Appropriate Body Mass Index and Waist Circumference Cutoffs for Middle and Older Age Group in Thailand: Data of 19,621 Participants from Thai Epidemiologic Stroke (TES) Study

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Objective: *To determine the appropriate body mass index (BMI) and waist circumference (WC) cutoff point for identification of at least one cardiovascular risk factor (hypertension, dyslipidemia, and type 2 diabetes) in Thailand, and to compare the discrimination ability of BMI with that of WC for discrimination of at least one cardiovascular risk factor.*
Material and Method: *Baseline health survey data of participants of Thai Epidemiologic Stroke (TES) Study, who were free from stroke, enrolled from five geographic regions around the country, were studied as cross-sectional analysis. Receiver operating characteristics curve (ROC) analysis was performed to determine the appropriate cutoff points of BMI and WC in identifying those with presence of at least one cardiovascular risk factors. The BMI or WC value with the shortest distance on the ROC curve was considered to be appropriate cutoffs. Comparing the ability of BMI in discrimination of at least one cardiovascular risk factor with that of WC was performed by comparing ROC area under curve (AUC).*
Results: *Among 19,621 (6,608 men and 13,013 women) participants with age range of 45 to 80 years, the average age was 59.8 years for men and 58.5 years for women. The appropriate cutoff point of BMI was 23 kg/m^2 in men and 24 kg/m^2 in women. The cutoffs of WC were 80 cm and 78 cm in men and women, respectively. In both gender, waist circumference (WC) (AUC in men = 0.684; 95% CI, 0.672-0.695, AUC in women = 0.673; 95% CI, 0.665-0.681) was significantly ($p < 0.001$) better than BMI (AUC in men = 0.667; 95% CI, 0.656-0.679, AUC in women = 0.636; 95% CI, 0.628-0.644) in discrimination of at least one cardiovascular risk factor.*
Conclusion: *In Thai adults aged 45 to 80 years, the cutoff points of BMI should be 23 kg/m^2 in men and 24 kg/m^2 in women. For WC, 80 cm and 78 cm should be considered to be appropriate cutoffs for men and women, respectively. Waist circumference (WC) as a simple obesity index should be advocated for public health screening.*

Keywords: *Body mass index, Waist circumference, Cutoff point, Cardiovascular risk factors, Thailand*

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Obesity characterized by an excess of body fat is a growing public health problem in both developed and developing countries[1-3]. It is an independent risk factor for cardiovascular disease (CVD) including stroke[4-6], and associates with cardiovascular disease risk factors such as hypertension, dyslipidemia, and type 2 diabetes[4,7].

From the public health perspective, it is important to define an appropriate criteria for screening for obesity in order to identify and prevent the development of obesity related disorders. Body mass index (BMI) and waist circumference (WC) measurement are commonly used for this purpose. The World Health Organization (WHO) has recommended BMI of $\geq$ 25 kg/m^2 as cutoff point for overweight and $\geq$ 30 kg/m^2 for obesity, WC of $\geq$ 94 cm and $\geq$ 80 cm as cutoff points for central obesity for male and female respectively[8]. However, these recommendations are based on data from Western populations, and might not be suitable for Asian populations because several epidemiologic studies in Asian populations have shown that Asians have higher amounts of body fat at lower BMI and WC than do Western populations[9-11]. Perhaps, this is leading to greater prevalence of

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cardiovascular risk factors at lower BMI and WC in Asians populations. Regarding these findings, Western Pacific regional office of the WHO, the International Association for the Study of Obesity (IASO), and the International Obesity Task Force (IOTF) collaborated in the redefining of new recommendations for Asian countries. These recommendations suggest that overweight is defined as BMI ≥ 23 kg/m^2 and central obesity is defined as WC of ≥ 90 cm and ≥ 80 cm for men and women, respectively[12]. However, these recommendations based on scanty data from Asian countries may not be appropriate to generalize to all Asian countries including Thailand.

The ability of BMI and WC to discriminate major cardiovascular risk factors, namely hypertension, dyslipidemia, and type 2 diabetes has been reported largely based on receiver operating characteristic (ROC) analysis. Waist circumference seem to be superior to BMI in the discrimination of cardiovascular risk factors[13,14]. However, direct comparison of these discrimination abilities by using formal statistical test is rarely performed.

