The Optimal Cut-Off Points of Body Mass Index which Reflect the Risk Factors of Cardiovascular Disease in the Urban Thai Male Population

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Objective: *To examine the optimal cut-off points of body mass index (BMI) which reflect the risk-level of cardiovascular disease (CVD) risk factors in urban Thai males.*
Material and Method: *A cross-sectional research was conducted on Thai males, aged 35-50 who worked and lived in Bangkok. Four hundred and thirteen government officers were selected for blood pressure, weight and height measurements. BMI were calculated and blood samples were collected for blood chemical analysis. Sensitivity, specificity and ROC curve analyses were used for data analysis.*
Results: *The prevalence of overweight subjects was 57.8 percent by the BMI $\geq$ 23 kg/m^2, i.e. the Asian cut-off point criteria, while it was only 32.7 percent by the BMI $\geq$ 25 kg/m^2, i.e. the WHO criteria. The cut-off points of BMI which corresponded with the at-risk level of SBP, DBP, TC, TG, LDL-C, and HDL-C were 23.5, 23.5, 22.5, 23.5, 23.0 and 24.0 kg/m^2, respectively. BMI at 23.5 kg/m^2 was suggested as the optimal cut-off point of BMI which reflects the risk-level of CVD risk factors.*
Conclusion: *The findings indicated that the Asian criteria might be more appropriate for urban Thai males who have a sedentary lifestyle than that the WHO criteria. However, the further study with larger sample size is needed to confirm the cut-off point of BMI at 23.5 kg/m^2.*

Keywords: *Body mass index, Cut-off point of body mass index, Cardiovascular disease, Hypertension, Dyslipidemia*

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Worldwide, cardiovascular disease (CVD) is a major cause of illness and death including premature death in both developed and developing countries[1]. In Thailand CVD mortality rates have steadily increasing each year and are now one of the five leading causes of death among the Thai population[2]. Obesity is now well recognized as a major determinant of non-communicable diseases such as CVD, hypertension, dyslipidemia and diabetes mellitus. Moreover, high blood pressure, elevated serum cholesterol, low-density lipoprotein cholesterol (LDL-C) and low high-density lipoprotein cholesterol (HDL-C) are included in the group of major causal risk factors of CVD[3].

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The prevalence of overweight and obesity has been increasing in most part of the world. According to World Health Organization Consultation on Obesity, the prevalence of obesity has been increasing rapidly since 1990. The prevalence of obesity in adults is 10-25 percent in most countries of Western Europe and 20-25 percent in some countries in the Americas[4]. In Thailand, the Fifth National Food and Nutrition Survey in 2005[5] undertaken by the Department of Health, Ministry of Public Health, found that the prevalent rate of overnutrition, as defined by body mass index (BMI) of 25 kg/m^2 or more, in the 19-59 age group was 23.7 percent (17.6 percent in males and 26.9 percent in females), which is similar to that of American and Western European countries. This was the result of changes in lifestyle and diet, along with an increase in life expectancy and the advert of urbanization.

Early obesity detection, prevention and management offer the best solutions(6). A BMI is as an indicator of fatness and it is used clinically to assess obesity. Its wide acceptance has been due to its simplicity and high specificity in screening for total body fatness (% Body Fat; % BF)(7). Previous cross-ethnic studies which examined the BMI-% BF in relation to age, gender and ethnicity have reported that Asians tend to possess greater % BF than Caucasians at the same BMI values(8-11). There are also reports that Asians have higher health problems at lower BMI values than Caucasians. The BMI cut-off point classification for overweight ($\geq$ 23.0 kg/m^2) and obesity ($\geq$ 25.0 kg/m^2) suggested for Asians was lower than that of the WHO criteria (overweight $\geq$ 25.0 kg/m^2 and obesity $\geq$ 30.0 kg/m^2)(12-16). A study of Thai women aged 30-39 years found that more than 70 percent of the subjects had normal BMI (20-24.9 kg/m^2) of this group, 60 percent had high levels of total cholesterol (TC) and 23.6 percent had normal levels of triglyceride (TG)(17).

