The associations of different measurements of obesity with cardiovascular risk factors in Chinese

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ABSTRACT

Background: Obesity increases the risks of cardiovascular diseases (CVD). This study examined the optimal cut-off values for overweight and obesity for CVD risks using different anthropometric indices in middle-aged Taiwanese.

Materials and Methods: A total of 2359 subjects aged 40 years and over were recruited in 2004 in Taiwan. Body mass index (BMI) was divided into four groups using three different definitions. Waist circumference (WC), waist-to-hip ratio (WC/HC), and waist-to-height ratio (WC/H) were divided into quartiles. The receiver operating characteristic analysis was used to compare their predictive validity and to find out their optimal cut-off values.

Results: Men were older and had greater height, weight, BMI, WC, WC/HC, WC/H, blood pressure (BP), fasting glucose, uric acid, and triglycerides than women. In all BMI definitions, subjects in higher BMI groups had higher BP, fasting glucose, triglycerides, uric acid, and WC than subjects in lower BMI groups. Compared to quartile I of WC, WC/HC, and WC/H, the odds ratios of having CVD risk factors increased in higher quartiles of WC, WC/HC, and WC/H. The optimal cut-off values for overweight/obesity in middle-aged Taiwanese in men and women were as follows: BMI of 23.7 and 22.4 kg/m^2, WC of 82.5 and 72.5 cm, WC/HC of 0.87 and 0.79, and WC/H of 0.50 and 0.46, respectively. WC/H is the best indicator for predicting CVD risks.

Conclusions: Obesity, presenting with higher BMI, WC, WC/HC, and WC/H, is closely related to CVD risk factors. WC/H is the best predictor of CVD risk factors in middle-aged Taiwanese.

Keywords: Body mass index, waist circumference, waist-to-hip ratio, waist-to-height ratio, cardiovascular disease, cut-off,

Introduction

The prevalence of obesity is increasing globally [1]. The World Health Organization (WHO) has reported that approximately 1.6 billion adults (age 15 years old and above) are overweight and at least 400 million adults are obese [2]. WHO further projects that by 2015, approximately 2.3 billion adults will be overweight and more than 700 million will be obese [2]. This problem occurs in Taiwan, where the age-adjusted prevalence of obesity increased from 10.5% to 15.9% for men from 1993-1996 to 2000-2001 [3]. Furthermore, Flegal et al. has proposed that obesity is the secondary preventable cause of death [4]. Obesity has been recognized as an important risk factor for many chronic diseases, such as diabetes, hypertension, and cardiovascular disease (CVD) [5-7]. Obesity also increases CVD and all-cause mortality [8-10].

Obesity consists of excessive fat deposits throughout in the body, whereas central obesity means the body fat in the mid-body region, much of it in the intra-abdominal area. Several methods have been proposed to estimate body fat, such as hydrodensitometry, bioelectrical impendence, dual energy X-ray absorptiometry (DEXA), and anthropometric indices (such as skinfold thickness measurements and body mass index (BMI)). For comparisons among areas, WHO has proposed using BMI and waist circumference (WC) to estimate fatness. BMI is a marker of overall (general) obesity. Compared with overall obesity, central obesity appears to be more strongly associated with CVD risk factors [11-14]. For the measurement of central obesity, a number of anthropometric measurements, such as WC, waist-to-hip ratio (WC/HC), and waist-to-height ratio (WC/H), are used in general practice [15-17]. However, which index of obesity best predicts CVD risk factors is still controversial.

Increasing obesity has led to a global burden of chronic diseases. For example, Amos *et al* has estimated that the incidence of diabetes will increase by 2- to 3-fold in Asia in 2010 due to the increasing prevalence of obesity [18]. Many studies have reported that obesity, measured by anthropometry, is strongly related to CVD risk factors. However, most of these studies focused on Caucasians, not Chinese. The criteria for defining obesity and metabolic syndrome need to consider the influence of ethnicity [19-21]. The increased risks associated with obesity have been found to occur at a lower BMI in Asians than in Caucasians [22, 23]. For a given weight, Asians have greater total body fat content and abdominal fat accumulation than do Caucasians [24, 25]. For example, Chang *et al* comparing obese Caucasians (BMI ≥ 30 kg/m^2) to Taiwanese with the same body fat level, reported that the equivalent BMI for Taiwanese was 26.2 kg/m^2 in men and 24.3 kg/m^2 in women, showing that Taiwanese have similar body fat to Caucasians at a much lower BMI level [24]. A similar phenomenon is also found in Singapore Chinese [26].Therefore, WHO has proposed a lower BMI value for overweight and obesity in the Asia-Pacific region than that suggested for Caucasians in 2000. Different countries have made their own definitions on obesity. Therefore, we assessed the relationships between obesity and CVD risk factors in a population-based study in Taiwan using three different BMI definitions. Only limited studies addressed this issue [27]. We also used the receiver operating characteristic (ROC) analysis to compare their predictive validity and to find out the optimal cut-off values for predicting CVD risk factors in middle-aged Taiwanese.

Materials and Methods

Study population and sampling method

The target population consisted of residents aged 40 and above in Taichung city, Taiwan in 2004. A total of 363,543 residents in this area during the time of study were identified, which represented about 4.09 % of the national population of the same age. A two-stage sampling design was used to identify residents, with a sampling rate proportional to size within each stage [28-30]. 4280 individuals were selected. Then, household visits were done by trained staff. The excluded criteria during household visit included death, hospitalization or imprisonment, living abroad, moving out, living in their children's house, mistake of the sampling frame, and not being at home during 3 visits made by interviewers. Except these reasons, all individuals were included in the study. During household visits, 750 individuals were identified who were not eligible and therefore, they were excluded from the study sample. Finally, 3530 individuals were invited to participate in this study. However, 1171 individuals refused to participate in this study. Hence, the study sample was 2359 individuals. The overall response rate was 66.8 %, as previously reported [30-32].