In Thailand, where the population characteristics might be different from other Asian countries[15], data regarding the association between arthropometrics and CVD risk factors are limited. The aims of the present study were: (1) to determine the appropriate BMI and WC cutoff point for identification of at least one cardiovascular risk factors (hypertension, dyslipidemia, and type 2 diabetes) in Thailand and (2) to compare the discrimination ability of BMI with that of WC for discrimination of at least one cardiovascular risk factor.

Material and Method

Study population

Thai Epidemiologic Stroke (TES) Study is a community based cohort study being ongoing to investigate the relationship between various risk factors, lifestyles, and stroke in Thailand. In the present study, baseline health survey data of participants who were free from stroke at baseline were included as cross-sectional analysis. A detailed description of the present study population and methods has been published elsewhere[16]. Briefly, the general population aged 45- 80 years, were enrolled from five geographic regions of Thailand, namely Bangkok (capital city), Chiang Mai province (northern region), Khon Kaen province (northeastern region), Chachoengsao province (central region) and Nakhon Si Thammarat province (southern region) on a voluntary basis. Participants were accrued by approaching directly via address lists, with the assistance of local health personnel, as well as by announcements in local media. Study sample was stratified by study region to ensure that the distribution was proportionately matched by study region with that of Thailand's population aged 45-80 years[17].

The present study was approved by the Ethical Review Committee for Research in Human Subjects, Ministry of Public Health, Thailand. Informed consent was obtained from each participant before data collection.

Baseline survey

Baseline health survey data were collected at a community place during 2004 and 2006. Measurement of blood pressure and anthropometric data, collection of blood sample after overnight fast, and face-to-face interview assessing demographic information and medical history were performed under standard operating procedures by a well-trained staff. Based on stroke screening questionnaire, participants who were suspected to have a stroke were interviewed and examined by board-certified neurologists for determining stroke status. The details of stroke screening questionnaire and method for verification of stroke status have been described in the authors' previous publication[16].

Blood pressure was measured in a sitting position, three times, one minute apart with the use of an automated blood pressure device (Omron HEM-907, Omron Healthcare Singapore PTE LTD, Singapore) after participants had rested at least for five minutes. Waist circumference was taken on bare skin, in a horizontal plane midway between the last rib and iliac crest[8,12]. Height and weight were measured in light clothes without shoes, to the nearest 0.1 cm and 0.1 kg, respectively. Digital weight measurement machine (TANITA BWB-800, TANITA Corporation, Japan) was used. Venous blood samples were obtained after a 12-hours overnight fast. Analyses for glucose and lipid profile were performed at Division of Clinical Chemistry, Faculty of Medicine Ramathibodi Hospital, which was certificated by the Centers for Disease Control, USA - National Heart, Lung and Blood Institute Lipid Standardization Program.

Definition

Average of three blood pressure measurements was used in these analyses, hypertension was defined as blood pressure ≥ 140/90 mmHg or self-reported use of antihypertensive medication. Fasting plasma glucose ≥ 7.0 mmol/l (126 mg/dl) or history of treatment for

diabetes was defined as diabetes. Hypercholesterolemia was defined by fasting total cholesterol ≥ 5.2 mmol/l (200 mg/dl) or self-reported use of medication for hypercholesterolemia. Never smokers were those who had never smoked at all, or have smoked less than 100 cigarettes in their lifetime. Current smoker was defined as having smoked 100 cigarettes or more in a lifetime and smokes cigarettes currently. Participants who smoked 100 cigarettes or more in their lifetime but currently do not smoke at all were defined as ex-smokers. Criteria for the diagnosis of stroke were those given by World Health Organization[18].

