Short Communication

Optimal cut-off levels to define obesity: body mass index and waist circumference, and their relationship to cardiovascular disease, dyslipidaemia, hypertension and diabetes in Malaysia

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Many studies in Asia have demonstrated that Asian populations may require lower cut-off levels for body mass index (BMI) and waist circumference to define obesity and abdominal obesity respectively, compared to western populations. Optimal cut-off levels for body mass index and waist circumference were determined to assess the relationship between the two anthropometric- and cardiovascular indices. Receiver operating characteristics analysis was used to determine the optimal cut-off levels. The study sample included 1833 subjects (mean age of 44 $\pm$ 14 years) from 93 primary care clinics in Malaysia. Eight hundred and seventy two of the subjects were men and 960 were women. The optimal body mass index cut-off values predicting dyslipidaemia, hypertension, diabetes mellitus, or at least one cardiovascular risk factor varied from 23.5 to 25.5 kg/m^2 in men and 24.9 to 27.4 kg/m^2 in women. As for waist circumference, the optimal cut-off values varied from 83 to 92 cm in men and from 83 to 88 cm in women. The optimal cut-off values from our study showed that body mass index of 23.5 kg/m^2 in men and 24.9 kg/m^2 in women and waist circumference of 83 cm in men and women may be more suitable for defining the criteria for overweight or obesity among adults in Malaysia. Waist circumference may be a better indicator for the prediction of obesity-related cardiovascular risk factors in men and women compared to BMI. Further investigation using a bigger sample size in Asia needs to be done to confirm our findings.

Key Words: abdominal obesity, body mass index, waist circumference, cardiovascular, Asia

INTRODUCTION

Obesity is a chronic metabolic disorder associated with cardiovascular disease and increased morbidity and mortality. Worldwide, in both developed and developing countries, the prevalence of obesity has reached epidemic levels.[1] The Malaysian National Health Morbidity Survey (NHMS) 2006 reported that 29.7% of Malaysian males are overweight and 10.0% males are obese. Malaysian females have a higher prevalence of obesity with 17.4% obese and 28.6%% overweight.[2]

The results from the NHMS survey were based on body mass index (BMI), the traditional measure for obesity.[3] While BMI is easily measured, recent conflicting evidence on its association with cardiovascular and obesity related health risk questions its usefulness as a measure of obesity.[4,5] A proxy measure for body fat; waist circumference (WC) which correlates with abdominal fat, as reference, is said to be a better predictor of cardiovascular risk.[6-8] The definition of obesity, whether based on BMI or WC measurements, is important for clinical practice in managing individual patients, as well as for public health practice in establishing the need for, and priorities of, preventive interventions in a population. The current WHO recommended BMI cut-off levels for defining overweight and obesity (25 kg/m^2 for overweight, 25–29.9 kg/m^2 pre-obese, 30 kg/m^2 or higher for obesity) were based on the association between BMI and mortality risk observed in European and US populations.[9] Likewise the National Cholesterol Education Program Adult Treatment Panel III recommended WC cut-off levels to define abdominal obesity as 102 cm for men and 88 cm for women.[10]

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Manuscript received 10 November 2008. Initial review completed 24 March 2009. Revision accepted 27 March 2009.

Clearly, it is not appropriate to use a single universal cut-off level to define obesity for all populations given the potential ethnic variation in body build and composition, as well as variation in the health risk associated with obesity among populations. Many studies in Asia have demonstrated that Asian populations may require a lower cut-off level for BMI and WC to define obesity and abdominal obesity respectively compared with western populations.[11-19] This has prompted WHO to recently revise its guidelines to define obesity for the Asia-Pacific region.[20] The purpose of this study was therefore to replicate these studies to determine optimal cut-off levels to define obesity based on BMI and WC in the three major ethnic populations in Malaysia (Malay, Chinese, Indian).

MATERIALS AND METHODS

We conducted a multi-center, cross-sectional observational study in 93 primary care clinics in Malaysia. The Ministry of Health's Medical and Research Ethics Committee approved the study proposal. Consent was obtained from all subjects. .

Study population

The study population consisted of adult men and women who attended primary care clinics in both the public and private sector across the country from May to September 2005. Age inclusion criteria were between $\geq$21 and $\leq$80 years. Pregnant women were excluded.