Anthropometric indices and biochemical determinations

The detailed methods used in this study for anthropometric indices measurements and biomedical determinations have been described previously [29]. In brief, trained staff measured height, WC, hip circumference (HC), weight, and blood pressure (BP). WC/HC was calculated as WC (cm) divided by HC (cm). WC/H was calculated as WC (cm) divided by height (cm). BMI was calculated as weight (kg) divided by height square (m^2) and was categorized into 4 groups according to three different definitions for obesity. First, BMI was defined from WHO [1] as: (1) Underweight: BMI < 18.5 kg/m^2; (2) Normoweight: 25 > BMI ≥ 18.5 kg/m^2; (3) Overweight: 30 > BMI ≥ 25 kg/m^2; (4) Obese: BMI ≥ 30 kg/m^2. Second, it was defined from the Asia-Pacific region of WHO [33] as: (1) Underweight: BMI <18.5 kg/m^2; (2) Normoweight: 23 > BMI ≥ 18.5 kg/m^2; (3) Overweight: 25 > BMI ≥ 23 kg/m^2; (4) Obese: BMI ≥ 25 kg/m^2. Third, BMI was defined from the Department of Health (DOH) of Taiwan [34] as: (1) Underweight: BMI < 18.5 kg/m^2; (2) Normoweight: 24 > BMI ≥ 18.5 kg/m^2; (3) Overweight: 27 > BMI ≥ 24 kg/m^2; (4) Obese: BMI ≥ 27 kg/m^2. Body composition was measured using bioelectrical impedance analysis (TBF-410, Tanita Co., Tokyo, Japan). Blood was drawn in the morning after a 12-h overnight fast and was sent for analysis within 4-h of collection. Biochemical markers were analyzed with a biochemical autoanalyzer (Beckman Cou, Fullerton, CA, USA) at the Clinical Laboratory Department (China Medical University Hospital, Taichung, Taiwan).

Cardiovascular disease risk factors and metabolic syndrome

Hypertension was defined as systolic BP ≥140 mmHg, and/or diastolic BP ≥90 mmHg, and/or hypertension history with anti-hypertensive drug treatment [35]. Diabetes was defined as fasting glucose ≥ 7 mmol/L and/or diabetes history with oral hypoglycemic agents or insulin treatment [36]. Hyperglycemia was defined as fasting glucose ≥ 5.6 mmol/L and/or diagnosed diabetes mellitus [36]. Dyslipidemia was defined as subjects with high triglycerides (TG) level (fasting TG ≥ 1.7 mmol/L) and/or high total cholesterol (TCHOL) level (TCHOL ≥ 5.17 mmol/L) and/or low high-density-lipoprotein cholesterol (HDL-C) level (HDL-C< 1.03 mmol/L in men or <1.29 mmol/L in women) [37]. Hyperuricemia was defined as serum uric acid ≥ 446.1 μmol/L in men or ≥ 386.6 μmol/L in women. Metabolic syndrome (MetS) was defined clinically, by the presence of 3 or more of the following American Heart Association/National Heart, Lung, and Blood Institute criteria (AHA/NHLBI) MetS criteria [37]: (1) central obesity (WC ≥ 90 cm in men, and ≥ 80 cm in women), (2) high TG level (≥ 1.7 mmol/L or on drug treatment for elevated triglycerides), (3) low HDL-C level (<1.03 mmol/L in men and <1.29 mmol/L in women or on drug treatment for reduced HDL-C), (4) high BP (systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg or under anti-hypertensive drug treatment in a patient with history of hypertension), and (5) high fasting plasma glucose concentration (≥ 5.6 mmol/L or on drug treatment for elevated glucose).

Statistical analysis:

The data are presented as means and SD(standard deviation) unless indicated otherwise. Student’s t test and analysis of variance (ANOVA) were used to test significant differences for continuous data on contrasting groups. Log transformation was used for variables with significant deviation from normal distribution, assessed by the Kolmogorov–Smirnov test before further analyses. The Chi-square (χ^2) test was used to compare the differences in categorical variables. Binary logistic regression analysis was used to estimate the odds ratios (ORs) of CVD risk factors for different WC, WC/HC, and WC/H groups. The ROC analysis was used to compare their predictive validity and to find out their optimal cut-off values. The area under the ROC curve (AUC) is a measure of the diagnostic power of a test. A perfect test will have an AUC of 1.0 and an AUC = 0.5 means the test performs no better than chance. Sensitivity and specificity of the anthropometric measurements have been calculated at all possible cut-off points to find the optimal cut-off values. The optimal sensitivity and specificity were the values yielding maximum sums from the ROC curves. Mann-Whitney test was used to compare the differences of AUCs for at least one CVD risk factor between WC/H and other three measurements (BMI, WC, WC/HC). All statistical tests were 2-sided at the 0.05 significance level. These statistical analyses were performed using the PC version of SPSS statistical software (13th version, SPSS Inc., Chicago, IL, USA).

Reporting of the study conforms to STROBE along with references to STROBE and the broader EQUATOR guidelines [38]. Ethics approval for patient recruitment and data analysis was obtained from the Institutional Review Board of the China Medical University Hospital. The informed consent was obtained from every study participant.