According to The Practical Guide: Identification, Evaluation, and Treatment of Overweight and Obesity in Adults released by the National Institutes of Health (NIH)[19], cardiovascular risk factors were defined as followings: (1) high LDL cholesterol as a concentration ≥ 4.14 mmol/l (160 mg/dl), (2) Low HDL cholesterol as a concentration < 0.91 mmol/l (35 mg/dl) for men and < 1.17 mmol/l (45 mg/dl) for women, (3) high blood pressure as a systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, and (4) high glucose as a fasting plasma glucose concentration > 6.94 mmol/l (125 mg/dl). Participants who had one or more of these conditions or taking medication for diabetes, hypertension, or hypercholesterolemia were classified as having at least one cardiovascular risk factor.

Statistical analysis of study

Continuous variables were presented as mean and standard deviation (SD). Categorical variables were described with percentages. The differences in baseline characteristics between gender and between participants who with and without at least one cardiovascular risk factor were analyzed using independent sample t-test and Chi-square test for continuous and categorical variables, respectively. All probability values were two sided, and level of significance was set at p-value < 0.05. Receiver operating characteristics curve (ROC) analysis was performed to determine the appropriate cutoff points of BMI and WC in identifying those with presence of at least one cardiovascular risk factor. Distance on the ROC curve of each BMI and WC value was calculated as the square root of $[(1\text{-sensitivity})^2 + (1\text{-specificity})^2]$. The BMI or WC value with the shortest distance on the ROC curve was considered to be appropriate cutoffs[20]. Positive and negative predictive value of each cutoff point was calculated. The ROC area under curve (AUC) with 95% CI of both BMI and WC were estimated. To compare the ability of BMI in discrimination of at least one cardiovascular risk factor with that of WC, formal statistical test for comparing ROC curve was done by the method proposed by Hanley JA and McNeil BJ[21].

All statistical analyses were performed using SPSS for Windows version 16.0 (SPSS Inc., Chicago, Illinois, USA) and MedCalc for Windows version 12.1.0.0 (MedCalc Software, Mariakerke, Belgium).

Results

Among 19,997 participants who completed the baseline survey, stroke was found in 376 (1.9%) participants. Therefore, 19,621 (6,608 men and 13,013 women) participants, with an age range of 45 to 80 years, who were free from stroke were included in the present study. Baseline characteristics of the present study sample are summarized in Table 1. The average age was 59.8 years for men and 58.5 for women. Most of the present study samples were in the age group of 45-59 years. Men showed significantly higher prevalence of smoking ($p < 0.001$), and significantly higher values for WC ($p < 0.001$), fasting plasma glucose ($p = 0.024$), and triglyceride ($p < 0.001$), whereas women had significantly higher prevalence of hypertension ($p = 0.001$), diabetes ($p = 0.007$), hypercholesterolemia ($p < 0.001$), and at least one cardiovascular risk factor ($p < 0.001$). Women also showed significantly higher values for BMI ($p < 0.001$), LDL cholesterol ($p < 0.001$), and HDL cholesterol ($p < 0.001$).

Comparisons of baseline characteristics between study sample who with and without at least one cardiovascular risk factor, which are shown in Table 2, demonstrated statistically significant differences ($p < 0.001$). Participants with at least one cardiovascular risk factor had higher prevalence of older age, women, lower educational level, unemployed/housework, never smoking, and had higher values for WC and BMI.

Table 3 shows the results from the ROC analyses for BMI in identifying the presence of at least one cardiovascular risk factor. In men, the appropriate cutoff point of BMI with the shortest distance on ROC was 23 kg/m^2, with the sensitivity, specificity, positive predictive value, and negative predictive value of 56.9% 68.9%, 84.3%, and 35.3%, respectively. In women, the corresponding cutoff point was 24 kg/m^2 (sensitivity = 59.8%, specificity = 61.8%, positive predictive value = 90.7%, and negative predictive value = 19.8%).