Study assessment and definitions

Relevant data was obtained from patients' medical records, by face-to-face interview or direct measurement. Data collected included socio-demographic measures such as age, gender, ethnicity, education level and occupation. Information on cigarette consumption and on medical history (cardiovascular diseases, lipid disorders, hypertension, diabetes, menopausal status and hormonal replacement therapy) was also collected.

Body weight, height and WC were measured by the attending physician. All physicians attended centralized training on measuring body weight, height and WC

Statistical methods

In order to provide sufficiently precise estimates, the sample size calculation considered our best knowledge of the prevalence of abdominal obesity and the precision that we were willing to accept.[21] Sample size was calculated based on the secondary analysis of a previous study.[22]

Continuous variables have been described by summary statistics such as mean, median, standard deviation and cumulative percent. Categorical (nominal/ordinal) variables were summarized by the frequencies of each category.

Receiver operating characteristic (ROC) analysis was used to compare the predictive validity, and to determine their optimal cut-off values.[23] Area under the curve (AUC) was also measured to determine the diagnostic power of a test, and to describe the probability that a test would correctly identify subjects with the disorder.[24]

Optimal cut-off values were measured by calculating the sensitivity and specificity of the anthropometric measurements at various cut-off points. Odds ratios were calculated as the ratios of having at least one cardiovascular disease (CVD) risk factor as compared to the lowest BMI (<20 kg/m^2) and WC (<70 cm) by gender and ethnicity based on the best judgement of the authors.

The relationship between BMI or WC and odds ratio of having at least one CVD risk factor by gender and ethnicity were also assessed. All data analyses were conducted using STATA statistical software (version 9.2 for WINDOWS; Clinical Research Centre, Malaysia).

RESULTS

The 93 participating clinics enrolled a total of 1893 subjects. Sixty cases were excluded due to age standardization as in the inclusion criteria.

The mean age of the subjects was 44 ($\pm$14) years and 56% of the sample was of the Malay ethnic origin (Table 1). The majority had not had tertiary education. Four percent of the subjects had pre-existing cardiovascular dis-

Table 1. Demographic and other baseline characteristics of enrolled subjects

Baseline Characteristics	Men (N= 872)	Women (N= 960)	Total (N=1833)
Mean age (years)	44 $\pm$ 14	44 $\pm$ 14	44 $\pm$ 14
Ethnicity. No. (%)			
Malay	406 (46.6)	483 (50.3)	889 (48.5)
Chinese	259 (29.7)	286 (29.8)	546 (29.8)
Indian	170 (19.5)	156 (16.3)	326 (17.6)
Other	26 (3.0)	29 (3.02)	55 (3)
Mean body weight (kg)	71.9 $\pm$ 14.4	63.9 $\pm$ 14.2	67.7 $\pm$ 14.8
Primary care clinic. No. (%)			
Public	526 (60.32)	515 (53.7)	1042 (56.9)
Private	346 (39.7)	445 (46.4)	791 (43.2)
Level of Education. No. (%)			
Less than High school	274 (31.42)	377 (39.3)	651 (35.5)
High school	400 (45.9)	382 (39.8)	782 (42.7)
Tertiary	197 (22.6)	196 (20.42)	394 (21.5)
Occupational status. No. (%)			
Employed	721 (82.7)	539 (56.2)	1261 (68.8)
Unemployed	43 (4.9)	340 (35.4)	383 (20.9)
Retired	90 (10.3)	47 (4.9)	137 (7.5)
Incapacitated for work	3 (0.3)	12 (1.3)	15 (0.8)
Smoking status. No. (%)			
Never	342 (39.2)	917 (95.5)	1259 (68.7)
Former	151 (17.3)	16 (1.7)	167 (9.1)
Current	378 (43.4)	23 (2.4)	402 (21.9)
(%) with Cardiovascular Disease	48 (5.5)	31 (3.23)	79 (4.3)
(%) with Lipid Disorders	163 (18.7)	162 (16.9)	325 (17.7)
(%) with Hypertension	239 (27.4)	257 (26.8)	496 (27.1)
(%) with Diabetes Mellitus	123 (14.1)	134 (14.0)	257 (14.0)
(%)postmenopausal	2 (0.2)	278 (29)	280 (15.3)

Values expressed as mean $\pm$ SD, median (inter-quartile range), or number (percentage) of patients.

