Original Article

Anthropometric indices as screening tools for cardiovascular risk factors in Singaporean women

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Previous studies have suggested the need to revise the World Health Organization (WHO) cut-off values for the various indices of obesity and fat distribution in Singapore. The purpose of this study was to delineate cut-off points of body mass index (BMI), waist-hip ratio (WHR), waist circumference (WC), and waist-stature ratio (WSR) as screening tools for cardiovascular risk factors in Singaporean women. Anthropometric indices were measured in a cross sectional survey of 566 subjects (60% Chinese individuals, 28% Malay individuals and 12% Indian individuals). Cardiovascular risk factors were determined by measuring blood pressure, serum lipids, and fasting blood glucose levels. Receiver Operating Characteristic (ROC) curves were constructed to determine cut-off points. Forward logistic regression and area under curves (AUC) were used to determine the best anthropometric index. For at least one cardiovascular risk factor (hypertension, dyslipidaemia and diabetes mellitus), the cut-off points for BMI, WHR, WC and WSR were around 23.6kg/m^2, 0.80, 77.8cm and 0.48 for Singaporean females. The AUC of WSR was the highest for all three risk factors in females (0.79 for hypertension, 0.70 for dyslipidaemia, 0.88 for diabetes mellitus). Regression analyses revealed that WSR was independently associated with all risk factors. For Singaporean female adults, the cut-off points were lower than the criteria suggested by the WHO, but were in agreement with those reported for Asians. BMI, WHR, WC and WSR may be used as screening tools for cardiovascular risk factors, of which WSR may be the best anthropometric index.

Key Words: abdominal fatness, public health, cut-off values, body mass index, obesity, waist hip ratio, Singapore.

Introduction

Obesity is an independent risk factor for cardiovascular diseases (CVD),[1] and is strongly associated with other cardiovascular risk factors like hypertension, dyslipidaemia and type 2 diabetes.[2,3] Against this background, various anthropometric indices of obesity such as body mass index (BMI), waist to hip ratio (WHR), waist circumference (WC) and waist to stature ratio (WSR) have been suggested as screening tools to identify individuals at risk of CVD.[2,4-9]

From the public health perspective, it is important to define cut-off points for the various anthropometric indices to achieve effective screening. The World Health Organization (WHO) has recommended WHRs of 1.0 and 0.85 as cut-off points for obesity for males and females respectively, WCs of 94 cm and 80 cm as cut-off points for central obesity for males and females respectively, and BMI cut-off points of ≥25kg/m^2 for overweight and ≥ 30kg/m^2 for obesity.[10] In the Asian populations, however, many studies have indicated the need to revise these cut-off values for the various indices of obesity and fat distribution.[2,5,7-9,11-14] In Singapore, Deurenberg-Yap *et al.*,[15] provided data to show that the Singaporean adults displayed a higher percentage of body fat for the same levels of BMI as European people. Based on percentage body fat alone, the authors concluded that the BMI cut-off values for overweight should be 2-3kg/m^2 lower than the recommended WHO values. In a recent study,[7] the prevalence of cardiovascular risk factors was also found to increase at lower BMI and WHR cut-off levels in Singaporeans. In these two studies, however, no specific cut-off values were proposed by the authors. Moreover, no cut-off values for WSR were recommended by the WHO, although it has been previously suggested the WSR may be the most appropriate anthropometric index in predicting a wide range of cardiovascular risk factors.[5,9] Therefore, the purpose of this study was to examine four anthropometric indices (BMI, WHR, WC and WSR) and three CVD risk factors (hypertension, type 2 diabetes and dyslipidaemia) by using receiver operating characteristic (ROC) analysis to find the optimal cut-off values in Singaporean female adults.