Results

Men were older and had greater height, weight, BMI, WC, WC/HC, WC/H, systolic BP, diastolic BP, fasting glucose, uric acid, TG, and prevalence of hypertension, diabetes, MetS, and hyperuricemia, and lower HC, fat %, TCHOL, HDL-C, and prevalence of dyslipidemia than women (**Table 1**). **Table 2** shows the association between BMI groups and biochemical markers for the three BMI definitions in men and women. Only the level of TCHOL did not significantly increase with increasing BMI levels in men. Across different BMI definitions and WC quartiles (data not shown), the prevalence of CVD risk factors (such as diabetes, hypertension, MetS, and hyperuricemia) was found to be significantly increased for increasing BMI levels using all three definitions or WC quartiles in both genders. Higher quartiles of WC were associated with higher BP, fasting glucose, TG, uric acid, and BMI and lower HDL-C than lower quartiles of WC (data not shown). **Figure 1** shows the ORs of CVD risk factors in different central obesity groups (WC, WC/HC, and WC/H). Compared to lowest quartile of WC, WC/HC, and WC/H, the ORs of having CVD risk factors (hyperglycemia, hypertension, dyslipidemia, hyperuricemia, MetS, and any CVD risk factors) increased among quartile II, III, and IV in both genders. For comparison, we further divided BMI into quartiles. The crude ORs for the fourth vs. first quartile of each obesity measurement showed that WC/H had the strongest relationship with all CVD risk factors in both genders. After further adjustment for age, the association still persisted but the ORs attenuated. The adjusted ORs for any CVD risk factors in men and women are 9.70(4.03-23.4) and 6.42(3.09-13.3) in BMI, 10.2(4.28-24.2) and 6.16(2.86-13.3) in WC, 8.85(3.71-21.1) and 4.23(2.08-8.59) in WC/HC, and 13.0(4.58-36.6) and 8.44(3.53-20.2) in WC/H, respectively (all *p* value <0.001). WC/H remains the strongest measurement associated with any CVD risk factors in both genders. The cut-off values of various anthropometric indices found optimally to predict hyperglycemia, hypertension, dyslipidemia, hyperuricemia, MetS, or at least one CVD risk factor using the ROC analysis in both sexes are summarized in **Table 3**. The optimal cut-off values for BMI vary from 23.7 to 24.9 kg/m^2 in men and 22.4 to 24.2 kg/m^2 in women. The optimal cut-off values for WC, WC/HC, and WC/H were from 82.5 to 87.5 cm, 0.87 to 0.90, and 0.50 to 0.52 in men and 72.5 to 77.3 cm, 0.79 to 0.81, and 0.46 to 0.50 in women, respectively. The AUCs of various anthropometric indices and the groups with at least one CVD risk factor were obtained for BMI (95 % confidence interval)-0.72(0.66-0.77) in men, 0.72(0.67-0.76) in women; WC-0.75(0.70-0.81) in men, 0.74(0.70-0.79) in women; WH/HC-0.75(0.69-0.80) in men, 0.70(0.65-0.75) in women; and WC/H-0.76(0.70-0.81) in men, 0.76(0.72-0.80) in women, respectively. Using Mann-Whitney test, the AUC of WC/H for at least one CVD risk factor is significantly higher than the AUCs of BMI, WC, or WH/HC (all *p* values < 0.001). Again, WC/H is a better indicator for screening overweight- or obesity-related CVD risk factors than the other three indices (BMI, WC and WC/HC) in both genders.

Discussion

In this study, we have demonstrated that the prevalence of CVD risk factors such as diabetes, hypertension, dyslipidemia, hyperuricemia, and MetS increased as BMI increased in middle-aged adult Taiwanese, using three different BMI definitions. Subjects with higher BMI, WC, WC/HC, and WC/H had higher BP, serum fasting glucose, TG, and uric acid than those with lower BMI, WC, WC/HC, and WC/H in both genders. The optimal cut-off values of these anthropometric indices for obesity are different from current suggestions. WC/H may be a better indicator for screening obesity-related CVD risk factors than the other three indices (BMI, WC and WC/HC) in middle-aged adult Taiwanese.

Increasing prevalence of obesity is found not only in Europe and the United states, but also in Asia [1]. For example, in Korea, prevalence of obese (BMI ≥ 25 kg/m^2) men and women has increased from 25.1% and 28.1% in 1998 to 32.4% and 29.4% in 2001 [39]. In this study, we used a well-designed sampling strategy in a metropolitan city in Taiwan, so that this cohort could represent the urban people of Taiwan. The Nutrition and Health Survey of Taiwan during 1993–1996, showed the prevalence of overweight and obesity to be 31.3% and 15.2% in middle-aged men and 28.3% and 24.4% in middle-aged women, using the criteria of DOH of Taiwan [3]. In our study, also using these criteria, the prevalence of overweight and obesity was 37.4% and 21.0 % in men and 26.7% and 16.7% in women. Thus in men, the prevalence of overweight and obesity has increased, but not in women. A similar trend of obesity was found in Japan. The prevalence of obesity (BMI $\geq$ 25kg/m^2) increased from 15.3% in the time-period of 1976–80 to 22.5% during 1991–95 in men, but a slight decrease occurred in women from 18.0% to 17.0% [40]. This merits further study. The prevalence of obesity between genders differs among countries or races. In many countries, obesity is more frequent in women than in men. For example, in the United States, the prevalence of obesity (BMI $\geq$ 30 kg/m^2) in adult in 1999–2002 was 27.6 % in men and 33.6 % in women [41]. However, in Taiwan, the prevalence of overweight (BMI $\geq$ 24 kg/m^2) in adult males was higher than in adult females in National Nutritional and Health Survey in Taiwan in 1993-1996 (22.9% vs. 20.3%) [3]. The National Health Research Institute survey in Taiwan in 2000-2001 also showed similar findings (prevalence of overweight and obese: 28.9 % and 15.9 % in men vs. 18.7 % and 10.7 % in women) [3]. Similarly, in Canadian Heart Health Surveys in Canada in 1986-1992, the prevalence of overweight (BMI $\geq$ 25 kg/m^2) was 58.1 % in men and 40.6 % in women [42]. From above findings, the prevalence of overweight or obesity between genders was quite different among countries or races.