Table 2. The areas under ROC curve (AUC), optimal cut-off values, sensitivities and specificities of BMI & WC indices associated with CVD risk factors in men

CVD Risk Factors	Ethnicity	BMI					WC				
		AUC	95% CI	Cut-off point (kg/m^2)	Sensitivity (%)	Specificity (%)	AUC	95% CI	Cut-off point (kg/m^2)	Sensitivity (%)	Specificity (%)
Dyslipidaemia	All	0.62	(0.57,0.67)	24.6	74.5	47.3	0.64	(0.59,0.69)	83.0	87.9	34.3
	Malay	0.67	(0.60,0.73)	24.7	81.8	47.5	0.68	(0.61,0.75)	88.0	75.8	51.3
	Chinese	0.61	(0.53,0.69)	25.2	69.6	52.7	0.63	(0.55,0.71)	94.0	55.4	67.2
	Indians	0.56	(0.46,0.66)	23.4	85.7	35.1	0.55	(0.46,0.65)	83.0	91.4	29.9
	WHO	-	-	30.0	5.7	98.3	-	-	102.0	2.0	99.4
	Asia 1	-	-	23.0	73.7	53.2	-	-	90.0	20.4	91.9
	Asia 2	-	-	25.0	45.0	78.0	-	-	-	-	-
Hypertension	All	0.67	(0.63,0.71)	24.3	77.4	47.9	0.69	(0.65,0.72)	86.0	81.9	45.7
	Malay	0.70	(0.64,0.76)	25.4	75.3	55.1	0.70	(0.64,0.76)	86.0	83.2	48.1
	Chinese	0.66	(0.60,0.73)	22.0	90.7	34.8	0.70	(0.63,0.76)	91.0	63.9	65.8
	Indians	0.65	(0.56,0.74)	24.1	80.0	45.0	0.64	(0.55,0.73)	83.0	97.5	32.6
	WHO	-	-	30.0	6.7	97.6	-	-	102.0	3.8	99.2
	Asia 1	-	-	23.0	72.0	47.6	-	-	90.0	24.2	90.0
	Asia 2	-	-	25.0	44.8	73.4	-	-	-	-	-
Diabetes	All	0.59	(0.54,0.64)	25.5	62.5	52.8	0.64	(0.59,0.69)	92.0	60.0	60.8
	Malay	0.62	(0.54,0.70)	25.7	69.6	53.5	0.66	(0.58,0.73)	88.0	76.1	49.9
	Chinese	0.58	(0.48,0.69)	25.5	65.6	53.7	0.60	(0.49,0.70)	97.0	47.9	73.6
	Indians	0.55	(0.46,0.65)	22.6	90.5	28.1	0.64	(0.55,0.73)	84.0	92.9	34.4
	WHO	-	-	30.0	10.7	97.2	-	-	102.0	3.7	99.0
	Asia 1	-	-	23.0	81.6	45.6	-	-	90.0	36.5	88.6
	Asia 2	-	-	25.0	59.2	71.6	-	-	-	-	-
CVD Risk*	All	0.65	(0.61,0.68)	23.5	80.3	42.0	0.69	(0.66,0.73)	83.0	86.8	41.6
	Malay	0.69	(0.63,0.74)	-	-	-	0.70	(0.65,0.76)	-	-	-
	Chinese	0.64	(0.57,0.71)	-	-	-	0.69	(0.63,0.75)	-	-	-
	Indians	0.61	(0.52,0.69)	-	-	-	0.66	(0.58,0.74)	-	-	-
	WHO	-	-	30.0	5.4	98.6	-	-	102.0	2.0	99.5
	Asia 1	-	-	23.0	72.1	55.5	-	-	90.0	20.1	93.2
	Asia 2	-	-	25.0	43.4	79.9	-	-	-	-	-

95% confidence interval; Obesity criteria for Caucasians by WHO[1]; Proposed overweight (Asia 1) and obesity (Asia 2) criteria for Asia Pacific region [26]. *at least one CVD risk factor (dyslipidaemia, hypertension or diabetes)

ease, while 17% had lipid disorders, 26% had hypertension and 13% had diabetes.