The study aimed to examine the optimal cut-off points of BMI which gauge the risk level of CVD risk factors such as hypertension and dyslipidemia of urban Thai males who were accustomed to sedentary ways of working and living.

Material and Method

Four hundred and thirteen Thai male employees aged 35-50 who live in Bangkok and who undertook annual physical check up at the Office of Public Health and Environmental Technology Service (OPHETS), Faculty of Public Health, Mahidol University were purposively sampled into this study. Participants who were taking medication for the control of blood pressure and/or plasma lipid, heavy smoker (smoking $\geq$ 16 cigarettes per day), heavy daily consumers of alcohol, and those who had any complications or diseases that induce weight increase were excluded.

Self-administered questionnaires used for collecting demographic data, health histories and health behavior habits were handed to the participants. Body weight was measured using a beam balance scale to the nearest 0.1 kg and body height was measured using height instrument to the nearest 0.1 cm. BMI was calculated by the body weight in kilograms divided by the squared meter of body height (kg/m^2). Blood pressure was measured using a mercury manometer, from the subjects left arm after at least 5 minutes of physical rest. Repeated measurements were applied to all participants who had systolic blood pressure (SBP) $\geq$ 140 mmHg and/or diastolic blood pressure (DBP) $\geq$ 90 mmHg, after at least 30 minutes of physical rest. A blood sample of 3-5 ml was obtained from each of the participants in the morning after the subjects had had at least 8 hours of overnight fasting and had also abstained from alcohol consumption for at least 24 hours. Serum levels of TC, TG and HDL-C were assayed by enzymatic colorimetric test. LDL-C was calculated from Freidwald's formula.

Multiple regression analysis was used to find the effect of the confounding variables on blood pressure, TC, LDL-C and HDL-C. Sensitivity and specificity analyses were used to find the optimal cut off-points of BMI which better corresponded with the risk level of CVD risk factors. The overall performance of each Receiver Operating Characteristic (ROC) curve was evaluated by calculating the area under curve (AUC), which is a measure of the diagnosis power of a test, and describes the probability that a test will correctly identify subjects with the disorder. This study was approved by the Committee on Human Rights Related to Human Experimentation, Mahidol University (Ref. No.107/2004). Informed consent was obtained from all participants.

Table 1. The number and percentage of BMI of samples classified by the WHO and Asian criteria

Variable	Number	Percentage
BMI (WHO)(18)		
Underweight (< 18.5 kg/m^2)	23	5.6
Normal (18.5-24.9 kg/m^2)	255	61.7
Overweight ($\geq$ 25.0 kg/m^2)	135	32.7
Pre-obese (25.0-29.9 kg/m^2)	115	27.9
Obese I (30.0-34.9 kg/m^2)	20	4.8
Obese II (35-39.9 kg/m^2)	0	0.0
Obese III ($\geq$ 40 kg/m^2)	0	0.0
Total	413	100.0
BMI (Asian)(19)		
Underweight (< 18.5 kg/m^2)	23	5.6
Normal (18.5-22.9 kg/m^2)	151	36.6
Overweight ($\geq$ 23 kg/m^2)	239	57.8
Pre-obese (23.0-24.9 kg/m^2)	104	25.1
Obese I (25.0-29.9 kg/m^2)	115	27.9
Obese II ($\geq$ 30.0 kg/m^2)	20	4.8
Total	413	100.0
Mean $\pm$ SD	23.93 $\pm$ 3.21	
Min-Max	16.71-34.33	