Our results also demonstrate that, using three different BMI definitions for obesity, each is similarly significantly associated with CVD risk factors, especially for hypertension, high TG, low HDL-C, and MetS. The same associations are also found using anthropometric indices for central obesity, such as WC, WC/HC, and WC/H. This reflects that both general obesity (present with BMI) and central obesity (present with WC, WC/HC, and WC/H) are positively associated with CVD risk factors. This is the first time that obesity (measured by different anthropometric indices and definitions) is strongly associated with CVD risk factors in Chinese.

The optimal cut-off values for BMI (23.7 kg/m^2 in men and 22.4 kg/m^2 in women) and WC (82.5 in men and 72.5 cm in women) in our study were lower than the definitions proposed by WHO for Asia-Pacific region (for Asian) [33], the DOH of Taiwan (for Taiwanese) [34], and WHO (for Caucasians) [1]. These cut-off values, however, were higher than our previous study done among adult Chinese (aged 20 years and over, the optimal cut-off values for BMI and WC were 23.6 and 22.1 kg/m^2 and 80.5 and 71.5 cm in men and women, respectively) [43]. The reason for these differences between these two studies may be due to age differences (mean age: 54.6 years in this study vs. 37.1 years in previous study). Study also reported that, for a given BMI, Asians have greater body fat accumulation than do Caucasians [24]. Therefore, our study supports that the cut-off values using BMI and WC to define overweight/obesity should be much lower in Taiwanese than in Caucasians.

BMI is an indicator of general obesity, reflecting neither abdominal fat nor body fat distribution. WHO recommends that BMI and WC are simple and practical measures for identifying overweight and obesity [1]. However, others have proposed that WC/HC or WC/H are better indicators for predicting CVD. For example, Ho et al reported that the most useful anthropometric predictors for CVD risk factors were WC and WC/HC for women and BMI and WC for men among Hong Kong Chinese [44]. In another Hong Kong Chinese study, Ko et al found WC/HC and WC/H are better predictors for diabetes, hypertension, and albuminuria [45]. Similar findings have also been reported in Caucasians. For instance, Rexrode and Lean found WC and WC/HC to be good predictors for CVD among a population without previous CVD [46, 47]. Dalton et al also found that WC/HC has the strongest association with type 2 diabetes, hypertension, and dyslipidemia [48]. WC/HC is found to be a superior predictor of CVD risk because it includes a measurement of HC, which is less dependent on body size than is WC [49]. Besides, WC/HC has been demonstrated be inversely associated with hyperglycemia, hypertension, dyslipidemia and CVD [48, 50, 51]. Although there are some advantages of the WC/HC over other indices, when considering the accuracy and feasibility of measurement, WC/HC may not be superior to WC, WC/H, or BMI.

More recently, WC/H has been shown to be another main predictor of CVD risk [52]. Our results indicate that, in middle-aged adult Taiwanese, the WC/H has the strongest association with any CVD risk factors and had the largest AUCs in relation to any CVD risk factors in both genders. This is similar to our previous report in adult Chinese which showed WC/H has the largest AUCs in relation to at least one CVD risk factor [43]. Tseng et al also found that WC/H is independently and better associated with urinary albumin excretion rate than WC or WC/HC in Chinese adult type 2 diabetic women [53]. Height, weight, and WC can be more easily measured in clinical settings, so the combination of BMI, WC, and WC/H should be used for screening overweight- or obesity-related CVD risk factors.

Although we had demonstrated these strong associations between different measurements of obesity and CVD risk factors in middle-aged adult Chinese, some limitations existed in the study. First, the cross-sectional design makes an assessment of causality between different measurements of obesity and CVD risk factors impossible to prove. Further prospective study is necessary. Secondly, the population is from a metropolitan city in Taiwan, it may not suitable to be applied in rural area in Taiwan as well as other countries. Third, since a wide range of 95% confidence interval of ORs for WC/H was found, it limited the application to claim this index the strongest measure associated with CVD risk.

Conclusion

We demonstrate that both general obesity (defined using different BMI definitions) and central obesity (defined using WC, WC/HC, and WC/H) are closely related to CVD risk factors in middle-aged adult Taiwanese. WC/H may be a better indicator for screening overweight- or obesity-related CVD risk factors than the other three indices (BMI, WC and WC/HC) in both genders in Taiwan. Regular use of these anthropometric indices should be done in daily practice.

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Disclosure statement

The authors declared no conflict of interest.

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Table 1. Anthropometric indices and metabolic factors between genders

	Men (n=1147)	Women (n=1212)	p value
Age (years)†	58.6 ±12.3(40-94)	55.2 ±10.6(40-92)	<0.001
Height (cm)†	166.4 ±6.2(137-192)	155.3 ±5.4 (134-171)	<0.001
Weight (kg)†	68.7 ±10.3(39.9-116)	57.6 ±8.6(27.6-100.8)	<0.001
BMI (kg/m^2)†	24.8 ±3.2(16.0-38.8)	23.9 ±2.4(12.4-41.4)	<0.001
WC (cm)†	86.4 ±8.7(51-120)	76.7 ±8.9(35-115)	<0.001
HC (cm)†	94.2 ±6.2(63-130.5)	94.7 ±5.6(73-130)	<0.001
WC/HC†	0.89 ±0.57(0.61-1.29)	0.81 ±0.60(0.45-1.13)	<0.001
WC/H*	0.52 ±0.05(0.31-0.71)	0.49 ±0.06(0.22-0.75)	<0.001
Fat (%)†	26.0 ±5.6(9.7-50.6)	36.1 ±6.2(3.4-55.9)	<0.001
BMI ≥ 23kg/m2 (%)‡	71.8	55.2	<0.001
BMI ≥ 24kg/m2 (%)‡	58.4	43.4	<0.001
BMI ≥ 25kg/m2 (%)‡	43.3	31.8	<0.001
BMI ≥ 27kg/m2 (%)‡	21.0	16.7	0.008
BMI ≥ 30kg/m2 (%)‡	5.7	5.3	0.717
Central obesity (%)‡,1	33.7	33.4	0.930
Systolic BP (mmHg)†	138.9 ±20.7(91-219)	132.7 ±22.7(89-231)	<0.001
Diastolic BP (mmHg)†	82.6 ±11.5(54-135)	75.5 ±12.3(43-130)	<0.001