The AUCs as in the ROC curves of BMI and WC anthropometric indices and CVD risk factors for men and women are summarized in Tables 2 and 3 respectively. Area under the curves of selected anthropometric indices and the groups with at least one CVD risk factor were 0.647 and 0.663 for BMI in men and women, and 0.691 and 0.693 for WC in men and women respectively. Area under the curves of 0.6-0.7 are found to be poor while 0.7-0.8 are considered fair.[23] In this study, AUCs for all the CVD risk factors except for dyslipidaemia were found to be higher for women than in men.

The optimal cut-off values of BMI and WC anthropometric indices for dyslipidaemia, hypertension, diabetes mellitus, or at least prediction of one CVD risk factor using the ROC analysis in men and women are summarized in Tables 2 and 3. The overweight (Asia 1) and obesity (Asia 2) criteria proposed for the Asia-Pacific region[20] and the obesity cut-off values by WHO in the year 1997 are also shown in the tables 2 and 3. In this study, the optimal BMI cut-off values predicting dyslipidaemia, hypertension, diabetes mellitus, or at least one CVD risk factor varied from 23.5 to 25.5 kg/m^2 in men and 24.9 to 27.4 kg/m^2 in women. As for WC, the optimal cut-off values varied from 83 to 92 cm in men and from 83 to 88 cm in women. In figures 1 and 2, the increasing risk of having at least one CVD risk factor was found to be associated with increasing BMI and WC in men and women. The same increasing trend was found in all ethnic groups without any obvious differences between the groups.

The odds of having at least one CVD risk factor in relation to BMI and WC was highest among the Chinese. Malay men had BMI cut-off values predicting hypertension and diabetes mellitus ranging from 25.4 to 25.7 kg/m^2 while that of Malay women ranged from 27.5 to 30.5 kg/m^2. In addition, Chinese men were found to have optimal BMI cut-off values of 25.2 kg/m^2 to predict dyslipidaemia while Indian women had the highest optimal BMI cut-off values of 31.2 kg/m^2 to predict diabetes mellitus.

The Malays had the highest WC cut-off values predicting dyslipidaemia, hypertension and diabetes mellitus in men which ranged from 91 to 97 cm. Indian women had WC cut-off values predicting dyslipidaemia and hypertension at 90 and 91 cm respectively. Chinese women had a WC cut-off value predicting diabetes mellitus of 88 cm.

Table 3. The areas under ROC curve (AUC), optimal cut-off values, sensitivities and specificities of BMI & WC indices associated with CVD risk factors in women.