Results

Findings from the descriptive analysis showed that the mean age among participants was 43.1 $\pm$ 5.0 year old. Most of them were married (70.2 percent) and had a Bachelor's degree (66.3 percent). According to the WHO criteria[18], 32.7 percent of participants were considered overweight, 27.9 percent pre-obese (BMI 25.0-29.9 kg/m^2) and 4.8 percent obese level I (BMI 30.0-34.9 kg/m^2). The findings based on the Asian criteria[19] found that 57.8 percent of participants were considered overweight, 25.1 percent pre-obese (BMI 23.0-24.9 kg/m^2), 27.9 percent obese level I (BMI 25.0-29.9 kg/m^2) and 4.8 percent obese level II (BMI $\geq$ 30.0 kg/m^2) (Table 1). The findings presented in Table 2 showed that the TG level, with the exception of the mean BMI level of the participants increased proportionately with the level of SBP, DBP, TC and LDL-C. On the other hand, the levels of HDL-C moved in the opposite direction than those of the BMI. This relationship remained statistically significant after excluding the effect of age, smoking habits and alcohol drinking behavior (data not presented).

Table 2. The mean BMI of the study subjects classified by blood pressure and lipid levels

Variables	Number	Percentage	BMI (mean $\pm$ SD)
SBP (mmHg)[20]			
Optimal (< 120 mmHg)	84	20.3	22.84 $\pm$ 3.29
Normal (< 130 mmHg)	115	27.8	23.00 $\pm$ 2.78
High-normal (130-139 mmHg)	133	32.3	24.02 $\pm$ 2.58
Hypertension ($\geq$ 140 mmHg)	81	19.6	26.21 $\pm$ 3.46
Mean $\pm$ SD	125 $\pm$ 12.16		
Min-Max	100-160		
DBP (mmHg)[20]			
Optimal (< 80 mmHg)	104	25.2	22.48 $\pm$ 2.74
Normal (< 85 mmHg)	208	50.4	23.74 $\pm$ 2.91
High-Normal (85-89 mmHg)	-	-	-
Hypertension ($\geq$ 90 mmHg)	101	24.4	25.85 $\pm$ 3.30
Mean $\pm$ SD	80.29 $\pm$ 8.13		
Min-Max	60-100		
TC (mg/dl)[21]			
Acceptable (< 200 mg/dl)	102	24.7	22.60 $\pm$ 3.60
Borderline (200-239 mg/dl)	197	47.7	23.82 $\pm$ 2.77
High-risk ($\geq$ 240 mg/dl)	114	27.6	25.28 $\pm$ 3.03
Mean $\pm$ SD	221.07 $\pm$ 39.22		
Min-Max	113-398		
TG (mg/dl)[21]			
Acceptable (< 200 mg/dl)	307	74.3	23.36 $\pm$ 3.02
Borderline (200-400 mg/dl)	96	23.3	25.69 $\pm$ 3.13
High-risk (> 400 mg/dl)	10	2.4	24.39 $\pm$ 3.50
Mean $\pm$ SD	162.35 $\pm$ 91.27		
Min-Max	42-596		
LDL-C (mg/dl)[21]			
Acceptable (< 130 mg/dl)	160	38.7	23.25 $\pm$ 3.57
Borderline (130-159 mg/dl)	138	33.5	23.79 $\pm$ 2.91
High-risk ($\geq$ 160 mg/dl)	115	27.8	25.02 $\pm$ 2.71
Mean $\pm$ SD	139.40 $\pm$ 37.06		
Min-Max	44.2-269.8		
HDL-C (mg/dl)[21]			
Acceptable (> 35 mg/dl)	372	90.1	23.74 $\pm$ 3.14
High-risk (< 35 mg/dl)	41	9.9	25.63 $\pm$ 3.34
Mean $\pm$ SD	49.16 $\pm$ 12.63		
Min-Max	18-99		