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Accepted 17 December 2004

Materials and methods

The subjects recruited in this study were employees of a tertiary hospital in Singapore, who underwent an annual health screening exercise after an overnight fast in August 2003. The analysis included 566 females aged 18-68yrs, and the ethnic composition was 60% Chinese, 28% Malays and 12% Indians. In all subjects, a questionnaire was used to obtain information regarding smoking status (smoker or non-smoker) and physical activity levels (Regular exercise or not; Regular exercise as participation in any form of sports for at least 20 minutes per occasion, for 3 or more days a week).

Height, waist and hip circumference (measured to nearest 0.1 cm) and weight (measured to the nearest 0.1 kg) were measured by trained nursing staff. All measurements were taken with subjects in light indoor clothes without shoes. Weight was obtained using calibrated digital scales (Seca, Hamburg, Germany). WC was taken midway between the inferior margin of the last rib and the crest of the ilium in a horizontal plane. Hip circumference was measured over the greater trochanters. WHR and WSR were then calculated, while BMI was calculated as weight (kg) divided by height squared (m^2).

After at least 5 min of sitting, blood pressure (BP) was measured in the right arm using a digital sphygmomanometer (Omron, Vernon, USA). The mean value of two readings measured one minute apart was used. If a finding of systolic BP ≥ 140mmHg and/or diastolic BP ≥ 90mmHg was found, the whole procedure was repeated using a standard mercury sphygmomanometer.

Three mls of overnight fasting blood samples were obtained from each participant. Serum levels of total cholesterol (TC), high-density lipoprotein (HDL)-cholesterol and triglycerides were assayed by enzymatic calorimetric techniques (ROCHE). Fasting blood glucose concentration was measured enzymatically by the hexokinase reference method.

In the present analysis, the cut-off values for hypertension were defined as systolic BP ≥ 140mmHg and/or diastolic BP ≥ 90mmHg.[16] Dyslipidaemia was defined as TC ≥ 6.2mmol/l, and/or elevated TC/HDL ratio ≥4.4,[17] and/or TG ≥ 1.4mmol/l.[18] Type 2 diabetes was defined as fasting blood glucose ≥7.0mmol/L.[19] 'At risk' was defined as having at least one of the above risk factors.

Statistical analysis

Statistical analysis was performed using with Statistical Package for Social Sciences (SPSS) for Windows (version 9.01; SPSS Inc, Chicago). Values are given as mean ± SD. Each value of an anthropometric index was used as a cut-off value to calculate its sensitivity and specificity in classifying a cardiovascular risk factor. The ROC curves were plotted using measures of sensitivity and 1-specificity for each anthropometric cut-off value. The ROC curve analysis allows visual evaluation of the trade-offs between sensitivity and specificity associated with different values of the test result.[20] The optimal cut-off point for each index was denoted by the value that yielded the largest sum of sensitivity and specificity.[21]

The overall performance of each ROC curve was evaluated by calculating the area under the curve (AUC), which is a measure of the diagnostic power of a test, and describes the probability that a test will correctly identify subjects with the disorder. The AUCs of the various anthropometric indices were compared using the Rockit 0.9B version (Metz CE, Department of Radiology, University of Chicago).

A forward stepwise multiple regression analysis was applied to the anthropometric indices to determine which indices were independently associated with having type 2 diabetes, hypertension, dyslipidaemia, or at least one CVD risk factor. In the analysis, adjustment was made for age, smoking status, physical activity level, and ethnicity. A P value <0.05 (2-tailed) was considered to be significant.

Results

The anthropometric and metabolic characteristics of the subjects by ethnic groups are shown in Table 1. Among the ethnic groups, Chinese women were the lightest, and had the lowest waist and hip circumferences, BMI, WHR and WSR. Chinese women also had the highest HDL levels, and the lowest TC/HDL and fasting blood glucose levels. The prevalence of having at least one risk factor was higher in Indian than Chinese females.