Table 1. Baseline characteristics of study sample

Variables	Total (n = 19,621)	Men (n = 6,608)	Women (n = 13,013)	p-value
Age (years; mean, SD)	58.9, 9.0	59.8, 9.2	58.5, 8.8	<0.001
Age group				<0.001
45-59 (years; %)	56.2	51.7	58.5	
60-69 (years; %)	28.4	30.1	27.6	
70-80 (years; %)	15.3	18.2	13.9	
Education level				<0.001
Illiterate (%)	2.7	1.1	3.5	
Primary (%)	78.6	75.1	80.4	
Secondary (%)	11.7	17.2	9.0	
University (%)	6.9	6.5	7.1	
Occupation				<0.001
Agricultural class (%)	30.7	41.3	25.3	
Non-manual class (%)	5.4	5.8	5.3	
Manual class (%)	35.4	34.0	36.1	
Unemployed/house work (%)	28.5	19.0	33.3	
Geographical area				<0.001
Bangkok (%)	10.6	7.4	12.2	
Central region (%)	24.2	21.5	25.5	
Southern region (%)	12.2	13.7	11.4	
Northern region (%)	22.1	25.5	20.3	
Northeastern region (%)	31.0	31.8	30.5	
BMI (kg/m^2; mean, SD)	24.4, 4.2	23.2, 3.8	25.0, 4.3	<0.001
Waist circumference (cm; mean, SD)	82.3, 11.0	83.1, 11.0	81.9, 10.9	<0.001
Smoking status				<0.001
Never (%)	70.4	25.1	93.2	
Ex-smoker (%)	15.7	38.7	4.1	
Current (%)	13.9	36.2	2.7	
Hypertension (%)	43.2	41.5	44.1	0.001
Diabetes mellitus (%)	15.9	15.0	16.4	0.007
Hypercholesterolemia (%)	65.7	55.2	71.0	<0.001
Fasting plasma glucose (mg/dl; mean, SD)	104.2, 32.9	105.0, 32.3	103.8, 33.2	0.024
LDL cholesterol (mg/dl; mean, SD)	142.6, 41.3	132.0, 39.6	148.0, 41.1	<0.001
HDL cholesterol (mg/dl; mean, SD)	42.4, 12.6	39.7, 12.2	43.8, 12.6	<0.001
Triglyceride (mg/dl; mean, SD)	164.3, 117.3	175.5, 129.8	158.6, 109.9	<0.001
At least one cardiovascular risk factor* (%)	82.2	74.6	86.1	<0.001

* Defined as the presence of any one or more of following conditions: (1) LDL cholesterol ≥ 160 mg/dl, (2) HDL cholesterol < 35 mg/dl for men and < 45 mg/dl for women, (3) systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, (4) fasting plasma glucose > 125 mg/dl, and (5) taking medication for diabetes, hypertension, or hypercholesterolemia

The ROC analyses for cutoff point of WC are presented in Table 4. For men, the appropriate cutoff point of WC was 80 cm, with the shortest distance on ROC (sensitivity = 66.8%, specificity = 62.8%, positive predictive value = 83.9%, and negative predictive value = 39.2%). In women, the corresponding cutoff point for WC was 78 cm (sensitivity = 65.9%, specificity = 61.7%, positive predictive value = 91.4%, and negative predictive value = 22.7%).

Table 5 shows the comparison of discrimination ability between BMI and WC in discrimination of at least one cardiovascular risk factor. In men, the

Table 2. Baseline characteristics of study sample who with and without at least one cardiovascular risk factor

Variables	Paticipants with risk factor* (n = 16,101)	Participants without risk factor* (n = 3,478)	p-value
Age (years; mean, SD)	59.6, 9.0	56.0, 8.4	<0.001
Age group			<0.001
45-59 (years; %)	53.2	69.7	
60-69 (years; %)	30.0	21.4	
70-80 (years; %)	16.8	8.8	
Gender (men;%)	30.5	48.2	<0.001
Education level			<0.001
Illiterate (%)	3.0	1.5	
Primary (%)	79.2	75.8	
Secondary (%)	11.3	13.7	
University (%)	6.5	9.0	
Occupation			<0.001
Agricultural class (%)	29.0	38.3	
Non-manual class (%)	5.1	7.2	
Manual class (%)	34.9	37.7	
Unemployed/house work (%)	31.0	16.8	
Geographical area			<0.001
Bangkok (%)	10.8	9.8	
Central region (%)	24.4	23.4	
Southern region (%)	11.5	15.0	
Northern region (%)	21.5	24.6	
Northeastern region (%)	31.8	27.3	
BMI (kg/m^2; mean, SD)	24.8, 4.2	22.5, 3.8	<0.001
Waist circumference (cm; mean, SD)	83.4, 10.9	77.1, 9.8	<0.001
Smoking status			<0.001
Never (%)	72.7	59.8	
Ex-smoker (%)	15.4	17.0	
Current (%)	11.9	23.2	
Hypertension (%)	52.6	0.0	<0.001
Diabetes mellitus (%)	19.4	0.0	<0.001
Hypercholesterolemia (%)	69.2	49.7	<0.001
Fasting plasma glucose (mg/dl; mean, SD)	106.9, 35.5	91.7, 9.5	<0.001
LDL cholesterol (mg/dl; mean, SD)	146.9, 42.8	122.9, 24.7	<0.001
HDL cholesterol (mg/dl; mean, SD)	40.5, 12.0	51.4, 11.3	<0.001
Triglyceride (mg/dl; mean, SD)	174.6, 122.6	116.9, 72.1	<0.001