According to the epidemiological criteria used in this study, the optimal cut-off points of BMI for each of the risk factors of CVD were denoted by high sensitivity value and each value of sensitivity and specificity must be over 50% to declare the reliability of the cut-off points of BMI as corresponding with the risk level of CVD risk factors. For each of the risk factors of CVD, the sensitivity associated with each optimal BMI cut-off value should be greater than its specificity. Moreover, the optimal cut-off points should have the highest area under the ROC curve. For example, in Table 3 the high-risk of CVD by SBP showed that the cut-off point of BMI at 24.0 kg/m^2 had the highest AUC but it had sensitivity value (57%) lower than specificity value (64%). Considering, the cut-off point of BMI at 23.0 kg/m^2 and 23.5 kg/m^2 had sensitivity value higher than specificity but the cut-off point of BMI at 23.5 kg/m^2 had AUC higher than the cut-off point of BMI at 23.0 kg/m^2. Therefore, the cut-off point of BMI at 23.5 kg/m^2 was selected as the optimal cut-off point which reflects a high-risk of CVD by SBP. Based on the same criteria, the optimal cut-off points of BMI which reflected high-risk of CVD by, DBP, TC, TG, LDL-C, and HDL-C were 23.5, 22.5, 23.5, 23, and 24.0 kg/m^2, respectively (Table 3). Moreover, the cut-off point of the WHO criteria ($\geq$ 25.0 kg/m^2) showed the sensitivity value lower than that of the Asian criteria ($\geq$ 23.0 kg/m^2) in this study.

Discussion

Weight-height indices especially BMI, are well accepted as indices for body fat content[7]. The BMI classification proposed by WHO suggest that cut-off points for overweight is BMI $\geq$ 25 kg/m^2 and for obesity, (BMI $\geq$ 30 kg/m^2)[18]. These criteria are based on observational studies from Europe on how morbidity and mortality relates to BMI, and therefore may not be applicable to Thai populations. Furthermore, BMI cannot differentiate between the components of body composition, such as fat mass and fat free mass of subject[22]. Consequently BMI can be large for those with short legs in proportion to their height as well as for those with a high level of muscularity. Consideration of these limitations is important when comparing BMI values obtained from subjects of different races[23].

According to the WHO classification of obesity, using BMI $\geq$ 30 kg/m^2, it was found that the prevalence of obesity was approximately 10-20 percent and 15-25 percent in European men and women respectively[7]. By contrast, the prevalence of obesity using the same criteria for Asian populations was less

Table 3. The sensitivity, specificity and AUC of SBP, DBP, TC, TG, LDL-C and HDL-C at varying cut-off points of BMI (n = 413)

BMI cut-off point (kg/m^2)	SBP ($\geq$ 140 mmHg)			DBP ($\geq$ 90 mmHg)			TC ($\geq$ 200 mg/dl)			TG ($\geq$ 200 mg/dl)			LDL-C ($\geq$ 130 mg/dl)			HDL-C (< 35 mg/dl)		
	Sens. (%)	Spec. (%)	AUC	Sens. (%)	Spec. (%)	AUC	Sens. (%)	Spec. (%)	AUC	Sens. (%)	Spec. (%)	AUC	Sens. (%)	Spec. (%)	AUC	Sens. (%)	Spec. (%)	AUC
25.0	55	75	.4125	55	75	.4125	36	76	.2736	55	75	.4125	34	70	.2380	61	70	.4270
24.5	63	66	.4158	64	66	.4224	45	71	.3195	63	66	.4158	43	62	.2666	63	61	.3843
24.0	68	61	.4148	68	60	.4080	51	67	.3417	68	61	.4148	49	57	.2793	**74**	**56**	.4144
23.5	**73**	**53**	.3869	**72**	**52**	.3744	59	64	.3776	**73**	**53**	.3869	59	54	.3186	76	49	.3724
23.0	76	49	.37724	75	48	.3600	49	60	.3840	76	49	.3724	**64**	**51**	.3264	80	45	.3660
22.5	84	40	.3360	81	39	.3159	**73**	**55**	.4015	84	40	.3360	72	46	.3312	83	36	.2988
22.0	88	33	.2904	88	32	.2816	80	51	.4080	88	33	.2904	81	40	.3240	85	29	.2465
21.5	88	26	.2288	91	27	.2457	84	42	.3528	88	26	.2288	82	34	.2788	90	24	.2255
21.0	95	21	.1995	97	22	.2134	89	37	.3293	95	21	.1995	90	28	.2520	90	18	.1620