The optimal cut-off values of the anthropometric indices in relation to each CVD risk factor are listed in Table 2. The BMI cut-off values for predicting hypertension, diabetes, dyslipidaemia ranged from 23.2 to 23.9 kg/m^2 in Singaporean women. The WHR cut-off values ranged from 0.80 to 0.82. The WC cut-off values ranged from 70.3 cm to 79.5 cm. The WSR cut-off values ranged from 0.48 to 0.51. As an overall estimation, the cut-off values for having at least one CVD risk factor of BMI, WHR, WC and WSR were 23.6 kg/m^2, 0.80, 77.8cm and 0.48 respectively.

ROC curve analysis was conducted to examine the best anthropometric index in detecting hypertension, dyslipidaemia, diabetes mellitus, and at least one CVD risk factor. The cut-off values and AUC of the anthropometric indices are summarized in Table 2. In Singaporean women, the AUC of BMI for the various cardiovascular risk factors ranged from 0.66 to 0.80. The AUC of WHR ranged from 0.67 to 0.85, while the AUC of WC and WSR ranged from 0.69 to 0.86 and from 0.70 to 0.88, respectively. The AUC of WSR was greater than that of BMI and WHR for dyslipidaemia and having at least one CVD risk factor (P<0.001). Moreover, the AUC of BMI (0.80) in predicting diabetes was also lower than that of WSR (AUC = 0.88, P<0.001).

For all risk factors, no statistical significant differences in AUCs were found between WSR and WC. Amongst the anthropometric indices, the AUC of WSR was highest for all three risk factors (0.79 for hypertension, 0.70 for dyslipidaemia, 0.88 for diabetes mellitus). As an overall estimation, WSR had the largest AUC for the presence of at least one CVD risk factor (0.73), and the related ROC curves are shown in Figure 1.

Table 1. Anthropometric indices and cardiovascular risk factors by ethnic group (mean ± SD)

	Females (N = 566)		
Variables	Chinese (N = 337)	Malay (N = 157)	Indian (N = 72)
Age (y)	39.0 ± 12.0	35.2 ± 12.0	39.4 ± 11.4
Weight (kg)	55.1 ± 8.9	60.0 ± 12.4*	63.0 ± 13.8*
Height (cm)	157.0 ± 6.3	155.0 ± 6.2	155.0 ± 5.6
Waist (cm)	72.0 ± 8.5	76.0 ± 5.7*	81.0 ± 13.0*
Hip (cm)	93.2 ± 8.0	97.1 ± 9.9*	100.7 ± 11.6*
BMI (kg/m^2)	22.2 ± 5.5	24.8 ± 5.2*	26.2 ± 5.4*
WHR	0.77 ± 0.05	0.78 ± 0.06*	0.80 ± 0.07*
WSR	0.46 ± 0.06	0.49 ± 0.07*	0.52 ± 0.08*
TC (mmol/l)	5.5 ± 1.0	5.4 ± 0.9	5.6 ± 0.9
HDL (mmol/l)	1.9 ± 0.43	1.7 ± 0.39*	1.5 ± 0.42*
LDL (mmol/l)	3.2 ± 0.9	3.2 ± 0.9	3.6 ± 0.8*
TG (mmol/l)	1.1 ± 0.74	1.1 ± 0.72	1.2 ± 0.56*
TC/HDL	3.0 ± 0.8	3.4 ± 0.9*	3.9 ± 1.2*
SBP (mmHg)	115.3 ± 14.8	117.0 ± 15.1	117.7 ± 15.5
DBP (mmHg)	74.1 ± 9.3	75.0 ± 9.3	75.7 ± 9.7
Glucose (mmol/l)	5.1 ± 0.73	5.4 ± 2.1*	5.6 ± 1.6*
Hypertension (%)	10.2	10.2	11.1
Dyslipidaemia (%)	32.3	35.7	45.8
Diabetes (%)	3.3	6.4	9.7
Risk (%)	37.4	39.5	55.6*

*Significant differences in means between ethnic groups (age-adjusted for all variables, Chinese as reference category).