CVD Risk Factors	Ethnicity	BMI					WC				
		AUC	95% CI	Cut-off point (kg/m^2)	Sensi-tivity (%)	Speci-ficity (%)	AUC	95% CI	Cut-off point (kg/m^2)	Sensi-tivity (%)	Speci-ficity (%)
Dyslipi-daemia	All	0.58	(0.53,0.63)	27.4	53.2	61.1	0.62	(0.58,0.67)	87.0	60.1	61.1
	Malay	0.64	(0.57,0.70)	27.5	69.7	53.8	0.66	(0.59,0.72)	87.0	69.7	59.1
	Chinese	0.57	(0.49,0.65)	25.7	45.8	68.3	0.61	(0.53,0.69)	83.0	64.4	60.7
	Indians	0.58	(0.47,0.68)	27.4	66.7	54.9	0.60	(0.49,0.70)	91.0	63.6	60.7
	WHO	-	-	30.0	5.57	98.6	-	-	102.0	2.0	99.4
	Asia 1	-	-	23.0	54.3	74.3	-	-	90.0	20.3	91.9
	Asia 2	-	-	25.0	32.0	88.1	-	-	-	-	-
Hyperten-sion	All	0.69	(0.65,0.73)	25.8	73.6	55.6	0.69	(0.65,0.73)	83.0	76.4	53.2
		0.70	(0.65,0.75)	30.5	53.2	78.1	0.69	(0.64,0.75)	88.0	64.3	66.3
	Chinese	0.72	(0.66,0.78)	24.9	67.1	69.7	0.72	(0.66,0.78)	84.0	67.1	69.2
	Indians	0.73	(0.64,0.81)	26.3	86.1	52.1	0.73	(0.64,0.82)	90.0	75.0	60.5
	WHO	-	-	30.0	7.15	98.5	-	-	88.0	7.0	98.8
	Asia 1	-	-	23.0	61.6	73.6	-	-	80.0	31.9	92.8
	Asia 2	-	-	25.0	38.2	87.7	-	-	-	-	-
Diabetes	All	0.61	(0.56,0.66)	24.9	74.2	45.3	0.68	(0.63,0.72)	88.0	63.6	64.8
	Malay	0.61	(0.54,0.68)	24.8	83.1	36.3	0.68	(0.62,0.75)	88.0	69.2	62.5
	Chinese	0.67	(0.58,0.76)	24.3	74.2	54.7	0.71	(0.63,0.80)	77.0	93.6	40.9
	Indians	0.50	(0.40,0.61)	31.2	83.3	26.7	0.56	(0.46,0.66)	86.0	75.0	44.2
	WHO	-	-	30.0	10.1	98.2	-	-	88.0	18.3	97.8
	Asia 1	-	-	23.0	79.0	71.5	-	-	80.0	50.6	91.4
	Asia 2	-	-	25.0	54.1	86.2	-	-	-	-	-
CVD Risk*	All	0.66	(0.63,0.70)	24.9	73.3	52.7	0.69	(0.66,0.73)	83.0	73.5	57.1
	Malay	0.68	(0.63,0.73)	-	-	-	0.71	(0.66,0.75)	-	-	-
	Chinese	0.71	(0.65,0.77)	-	-	-	0.71	(0.65,0.77)	-	-	-
	Indians	0.61	(0.53,0.70)	-	-	-	0.64	(0.56,0.73)	-	-	-
	WHO	-	-	30.0	5.73	98.9	-	-	88.0	8.1	98.8
	Asia 1	-	-	23.0	55.8	76.4	-	-	80.0	25.0	94.2
	Asia 2	-	-	25.0	33.1	89.6	-	-	-	-	-

95% confidence interval; Obesity criteria for Caucasians by WHO[1]; Proposed overweight (Asia 1) and obesity (Asia 2) criteria for Asia Pacific region [26]. *at least one CVD risk factor (dyslipidaemia, hypertension or diabetes)

DISCUSSION

Obesity is an independent risk factor for cardiovascular disease (CVD) and it is known to be associated with other risk factors such as hypertension, dyslipidaemia and diabetes mellitus. Body mass index is known to be closely related to the total amount of body fat and is widely used to define the criteria for overweight or obesity.[25] Many population studies show increasing morbidity and mortality risk with increasing BMI.[26] Increased CVD risk related to obesity at lower BMI cut-off levels have been found in Asians.[27] Studies have shown that Asians are predisposed to visceral or central obesity. There are suggestions that lower BMI cut-off points are indicated to define obesity in Asians.[4,5,9,16] Our study also attempts to replicate several earlier studies such as Deurenberg-Yap M et al (1999) and Hsieh et al (2000) performed in Singapore and Japan which examine the health risk factors of obesity.[4,9] These previous studies have found that the increased risk related to obesity for Asians start at lower BMI values than those in Europe and the United States. In our study, the optimal BMI cut-off point for at least one cardiovascular risk associated with obesity is 23.5 kg/m^2 in men and 24.9 kg/m^2 in women. Lin et al reported similar cut-off levels for Taiwanese men (23.6 kg/m^2) but Taiwanese women had a lower BMI of 22.1 kg/m^2.[17] A Singaporean study conducted by Pua et al on female subjects, reported a BMI cut-off level of 23.6 kg/m^2.[24]

From our study, we also found that the increasing risk of at least one CVD risk factor was strongly associated with increasing BMI in men and women (Figures 1). The two anthropometric indices (BMI and WC) have been reported to be associated with certain CVD risk factors.[28] The WC appeared to be better predictor of diabetes than BMI since the AUC for WC versus BMI for both men and women seemed higher for WC (0.6409 versus 0.5878 for men and 0.6765 versus 0.6078 in women). The confidence intervals show that these are fairly precise estimates (difference of upper and lower intervals of about 0.1). This is in line with what Li et al (2002)[17] found- i.e. that WC is the more dominant predictor of risk than age, WHR (waist hip ratio) or BMI. However, Chan et al (1997)[19] reported that BMI was not a significant predictor