Fasting glucose (mmol/L)†	5.89 ±1.64(3.77-21.6)	5.60 ±1.50(3.77-18.7)	<0.001
Uric acid (μmol/L)†	379.7 ±127.0(107-3628	300.4 ±66.9(125-654)	<0.001
TCHOL (mmol/L)†	5.19 ±0.95(2.25-9.52)	5.32 ±0.99(2.69-8.84)	0.001
TG (mmol/L)†	1.54 ±1.26(0.27-16.0)	1.21 ±0.80(0.24-11.1)	<0.001
HDL-C (mmol/L)†	1.07 ±0.28(0.51-2.91)	1.30 ±0.33(0.53-2.72)	<0.001
TCHOL/HDL-C†	5.06 ±1.30(1.8-13.1)	4.29 ±1.08(1.8-8.4)	0.420
Hypertension (%)‡,2	53.8	38.4	<0.001
Diabetes (%)‡,3	14.1	10.3	0.005
Dyslipidemia (%)‡,4	81.1	84.7	0.022
MetS (%)‡,5	44.6	35.2	<0.001
Hyperuricemia (%)‡,6	15.9	10.5	<0.001

Present with mean ± SD (range) in continuous variables and percentage in categorical variables; presented in SI units

*Student's *t*-test for unpaired data was used for the comparison of mean values between groups

†Statistics were tested using the log-transformed values

‡Pearson Chi-Square test for categorical data

Abbreviation: BMI: body mass index, WC: waist circumference, HC: hip circumference, WC/HC: waist-to-hip ratio, WC/H: waist-to-height ratio, BP: blood pressure, TCHOL:

total cholesterol, TG: triglycerides, HDL-C: high-density-lipoprotein cholesterol,

[1] Central obesity is defined as waist circumference ≥ 90 cm in men, and/or ≥ 80 cm in women.

[2]Hypertension was defined as systolic BP ≥ 140 mmHg, and/or diastolic BP ≥ 90 mmHg, and/or hypertension history and on anti-hypertensive drug treatment

[3]Diabetes was defined as fasting glucose ≥ 7mmol/L and/or diabetes history and on oral hypoglycemic agents or insulin treatment

[4]Dyspilidemia defined as subjects with high TG (triglycerides ≥ 1.7 mmol/L) and/or high TCHOL (total cholesterol ≥ 5.17 mmol/L) and/or low HDL-C (HDL-C< 1.03 mmol/L in men or <1.29 mmol/L in women)

[5]MetS: metabolic syndrome was defined by the American Heart Association/National Heart, Lung, and Blood Institute criteria

[6]Hyperuricemia was defined as serum uric acid ≥ 446.1 μmol/L in men or ≥ 386.6 μmol/L in women; others were defined as normouricemia

Table 2. The relationship between BMI groups and cardiovascular disease (CVD) risk factors in different BMI definition in men (n=1147, Table 2a) and in women (n=1212, Table 2b).

(2a) in men

BMI definition[*]	CVD risk factors	BMI groups[†] 1	2	3	4	p value
I	Systolic BP (mmHg)	125.4±19.2	134.1±20.8	136.7±19.7	143.6±20.3	<0.001
II		125.4±19.2	134.3±20.6	139.5±19.5	147.2±20.4	<0.001
III		125.4±19.2	135.5±20.3	142.5±20.2	151.0±19.6	<0.001
I	Diastolic BP (mmHg)	73.8±13.9	79.3±11.3	81.2±10.5	85.8±11.3	<0.001
II		73.8±13.9	79.5±11.0	83.3±10.5	87.8±11.7	<0.001
III		73.8±13.9	80.3±10.9	85.2±11.2	89.8±11.3	<0.001
I	Glucose (mmol/L)	5.14±0.42	5.75±1.71	5.84±1.59	6.03±1.65	0.025
II		5.14±0.42	5.77±1.63	5.87±1.62	6.22±1.69	0.001
III		5.14±0.42	5.80±1.65	5.97±1.61	6.41±1.84	0.005
I	TG (mmol/L)	0.77±0.43	1.20±0.96	1.53±1.29	1.79±1.36	<0.001
II		0.77±0.43	1.28±1.07	1.63±1.25	1.94±1.52	<0.001
III		0.77±0.43	1.37±1.16	1.74±1.38	2.12±1.18	<0.001
I	TCHOL	5.02±0.90	5.11±0.97	5.21±0.95	5.22±0.95	0.330

II	(mmol/l)	5.02±0.90	5.14±0.97	5.24±0.91	5.18±0.99	0.369
III		5.02±0.90	5.16±0.96	5.21±0.96	5.30±0.89	0.567
I	HDL-C (mmol/L)	1.50±0.37	1.18±0.33	1.05±0.24	1.01±0.24	<0.001
II		1.50±0.37	1.14±0.30	1.04±0.25	0.97±0.21	<0.001
III		1.50±0.37	1.11±0.29	1.02±0.25	0.95±0.21	<0.001
I	Uric acid (mmol/L)	339.0±74.9	355.0±77.6	380.5±82.3	395.9±168.1	<0.001
II		339.0±74.9	361.0±78.4	396.4±178.0	388.6±84.0	<0.001
III		339.0±74.9	368.1±81.0	396.9±176.8	388.9±89.5	0.002
I	Waist circumference (cm)	66.1±5.8	78.7±5.7	84.6±4.7	92.8±6.9	<0.001
II		66.1±5.8	80.4±5.9	87.8±5.1	96.5±6.9	<0.001
III		66.1±5.8	81.8±6.0	91.4±5.5	102.8±7.0	<0.001