* Defined as the presence of any one or more of following conditions: (1) LDL cholesterol ≥ 160 mg/dl, (2) HDL cholesterol < 35 mg/dl for men and < 45 mg/dl for women, (3) systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, (4) fasting plasma glucose > 125 mg/dl, and (5) taking medication for diabetes, hypertension, or hypercholesterolemia

difference between the area under curves (AUC) of BMI and WC was statistical significance (AUC of BMI = 0.667; 95% CI, 0.656-0.679: AUC of WC = 0.684; 95% CI, 0.672-0.695: $p < 0.001$). In women, area under curves (AUC) of BMI and WC were 0.636 (95% CI, 0.628-0.644) and 0.673 (95% CI, 0.665-0.681), respectively, which was also statistically significant difference ($p < 0.001$).

Discussion

The results of the present population based study, which included the study samples of 6,608 men

Table 3. Sensitivity, specificity, predictive value and distance in the receiver operating characteristic (ROC) curve of BMI cutoffs for identifying subjects with at least one cardiovascular risk factor*

BMI (kg/m^2)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Distance in ROC curve
Men					
21	76.3	47.0	80.8	40.3	0.580
22	67.3	57.8	82.4	37.6	0.534
23	56.9	68.9	84.3	35.3	0.532
24	46.6	78.1	86.2	33.3	0.577
25	35.8	84.8	87.3	31.1	0.660
Women					
22	77.5	40.3	89.0	22.4	0.638
23	69.3	50.8	89.7	21.0	0.580
24	59.8	61.8	90.7	19.8	0.555
25	49.7	71.0	91.4	18.5	0.580
26	40.0	78.0	91.9	17.3	0.639

* Defined as the presence of any one or more of following conditions: (1) LDL cholesterol ≥ 160 mg/dl, (2) HDL cholesterol < 35 mg/dl for men and < 45 mg/dl for women, (3) systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, (4) fasting plasma glucose > 125 mg/dl, and (5) taking medication for diabetes, hypertension, or hypercholesterolemia

Table 4. Sensitivity, specificity, predictive value and distance in the receiver operating characteristic (ROC) curve of WC cutoffs for identifying subjects with at least one cardiovascular risk factor*

WC (cm)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Distance in ROC curve
Men					
78	72.6	55.8	82.7	41.0	0.520
79	69.6	58.9	83.2	40.0	0.511
80	66.8	62.8	83.9	39.2	0.498
81	64.1	65.0	84.4	38.5	0.501
82	60.6	68.1	84.8	37.4	0.506
Women					
76	72.4	52.4	90.7	24.3	0.535
77	69.5	58.2	91.1	23.6	0.517
78	65.9	61.7	91.4	22.7	0.513
79	62.6	64.8	91.6	21.9	0.514
80	58.8	67.7	91.8	21.1	0.523

* Defined as the presence of any one or more of following conditions: (1) LDL cholesterol ≥ 160 mg/dl, (2) HDL cholesterol < 35 mg/dl for men and < 45 mg/dl for women, (3) systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, (4) fasting plasma glucose > 125 mg/dl, and (5) taking medication for diabetes, hypertension, or hypercholesterolemia