Table 2. Optimal cut-off values, sensitivity, specificity, and area under curve of various anthropometric indices to predict hypertension, Type II diabetes mellitus, dyslipidaemia based on ROC analysis

	Females (N = 566)				
Indices	CVD Risk Factor	Cut-off	Sens. (%)	Spec. (%)	AUC (95%CI)
BMI (kg/m^2)	Hypertension	23.4	83.3	61.3	0.76 (0.70 – 0.80)
	Dyslipidaemia	23.9	55.0	71.7	0.66 (0.61 – 0.71)*
	Diabetes	23.2	96.4	57.4	0.80 (0.72 – 0.89)*
	Risk	23.6	59.6	73.1	0.69 (0.65 – 0.74)*
WHR	Hypertension	0.80	65.0	74.3	0.74 (0.68 – 0.80)
	Dyslipidaemia	0.80	54.0	74.7	0.67 (0.62 – 0.71)*
	Diabetes	0.82	71.4	79.4	0.85 (0.78 – 0.92)
	Risk	0.80	54.4	77.5	0.69 (0.65 – 0.74)*
WSR	Hypertension	0.51	68.3	77.9	0.79 (0.73 – 0.84)
	Dyslipidaemia	0.48	62.6	71.7	0.70 (0.65 – 0.75)
	Diabetes	0.50	92.8	68.4	0.88 (0.81 – 0.94)
	Risk	0.48	64.5	76.0	0.73 (0.69 – 0.78)
WC (cm)	Hypertension	77.3	73.3	70.7	0.77 (0.71 – 0.83)
	Dyslipidaemia	70.3	77.8	51.9	0.69 (0.64 – 0.73)
	Diabetes	79.5	88.9	74.1	0.86 (0.79 – 0.94)
	Risk	77.8	54.2	80.4	0.72 (0.68 – 0.76)

*Significantly different from AUC of WSR (P < 0.01).

All four anthropometric indices were significantly inter-correlated (P<0.001). In particular, strong and positive correlations were found between WSR and WC (r= 0.96), and WSR and BMI (r = 0.85), while a positive correlation existed between WSR and WHR (r=0.65) (Table 3). Results of the regression analysis are shown in Table 4. Of the four obesity indices tested, WSR was independently associated with all CVD risk factors. The proportion of variance (Nagelkerke–R^2) of the anthropometric indexes accounting for each CVD risk factor ranged from 21 to 27% in Singaporean females.

Discussion

The results of our study indicate that the derived optimal cut-off values of BMI, WC and WHR are lower than those recommended by the WHO.[10] The WHO recommends 25 and 30kg/m^2 as BMI cut-off points for overweight and obesity, respectively. In the present study, the specificity of these values to predict risk factors was more than 80%, but the sensitivity was less than 50%. The WHO also recommends WHRs of 1.0 and 0.85 for males and females respectively, and a WC cut-off value of 80cm to define central obesity in females. The specificity

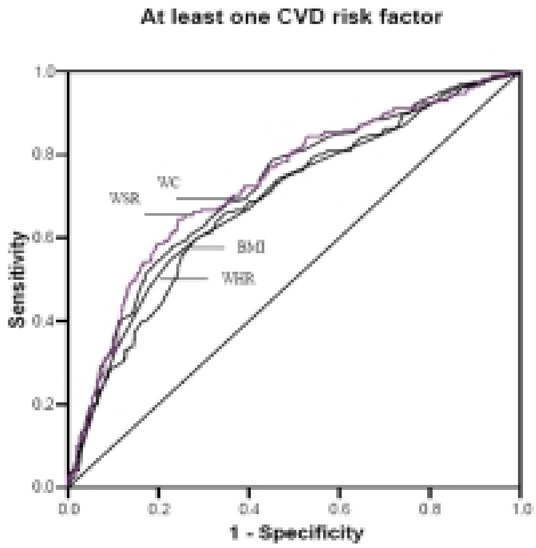

Figure 1. ROC curves of body mass index (BMI), waist to hip ratio (WHR), waist circumference (WC) and waist to stature ratio (WSR) in identifying subjects with at least one cardio-vascular disease risk factor in Singaporean female adults

of these cut-off points in predicting the presence of at least one risk factor in our female subjects was more than 90%, with a low attendant sensitivity of less than 20%. Taken together, these results indicate that these cut-off values are inappropriately high for Singaporean females.