(2b) in women

BMI definition*	CVD risk factors	BMI groups†				p value
		1	2	3	4	
I	Systolic BP (mmHg)	130.0±29.1	124.3±19.7	133.8±22.0	143.2±22.2	<0.001
II		130.0±29.1	126.2±20.4	137.4±22.0	146.4±22.3	<0.001
III		130.0±29.1	127.7±21.0	140.5±20.8	157.1±23.6	<0.001
I	Diastolic BP	69.3±13.8	71.6±11.2	75.6±11.9	81.1±11.8	<0.001

II	(mmHg)	69.3±13.8	72.5±11.5	77.9±11.9	82.3±11.8	<0.001
III		69.3±13.8	73.0±11.6	80.0±11.3	86.5±13.1	<0.001
I	Glucose (mmol/L)	5.24±0.76	5.31±1.09	5.81±1.74	5.86±1.73	<0.001
II		5.24±0.76	5.42±1.32	5.79±1.61	5.93±1.83	<0.001
III		5.24±0.76	5.49±1.38	5.82±1.74	6.07±1.69	<0.001
I	TG (mmol/L)	0.88±0.51	1.00±0.62	1.30±0.94	1.44±0.82	<0.001
II		0.88±0.51	1.06±0.75	1.36±0.74	1.50±0.93	<0.001
III		0.88±0.51	1.11±0.77	1.41±0.82	1.60±0.83	<0.001
I	TCHOL (mmol/L)	5.00±1.10	5.19±0.99	5.39±0.98	5.48±0.96	<0.001
II		5.00±1.10	5.23±0.99	5.50±1.01	5.39±0.89	<0.001
III		5.00±1.10	5.26±0.99	5.50±0.98	5.38±0.88	0.001
I	HDL-C (mmol/L)	1.51±0.44	1.36±0.34	1.28±0.32	1.21±0.28	<0.001
II		1.51±0.44	1.35±0.34	1.26±0.31	1.18±0.26	<0.001
III		1.51±0.44	1.33±0.34	1.22±0.28	1.17±0.26	<0.001
I	Uric acid (mmol/L)	270.7±58.5	282.2±60.7	305.3±65.2	323.3±69.0	<0.001
II		270.7±58.5	285.1±62.3	314.9±63.5	331.0±71.9	<0.001
III		270.7±58.5	290.4±63.3	319.1±67.3	344.3±74.0	<0.001
I	Waist	63.6±8.0	70.9±5.1	76.8±5.0	85.3±7.7	<0.001

II	circumference	63.6±8.0	72.0±5.5	80.0±5.8	88.3±8.0	<0.001
III	(cm)	63.6±8.0	73.0±5.8	83.3±6.0	95.0±8.0	<0.001

Present with mean ± SD

*BMI was defined as follows: I: using WHO for Asia-Pacific region; II: using Taiwan criteria; III: using WHO criteria;

†BMI groups: Group 1: underweight; group 2: normoweight; group 3: overweight; group 4: obesity, detailed description in the text;

ANOVA test was used in (2b) for continuous variables

Table 3. The optimal cut-off values, sensitivities and specificities for various anthropometric indices predictive of CVD risk factors in both genders*. (a) in men; (b) in women.

(3a) in men

CVDs		BMI			WC			WC/HC			WC/H		
		Cut-off	Sensitivity (%).	Specificity (%).	Cut-off	Sensitivity (%).	Specificity (%).	Cut-off	Sensitivity (%).	Specificity (%).	Cut-off	Sensitivity (%).	Specificity (%).
Hyperglycemia	**optimal**	24.7	56.3	56.4	86.5	56.5	59.1	0.89	56.3	56.3	0.52	58.0	58.0
	Asia 1	23.0	78.0	33.0									
	Asia 2	25.0	51.0	62.6	90	42.5	73.4						
	Taiwan	27.0	27.3	84.0									
	WHO	30.0	8.0	96.2	102	8.8	97.0						
Hypertension	**optimal**	24.5	61.7	61.7	85.5	63.3	59.6	0.89	64.8	64.7	0.52	64.8	64.7
	Asia 1	23.0	79.4	36.8									
	Asia 2	25.0	52.8	67.4	90	44.5	78.9						
	Taiwan	27.0	27.9	87.0									
	WHO	30.0	8.8	97.9	102	8.8	98.1						
Dyslipidemia	**optimal**	24.2	58.9	59.0	84.5	62.4	59.0	0.88	59.8	59.9	0.51	60.2	60.4
	Asia 1	23.0	75.3	42.9									
	Asia 2	25.0	46.8	71.0	90	35.6	74.7						
	Taiwan	27.0	22.9	87.1									
	WHO	30.0	6.5	97.7	102	6.2	97.2						
Hyperuricemia	**optimal**	24.9	56.6	56.6	87.5	53.8	57.6	0.90	60.4	60.4	0.52	57.1	57.5
	Asia 1	23.0	81.9	30.0									
	Asia 2	25.0	52.2	58.2	90	44.5	68.4						
	Taiwan	27.0	23.1	79.4									
	WHO	30.0	3.8	94.0	102	4.4	94.2						
MetS	**optimal**	24.7	69.3	69.3	86.5	74.4	73.5	0.89	68.9	68.3	0.52	72.0	72.3
	Asia 1	23.0	88.5	41.4									
	Asia 2	25.0	65.9	74.6	90	61.6	88.8						
	Taiwan	27.0	37.8	92.4									
	WHO	30.0	11.2	98.7	102	11.5	99.2						
Any CVD risk	**optimal**	23.7	65.1	65.4	82.5	71.4	71.6	0.87	69.4	69.1	0.50	67.9	66.7
	Asia 1	23.0	74.0	55.6									
	Asia 2	25.0	45.4	82.7	90	64.7	87.7						
	Taiwan	27.0	22.3	95.1									

