterolemia. While the AUC for BMI among the respondents was quite similar among the races for each disease, BMI was highly sensitive towards Malay and Indian respondents. Higher sensitivity ensures that BMI could detect the risk of having the diseases more efficiently (Cheong et al., 2013). The difference in genetic, dietary patterns, health risk behaviors, and sociodemographic characteristics were suggested as the factors that influenced the BMI cut-off points and hence the riskof having diseases (Cheong et al., 2013; Won et al., 2017). Among the Chinese population in China, it was found that lower BMI was more significant for male Chinese than females and was attributed to the culture of eating out of the home (Zhang et al., 2018; Jia et al., 2018; Bei-Fan et al., 2003).

The significance of this new set of BMI cut-off points is that it targets the specific NCD for a more accurate and early detection compared to using the previous set of BMI results available in 2012.Our study has managed to produce a more reliable and revised BMI cut-off point that is able to detect NCD at a lower BMI compared to availableBMI classification. These findings highlight the importance of recognizing the issue of BMI and obesity to tackle NCD. These new revised BMI cut-off points should be considered by the Ministry of Health Malaysia, other stakeholders, policy makers for considering to implement this as a guideline and to be added in Malaysia clinicalpractice guidelines for health care workers.

The usage of lower BMI cut-off points should be considered especially for early screening of patients with elevated BMI but still are categorized as normal BMI. These significant findings are important as people with normal BMI are usually not screened for NCDs at tertiary clinics or hospitals. This category of patients might be overlooked and if not treated early, might develop into full blown uncontrolled NCDs in the future. Another important significance of this study is that it provides substantial results to review Malaysian Clinical Practice Guidelines for Diabetes and Obesity which clearly states that only patients with BMI>23 should be screened for NCDs.

5. Conclusions

Increase BMI has been well proven to be a risk factor associated with NCDs. Using this new set of BMI as an early detection is one of the keys to prevent and reduce the prevalence of NCDs. A new set of modified BMI demonstrates the potential benefit of early detection and early intervention in preventing morbidity and mortality. From this study lowering the BMI cut-off points in defining overweight would increase the prevalence of overweight and obesity within a population, and hence, increasing the awareness that could trigger action to combat overweight.

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Availability of data and materials:

The dataset of this manuscript belongs to the Ministry of Health Malaysia. At present, the data are not publicly available but can be obtained from the authors upon reasonable request and with the permission from the Director General of Health, Malaysia.

Ethics approval and consent to participate:

Ethical approvals were obtained from the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia bearing registration number NMRR-18-3085- 44207(IIR).

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