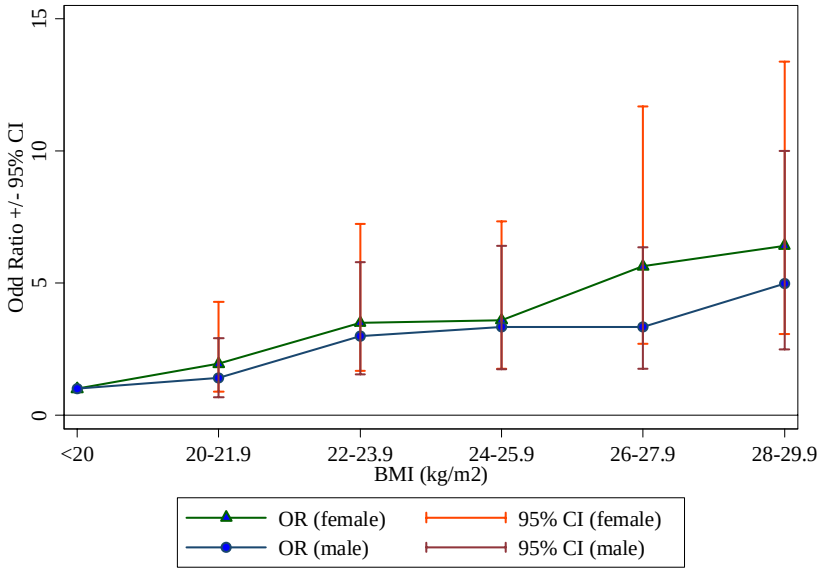

Figure 1. The relationship between BMI and the odds ratio of having at least one CVD risk factor in both sexes.

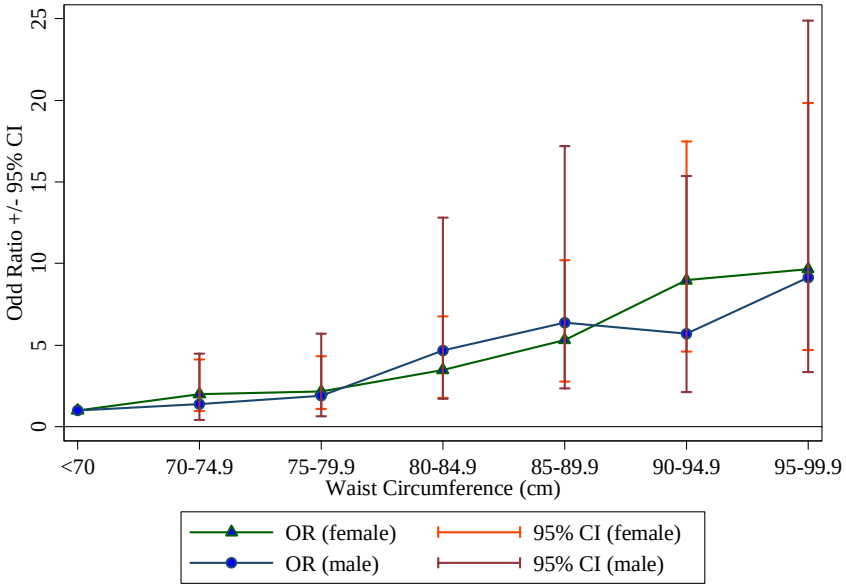

Figure 2. The relationship between WC and the odds ratio of having at least one CVD risk factor in both sexes.

of diabetes in either sex. Zhu et al, 2005 also proposed WC cut-offs as a better indicator for predicting CVD risk factors.[28] Of the two indices we studied, WC in women was found to have the largest areas under the ROC curve (women= 0.693, 95% CI 0.658-0.727) in relation to at least one CVD risk factor (i.e. hypertension or diabetes or dyslipidaemia) (Table 3). The increasing risk of having at least one risk factor was also found to be associated with increasing WC in men and women (Figures 2).