WHO	30.0	6.0	98.8	102	5.9	98.2

(3b) in women

CVDs		**BMI**			**WC**			**WC/HC**			**WC/H**		
		Cut-off	**Sensitivity (%).**	**Specificity (%).**	**Cut-off**	**Sensitivity (%).**	**Specificity (%).**	**Cut-off**	**Sensitivity (%).**	**Specificity (%).**	**Cut-off**	**Sensitivity (%).**	**Specificity (%).**
Hyperglycemia	**optimal**	23.8	60.6	60.7	76.5	63.3	61.8	0.81	60.9	61.0	0.50	63.3	63.1
	Asia 1	23.0	69.0	50.8									
	Asia 2	25.0	41.0	72.3	80	49.3	73.7						
	Taiwan	27.0	21.3	85.4									
	WHO	30.0	8.6	96.2	88	18.3	92.5						
Hypertension	**optimal**	23.8	66.2	66.2	76.5	68.0	67.8	0.81	63.4	63.4	0.49	68.0	68.1
	Asia 1	23.0	73.8	56.3									
	Asia 2	25.0	48.8	78.8	80	52.3	78.4						
	Taiwan	27.0	28.4	90.6									
	WHO	30.0	10.8	98.1	88	20.9	95.4						
Dyslipidemia	**optimal**	22.8	61.6	61.8	73.5	63.8	64.5	0.79	59.4	59.7	0.47	63.0	62.9
	Asia 1	23.0	59.0	65.6									
	Asia 2	25.0	34.3	82.3	80	35.8	80.1						
	Taiwan	27.0	18.0	90.3									
	WHO	30.0	5.6	96.2	88	11.3	91.9						
Hyperuricemia	**optimal**	24.2	60.6	60.8	77.3	59.1	60.1	0.81	60.6	60.7	0.50	60.6	60.6
	Asia 1	23.0	73.2	46.9									
	Asia 2	25.0	48.0	70.1	80	51.2	68.7						
	Taiwan	27.0	28.3	84.7									
	WHO	30.0	11.0	95.4	88	25.2	90.9						
MetS	**optimal**	24.0	71.6	71.6	77.3	77.0	77.2	0.81	68.8	68.9	0.50	76.3	76.3
	Asia 1	23.0	81.7	59.1									
	Asia 2	25.0	58.2	82.5	80	68.1	85.5						
	Taiwan	27.0	33.8	92.6									
	WHO	30.0	11.7	98.2	88	25.1	96.9						
Any CVD risk	**optimal**	22.4	65.8	65.8	72.5	68.2	72.6	0.79	65.3	65.0	0.46	71.2	71.8
	Asia 1	23.0	58.8	77.8									
	Asia 2	25.0	34.1	89.7	80	35.7	88.9						
	Taiwan	27.0	18.0	95.7									
	WHO	30.0	5.8	99.1	88	12.0	100						

Definition, abbreviations, and description as table 1, 2

*: Asia 1: overweight using BMI definition from the WHO for Asia-Pacific region

*: Asia 2: obesity using BMI definition from the WHO for Asia-Pacific region

*: Taiwan: obesity using BMI definition from the Department of Health (DOH) of Taiwan

*: WHO: obesity using BMI definition from the WHO for Caucasians

Legend to the figures:

Figure 1. Different waist circumference (WC), waist-to-hip ratio (WC/HC), and waist-to-height ratio (WC/H) groups versus cardiovascular disease risk factors (hyperglycemia, hypertension, dyslipidemia, hyperuricemia, metabolic syndrome, and any cardiovascular disease (CVD) risk factor) among genders. WC groups are defined by quartile (1: ≤ 80.5, 2: 81.0~86.5, 3: 87.0~91.5, 4: ≥ 92.0 cm for men and 1: ≤ 70.0, 2: 70.5~75.0, 3: 75.5~81.5, 4: ≥82.0 cm for women). WC/HC groups are defined by quartile (1: ≤ 0.86, 2: 0.86~0.89, 3: 0.89~0.93, 4: ≥ 0.93 for men and 1: ≤ 0.77, 2: 0.77~0.80, 3: 0.80~0.84, 4: ≥ 0.84 cm for women). WC/H groups are defined by quartile (1: ≤ 0.49, 2: 0.49~0.52, 3: 0.52~0.55, 4: ≥ 0.55 cm for men and 1: ≤ 0.45, 2: 0.45~0.49, 3: 0.49~0.53, 4: ≥0.53 for women). Any CVD risk factor is defined as subjects who met any of the follows: hyperglycemia, hypertension, dyslipisemia, and hyperuricemia. Reference group is quartile I of each central obesity index (WC, WC/HC, WC/H)

Figure (1a)