than 3 percent in both Japan and China[24]. Based on the WHO classification, Asian populations, such as the Chinese, are often considered non-obese. Previous cross-ethnic studies which examined the BMI-% BF relationship with respect to age, gender and ethnicity have reported that Asians tend to possess greater % BF than Caucasians of the same BMI values[8-11]. There are also reports that Asians have higher morbidities at lower BMI values than Caucasians. In the Asian criteria, the cut-off points of BMI for overweight ($\geq$ 23.0 kg/m^2) and obesity ($\geq$ 25.0 kg/m^2) are lower than those of WHO criteria (overweight $\geq$ 25.0 kg/m^2 and obesity $\geq$ 30.0 kg/m^2)[12-16].

The results illustrated that using the Asian criteria as BMI $\geq$ 23 kg/m^2 revealed almost double a prevalence rate of overweight as compared with the WHO criteria at BMI $\geq$ 25 kg/m^2. The findings also demonstrated that the BMI levels increase with systolic blood pressure, diastolic blood pressure, TC and LDL-C but decrease with HDL-C levels. They also confirmed that individuals who have a higher BMI are at higher risk of developing hypertension and dyslipidemia than lean people[25].

Only 24.7 percent of studied samples had acceptable levels of both TC and LDL-C, while 90 percent of samples had an acceptable level of HDL-C. This is most likely why the result shows high level of TC, the majority of which were at the borderline level or above. There were 61.3 percent of our samples had LDL-C at borderline and high-risk levels. It is interesting that this figure complies with the cut-off point of BMI according to the Asian criteria which places the overweight rate of the samples at 57.8 percent as compared to the WHO figure which is 32.7 percent.

Triglyceride which has generally been accepted as a coronary risk factor was found in this study to be unrelated to BMI in the high-risk group. Our finding was not consistent with previous studies[26] because the percentage of samples who had TG at a high-risk level was only 2.4 percent. The study results showed the optimal cut-off points of BMI that reflect hypertension (both systolic blood pressure and diastolic blood pressure) at 23.5 kg/m^2. The elevated TC was 22.5 kg/m^2, elevated TG was 23.5, elevated LDL-C was 23.0 kg/m^2 and the reduced HDL-C was 24.0 kg/m^2. The optimal cut-off point of BMI at 23.5 kg/m^2 reflected the majority of risk factors of CVD especially SBP and DPB which were classified as a major risk factor of CVD. This cut-off point of BMI was a little bit higher than the Asian criteria but was closely related to those from studies in Hong Kong[27] and Singapore[28] and was lower than those recommended by WHO. Elevated LDL-C, one of the major risk factor of CVD was the only one that had the cut-off point of BMI which reflect the risk level at 23 kg/m^2 corresponding to that of the Asian criteria. Therefore, the cut-off point of BMI at 23.5 kg/m^2 was suggested to be the optimal cut-off point for screening the risk factors of CVD.

It must be acknowledged that all anthropometric cut-off points are to a certain extent arbitrary. Any precise choice of cut-off values must balance between the need to safeguard against a CVD event, and the burden of increased clinical practice once a patient is labeled as a CVD risk[29]. The sensitivity of the cut-off points of BMI of both WHO and Asian criteria were found very low in this study. Therefore, the current WHO criteria to classify overweight and obesity may not be appropriate for Thai males aged 35-50. This data demonstrates that if a WHO criterion to label obesity at BMI of $\geq$ 30 kg/m^2 is taken as an indication for therapeutic intervention, then the majority of Thai males would be overlooked. Consequently, the whole approach to combat the epidemic of adult chronic disease such as coronary heart disease and stroke will probably be less effective. Therefore, the cut-off point of BMI according to the Asian criteria may be more suitable for this Thai male population group. Hence, this finding supports using the lower BMI criteria to classify obesity in Asian.