In our study, the optimal cut-off values using WC were 83 cm in both men and women. These values were apparently lower than the values for Caucasians (102 cm for men and 88 cm for women)[3] but values for women seemed to be higher than previously recommended in the Asian population (90 cm for men and 80 cm for women).[20] In summary, further studies are needed to determine the appropriate cut-off levels to define overweight and obesity in the Asia-Pacific region.

Study limitations

There are a number of limitations that may account for the differences in results observed between this study and others. Firstly, difference in methods of measurement,[29] sample size and study design. Secondly, selection bias due to patient recruitment in the primary care clinic settings that would potentially lower the event rate for CVD as compared to those patients seen in specialist clinics.

CONCLUSION

In our study, we have identified the levels of BMI and WC anthropometric indices that define overweight and obesity associated with abnormal values of obesity related

CVD risk factors in an Asian population. These levels of anthropometric indices and the risk factors are based on arbitrary cut-offs and may not indicate a clinical condition when it is redefined again. Thus, the recommended cut-off levels indicate levels of anthropometric indices above which people should be screened for other CVD risk factors. Our study suggested that the optimal cut-off values of: (i) BMIs of 23.5 kg/m^2 in men and 24.9 kg/m^2 in women and (ii) WCs of 83 cm in both men and women may be more suitable for defining overweight or obesity among adults in Malaysia. Waist circumference especially, may be a better indicator for predicting obesity-related CVD risk factors in men and women compared to BMI. It can be argued that in most individuals, BMI is an adequate indicator for defining obesity except for those who are athletic with high muscle mass; but other anthropometric measurements such as waist circumference, waist-to-height ratio and waist-to-hip ratio are complementary to BMI and provide relatively accurate diagnosis of obesity in identifying patients who are at risk of cardiovascular diseases. There is a need for a large scale prospective study to determine the longitudinal effect of obesity on CVD risk factors to accurately identify the optimal cut-off level for BMI and WC among Asians, stratified by ethnicity, age and gender.

ACKNOWLEDGEMENT

We thank the Director-General of Health, Malaysia his encouragement and for granting permission to publish this paper. We also thank the Clinical Research Centre of the Ministry of Health for supporting this work and all those whose names are not mentioned here but have rendered their excellent service especially during data collection and data entry. The full list of contributors for this study can be obtained at web appendix; http://www.crc.gov.my/publications/documents/Synopsis/mySon.pdf.

AUTHOR DISCLOSURES

The MYSoN study was funded through an unrestricted grant from Sanofi-aventis. Vadivale M and Ng B are employees of Sanofi-aventis Malaysia.

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Short Communication

Optimal cut-off levels to define obesity: body mass index and waist circumference, and their relationship to cardiovascular disease, dyslipidaemia, hypertension and diabetes in Malaysia

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在馬來西亞定義肥胖的理想切點：身體質量指數和腰圍，與心血管疾病、脂質異常、高血壓和糖尿病的相關性

亞洲許多研究都認為亞洲人比西方人可能需要較低的身體質量指數(BMI)和腰圍切點，以分別定義肥胖和腹部肥胖。訂定適宜的身體質量指數和腰圍切點來評估這兩個體位指標和心血管疾病指標的相關性。應用接受器操作特性曲線(ROC)分析決定理想切點。研究樣本包含來自馬來西亞 93 個初級醫護診所中的 1833 個受試者（平均年齡 44±14 歲）。其中男性 872 位和女性 960 位。可預測血脂異常、高血壓、糖尿病或至少一個心血管疾病危險因子的身體質量指數切點範圍，在男性為 23.5-25.5 kg/m^2，女性為 24.9-27.4 kg/m^2。至於腰圍的適當切點範圍，男性為 83-92 cm，女性為 83-88 cm。從我們的研究中顯示，定義馬來西亞成年人的過重或肥胖標準，更適合的身體質量指數的理想切點，男性和女性分別為 23.5 kg/m^{2}和 24.9 kg/m^2；男性和女性腰圍的理想切點都為 83 cm。腰圍相較於身體質量指數，可能是一個評估男性和女性肥胖相關的心血管危險因子更好的預測指標。在亞洲，可能需要進一步使用一個更大的樣本數調查，以證實我們的發現。

關鍵字：腹部肥胖、身體質量指數、腰圍、心血管疾病、亞洲