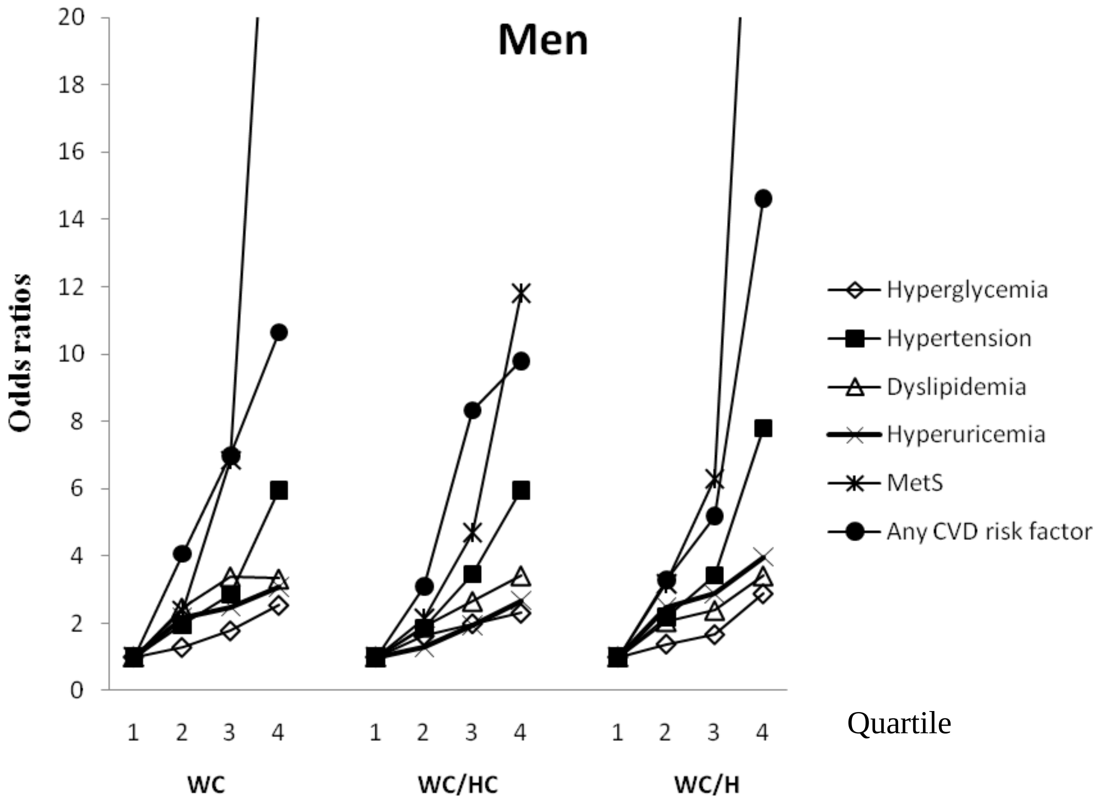
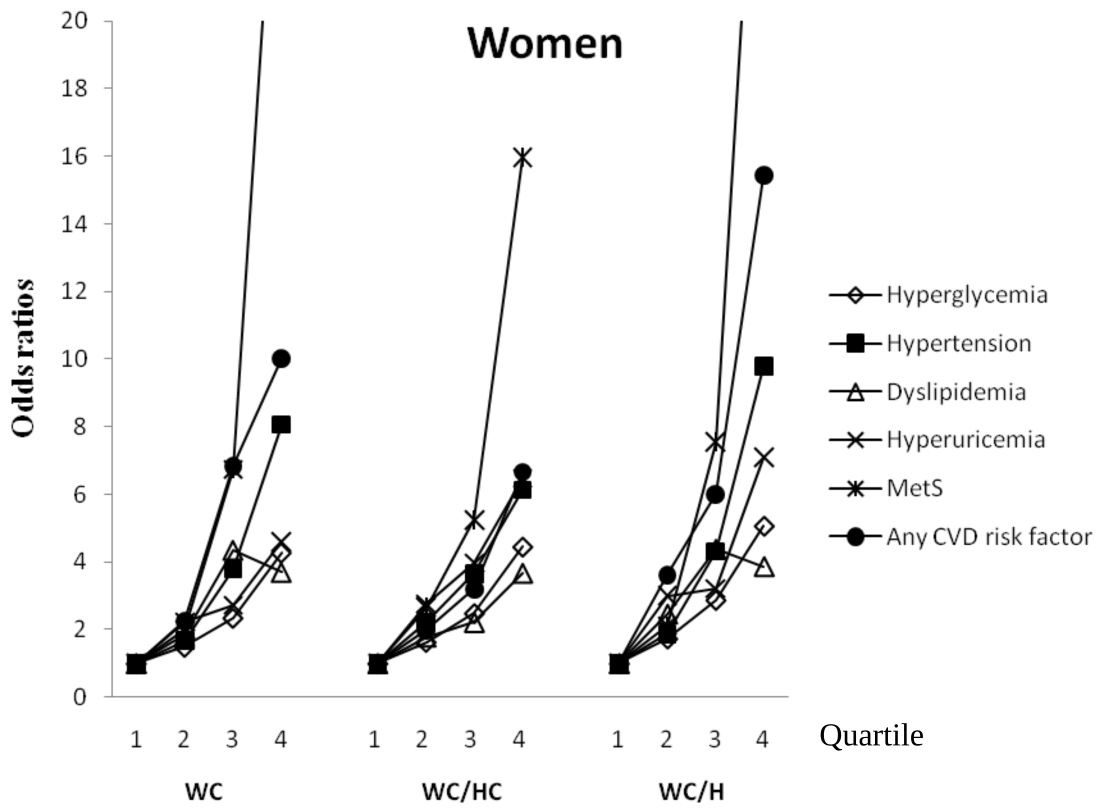

Men
Odds ratios
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4
1 2 3 4
1 2 3 4
WC
WC/HC
WC/H
Quartile
Hyperglycemia
Hypertension
Dyslipidemia
Hyperuricemia
MetS
Any CVD risk factor

Figure (1b)



Women
Odds ratios
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4
1 2 3 4
1 2 3 4
Quartile
WC
WC/HC
WC/H
Hyperglycemia
Hypertension
Dyslipidemia
Hyperuricemia
MetS
Any CVD risk factor