However, the weaknesses of the study could be taken into consideration before applying the cut-off points of BMI at 23.5 kg/m^2 for reflecting the risk factors of CVD. Firstly, even though, the optimal cut-off points of BMI were selected following the epidemiological criteria, the sensitivity and specificity of each selected cut-off points of BMI were not high (sensitivity were 63%-74% and specificity were 51%-56%). Moreover, the AUC values were less than 0.5. These mean that each of the optimal cut-off points of BMI suggested in this study may not be appropriate for screening its respective risk factors of CVD. Secondly, the sample size of only 413 participants might be too small. Thirdly, the samples of the study were not population based and limited to Thai males aged 35-50 years who lived in Bangkok. Hence, these results were limited for generalization to general population. Further study in a larger sample size using population based is needed to confirm these results.

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จุดตัดของดัชนีมวลกายที่สะท้อนปัจจัยเสี่ยงต่อการเกิดโรคหัวใจและหลอดเลือดในกลุ่มชายไทยที่อาศัยอยู่ในเขตเมือง

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วัตถุประสงค์: *เพื่อหาจุดตัดของดัชนีมวลกายที่สามารถสะท้อนปัจจัยเสี่ยงต่อการเกิดโรคหัวใจและหลอดเลือดในชายไทยที่อาศัยในเขตเมือง*

วัสดุและวิธีการ: *การศึกษาแบบภาคตัดขวางในชายไทยอายุ 35-50 ปี ทำงานในหน่วยงานราชการ และอาศัยอยู่ในเขตกรุงเทพมหานคร จำนวน 413 คน ทำการชั่งน้ำหนักและวัดส่วนสูงเพื่อคำนวณค่าดัชนีมวลกาย วัดความดันโลหิต และเก็บตัวอย่างเลือดเพื่อวิเคราะห์ดัชนีบ่งชี้ทางชีวเคมี วิเคราะห์ข้อมูลด้วยการหาค่าความไวและค่าความจำเพาะ และ ROC curve*

ผลการศึกษา: *เมื่อใช้จุดตัดของดัชนีมวลกายที่ $\geq$ 23 กก./ม^2 ตามเกณฑ์สำหรับคนเอเชีย พบว่า กลุ่มตัวอย่างร้อยละ 57.8 มีภาวะน้ำหนักตัวเกิน ขณะที่เมื่อใช้จุดตัดของดัชนีมวลกายที่ $\geq$ 25 กก./ม^2 ตามเกณฑ์ขององค์การอนามัยโลก พบกลุ่มตัวอย่างมีภาวะน้ำหนักตัวเกินเพียงร้อยละ 32 จุดตัดของดัชนีมวลกายที่สามารถสะท้อนถึงภาวะความดันโลหิตซีสโตลิคและไดแอสโตลิคสูง ภาวะโคเลสเตอรอลรวมในเลือดสูง ไตรกลีเซอไรด์ในเลือดสูง ไลโปโปรตีนชนิดความหนาแน่นต่ำในเลือดสูง และไลโปโปรตีนชนิดความหนาแน่นสูงในเลือดต่ำ คือ จุดตัดของดัชนีมวลกายที่ 23.5, 23.5, 22.5, 23.5, 23 และ 24 กก./ม^2 ตามลำดับ ดัชนีมวลกายที่ 23.5 กก./ม^2 เป็นจุดตัดที่เสนอแนะสำหรับสะท้อนปัจจัยเสี่ยงต่อการเกิดโรคหัวใจและหลอดเลือด*

สรุป: *ผลการศึกษาชี้ว่า จุดตัดของดัชนีมวลกายตามเกณฑ์สำหรับคนเอเชีย น่าจะเหมาะสมกับกลุ่มประชากรชายไทยในเขตเมืองที่มีวิถีชีวิตมีการเคลื่อนไหวร่างกายน้อย ดีกว่าการใช้จุดตัดตามเกณฑ์ขององค์การอนามัยโลก อย่างไรก็ตาม ยังต้องการการศึกษาในกลุ่มตัวอย่างที่มีขนาดใหญ่เพื่อยืนยันจุดตัดดัชนีมวลกายที่ 23.5 กก./ม^2*