Table 5. Comparison of AUC* (with 95% CI) of BMI with that of WC for identifying subjects with at least one cardiovascular risk factor**

Measurement	BMI	WC	Difference between areas	p-value***
Men	0.667, 0.656-0.679	0.684, 0.672-0.695	0.016, 0.009-0.024	<0.001
Women	0.636, 0.628-0.644	0.673, 0.665-0.681	0.037, 0.029-0.045	<0.001

* Area under receiver operating characteristic (ROC) curve
** Defined as the presence of any one or more of following conditions: (1) LDL cholesterol ≥ 160 mg/dl, (2) HDL cholesterol < 35 mg/dl for men and < 45 mg/dl for women, (3) systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, (4) fasting plasma glucose > 125 mg/dl, and (5) taking medication for diabetes, hypertension, or hypercholesterolemia
*** p-value for comparison of area under receiver operating characteristic (ROC) curve of BMI with that of WC for identifying subjects with at least one cardiovascular risk factor

and 13,013 women, aged 45 to 80 years from five regions around the country, provided evidences that BMI of 23 kg/m^2 for men and 24 kg/m^2 for women were appropriate cutoffs for identifying at least one cardiovascular risk factor, and WC of 80 cm and 78 cm were appropriate cutoffs for men and women, respectively. Comparing with BMI, WC was significantly better ($p < 0.001$) in terms of discrimination in at least one cardiovascular risk factor (Table 5).

According to WHO recommendation for a white population, the practical action points for considering the increased risk of co-morbidity are BMI = 25 kg/m^2[8]. This recommendation might not be appropriate for Asians countries because the prevalence of CVD risk factors in Asian is substantial at below the BMI cutoff point of 25 kg/m^2[22,23]. Therefore, in 2000, in spite of limited data from Asian countries, WHO recommended BMI of 23 kg/m^2 as a cutoff point in both genders for an Asian population and ask for revision in the light of further validation of studies and clinical experience[12]. Since this recommendation, several studies have examined appropriate cutoffs for overweight in Asians populations. Most studies[14,20,24-26] have suggested a BMI cutoff of 21-24 kg/m^2, which was similar to the authors' results.

In 2000, WC of 90 cm and 80 cm were suggested by WHO as cutoffs for Asians men and women, respectively[12]. However, recent review[27] showed that WC cutoff points were varied between Asian populations (Table 6), and seem to be lower than those recommended for Asians by WHO[12]. In addition, a study from India, which included 2,050 participants aged more than 18 years demonstrated 78 cm and 72 cm as optimal cutoffs for WC in men and women, respectively[25]. Data from a study in Taiwan (26,359 men and 29,204 women with mean age of 37.3 years and 37.0 years, respectively) also suggested lower cutoffs of WC (80.5 cm in men and 71.5 in women)[26]. The authors' findings showed that WC of 80 cm for men and 78 cm for women were appropriate cutoffs were quite similar to those reported in most previous studies (Table 6)[27], however, in women, the authors' cutoffs seem to be higher comparing with those reported from India[25] and Taiwan[26].

In Thailand, previous studies using percentage body fat as a predicting outcome showed that cutoff points for BMI were 27 kg/m^2 in men and 25 kg/m^2 in women[28], and for WC were 93 cm in men and 84 cm in women[29]. These findings were different from the authors' results, perhaps because different predicting outcome was used. In the present study, health related outcome such as at least one cardiovascular risk factor rather than percentage body fat was used as predicting outcome. A study with a sample of 5,305 participants (aged $\geq$ 35 years)[13], which used cardiovascular risk factors as predicting outcome suggested that the cutoff point of BMI in Thailand was 23 kg/m^2 which was in line with the authors' results, but suggested cutoffs for WC was around 82-85 cm (measurement from the horizontal plane at 1 cm above the navel) in both gender which was quite different from the present study (80 cm for men and 78 cm for women). This observation might be due to difference in age distribution of the study sample and measurement location for WC. The present study included participants who were rather old (aged 45-80 years) and had a higher prevalence of cardiovascular risk factors. Regarding measurement location for WC, one might expect that all WC sites do not provide the same measurement estimate[30]. In a recent review, there were 8 different measurement locations documented for WC: (1) midway between the last rib and iliac crest, (2) point of minimal circumference, (3) immediately above the iliac crest, (4) navel, (5) 1 inch above the navel, (6) 1 cm above the navel, (7) at the lowest rib, and (8) point of largest circumference around the waist[30,31]. In the present study, midway between the last rib and iliac crest was used as a location site. A study of 998 participants aged 45 to 50 years proposed BMI of 23 kg/m^2, WC of 84 for men and WC of 80 for women[32], whereas the present study included participants aged 45 to 80 years, which might lead to the difference findings in WC cutoffs.

In men, there was some overlapping of 95% confidence interval of AUC for BMI (AUC = 0.667; 95% CI, 0.656-0.679) with that for WC (AUC = 0.684;

Table 6. Suggested waist circumference cutoffs (cm) from some previous studies in Asian countries[27]

Populations	Men	Women	Age range (years)
Chinese (mainland China, Hong Kong, Taiwan)	80.5-95.1	71.5-83.7	15-93
East Asian (Korea, Japan)	85-90	78-86	18-88
South Asian (Bangladesh, India, Nepal, Pakistan, Sri Lanka)	87	82	$\geq$ 20

95% CI, 0.672-0.695) (Table 5). Non-overlapping of 95% confidence interval usually indicate that there is statistically significant difference between population parameters, that is, p-value calculated by formal statistical test is less than 0.05. However, the reversal might not be true, that is, overlapping of 95% confidence interval might not indicate that there is no statistically significant difference by a formal test[33,34]. In the present case, it could be better to rely on a formal statistical test rather than overlapping or non-overlapping of 95% confidence interval, if the formal statistical test exists[33,34]. In the present study, based on formal statistical test for comparing ROC curve proposed by Hanley JA and McNeil BJ[21], WC (AUC = 0.673-0.684) was significantly ($p < 0.001$) better than BMI (AUC = 0.636-0.667) in discrimination of at least one cardiovascular risk factor in both gender (Table 5). In addition, the 95% CI of difference between the areas also did not cross zero. However, these differences were small (0.016-0.037) (Table 5). These findings were in line with a previous study in Thailand[13], and a recent meta-analysis[35]. Although WC was just slightly better than BMI as a discriminator of cardiovascular risk factors, it should be advocated for public health screening in order to early detection and treatment of cardiovascular risk factors because WC measurement is inexpensive and simpler comparing to BMI measurement.

The strengths of the present study were large sample size enrolled from the general population (aged 45-80 years) from five regions around the country rather than selected population. Assessments of all participants were performed by well-trained personnel using standardized protocol. However, some limitations exist. The present study sample had a high prevalence of cardiovascular risk factors, possibly, because the sample was rather old (aged 45-80 years). Therefore, the present results may not be appropriate to generalize the younger age group. Participants were enrolled on the voluntary basis so the present study sample was not established by random sampling but it covers all major demographic strata of the Thai general population aged 45 to 80 years. Unfortunately, apart from stroke status, data regarding other chronic diseases such as cancer, chronic kidney disease, were not collected so the authors did not exclude those chronic diseases from the present study. Because of cross-sectional analyses in the present study, the direct causal relationship between BMI, WC, and cardiovascular risk factors could not be firmly established.

In conclusion, the present study of general Thai population aged 45-80 years demonstrated that the appropriate cutoff points for BMI were 23 kg/m^2 for men and 24 kg/m^2 for women. For WC, 80 cm and 78 cm were appropriate cutoffs for men and women, respectively. Waist circumference was a better discriminator of cardiovascular risk factors than BMI. Therefore, the national cutoffs of WC in Thailand might be reconsidered. Waist circumference (WC) as a simple obesity index should be advocated for public health screening in order to early detection and treatment of cardiovascular risk factors.

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Potential conflicts of interest

None.

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ค่าดัชนีมวลกายและค่ารอบเอวที่เหมาะสมสำหรับกลุ่มอายุวัยกลางคนขึ้นไปในประเทศไทย: ข้อมูลอาสาสมัคร 19,621 รายของโครงการศึกษาระบาดวิทยาโรคหลอดเลือดสมองในประเทศไทย

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วัตถุประสงค์: เพื่อหาค่าดัชนีมวลกายและค่ารอบเอวที่เหมาะสมในการบ่งชี้ถึงปัจจัยเสี่ยงของโรคหัวใจและหลอดเลือดอย่างน้อย 1 ชนิด (ความดันโลหิตสูง, ภาวะไขมันผิดปกติ, และเบาหวานชนิดที่ 2) ในประเทศไทย และเปรียบเทียบความสามารถในการจำแนกปัจจัยเสี่ยงดังกล่าวระหว่างค่าดัชนีมวลกายกับค่ารอบเอว

วัสดุและวิธีการ: การศึกษานี้ได้นำข้อมูลการสำรวจสถานะสุขภาพของอาสาสมัครของโครงการศึกษาระบาดวิทยาโรคหลอดเลือดสมองในประเทศไทยที่มิได้ป่วยด้วยโรคหลอดเลือดสมอง ซึ่งได้ทำการรวบรวมจาก 5 พื้นที่ของประเทศไทยมาทำการศึกษาในลักษณะภาคตัดขวางได้ทำการวิเคราะห์หาค่าที่เหมาะสมของดัชนีมวลกายและรอบเอวในการบ่งชี้ถึงปัจจัยเสี่ยงของโรคหัวใจและหลอดเลือดอย่างน้อย 1 ชนิด ด้วยเทคนิค Receiver operating characteristics curve (ROC) analysis ค่าดัชนีมวลกายและค่ารอบเอวที่มีระยะทางบนกราฟ ROC สั้นที่สุดจะได้รับการพิจารณาเป็นค่าที่เหมาะสม นอกจากนี้ยังได้เปรียบเทียบความสามารถในการจำแนกปัจจัยเสี่ยงดังกล่าวระหว่างค่าดัชนีมวลกายกับค่ารอบเอวโดยการเปรียบเทียบพื้นที่ใต้กราฟ (ROC area under curve, AUC)

ผลการศึกษา: การศึกษานี้มีจำนวนอาสาสมัคร 19,621 ราย (ชาย 6,608 ราย, หญิง 13,013 ราย) มีอายุตั้งแต่ 45-80 ปี อายุเฉลี่ยเพศชายเท่ากับ 59.8 ปี เพศหญิงเท่ากับ 58.5 ปี ค่าดัชนีมวลกายที่เหมาะสมเท่ากับ 23 kg/m^2 ในเพศชายและ 24 kg/m^2 ในเพศหญิง ค่าที่เหมาะสมสำหรับรอบเอวเท่ากับ 80 เซนติเมตร และ 78 เซนติเมตร ในเพศชายและหญิงตามลำดับ ในทั้งสองเพศค่ารอบเอว (ค่า AUC ในเพศชายเท่ากับ 0.684; 95% CI, 0.672-0.695, ค่า AUC ในเพศหญิงเท่ากับ 0.673; 95% CI, 0.665-0.681) มีความสามารถในการจำแนกปัจจัยเสี่ยงของโรคหัวใจ และหลอดเลือดอย่างน้อย 1 ชนิดได้ดีกว่าค่าดัชนีมวลกาย (ค่า AUC ในเพศชายเท่ากับ 0.667; 95% CI, 0.656-0.679, ค่า AUC ในเพศหญิงเท่ากับ0.636; 95% CI, 0.628-0.644) อย่างมีนัยสำคัญทางสถิติ ($p < 0.001$)

สรุป: ในคนไทยอายุตั้งแต่ 45-80 ปี ค่าดัชนีมวลกายที่เหมาะสมควรเท่ากับ 23 kg/m^2 ในเพศชายและ 24 kg/m^2 ในเพศหญิง ขนาดรอบเอวเท่ากับ 80 เซนติเมตร และ 78 เซนติเมตรควรได้รับการพิจารณาเป็นค่าที่เหมาะสมในเพศชายและหญิงตามลำดับ และควรใช้การวัดรอบเอวสำหรับการคัดกรองภาวะอ้วนในระดับชุมชน