To date, few studies have examined the association between CVD risk factors and obesity indices at various cut-off values in Singaporeans. In the study by Deurenberg-Yap,[7] Singaporean adults were assigned to categories of BMI and WHR using pre-set border values

Table 3. Age adjusted partial correlation coefficients amongst various anthropometric indices by gender

Variables	BMI	WHR	WSR	WC
Females (*N* = 566)				
BMI		0.39*	0.85*	0.83*
WHR	0.39*		0.65*	0.67*
WSR	0.85*	0.65*		0.96*
WC	0.83*	0.67*	0.96*	

recommended by the International Obesity Task Force during the Asian BMI/Obesity Workshop Meeting in Milan in 1999. For all the ethnic groups, it was found that at low categories of BMI (between 22 and 24kg/m^2) and WHR (between 0.80 and 0.85 for women and between 0.90 and 0.95 for men), the odds ratios (ranging from 1.97 to 4.38) for having at least one CVD risk factor were significantly higher compared to the reference category. Using ROC analysis, the results of our study are consistent with that of Deurenberg-Yap's,[7] and extend their findings to include specific BMI cut-off values at 23.6 kg/m^2, WHR cut-off values at 0.80, WC cut-off values at 77.8cm and WSR cut-off values of 0.48 for Singaporean women.

Comparing our results with that of other similar studies performed in Asia, the optimal cut-off values in relation to each CVD risk factor were in good agreement with those obtained from the Chinese,[14] Hong Kong Chinese[13] and Taiwanese.[9] However, our results were apparently higher than those obtained from the Japanese women[12] (BMI cut-off values ranged from 22.1 to 23.1 kg/m^2, WC cut-off values ranged from 70 to 73cm).

In relation to having at least one risk factor (i.e. dyslipidaemia, hypertension or type 2 diabetes), the cut-off values for Taiwanese women[9] were apparently lower (22.1kg/m^2, 0.76, 71.5cm and 0.45 for BMI, WHR, WC and WSR respectively). While these differences may be attributed to the multi-ethnic nature of our subjects, ethnicity was, however, not found to be independently associated with the risk of having at least one risk factor on regression analysis, with adjustment made for age, smoking habits, physical activity levels, and other indices of obesity. This finding was consistent with that of Deurenberg-Yap's,[7] who also found that ethnicity did not have a statistically significant impact on the odds ratios of the different categories of BMI and WHR in 4723 Singapore adults. Consequently, during the computation of cut-off points in our study, the decision was made to pool subjects of all ethnic groups together to increase the power of the analysis.

Alternatively, the differences in findings may reflect the different decision rules used to determine cut-off values. In the present study, the optimal cut-off point for each index was denoted by the value that yielded the largest sum of sensitivity and specificity. For at least one CVD risk factor, the specificity (73.1%–80.4%) associated with each optimal anthropometric cut-off value was greater than its attendant sensitivity (54.4% – 64.5%). In the study by *Ito et al.*,[12] the cut-off point was determined by the value where the value of sensitivity was equal to that of specificity. Ostensibly, applying this decision rule in our study may potentially lower the cut-off points of the various anthropometric indices by enhancing sensitivity at the expense of reduced specificity. Notwithstanding these methodological differences, it must be acknowledged that all anthropometric cut-off points are arbitrary, and any decision rules to determine cut-off values must balance the need to prevent a significant proportion of CVD events, and the clinical practice burden of labeling a patient as being at risk for CVD.[14] Nonetheless, we believe that our study has provided convergent evidence to support recent proposals to revise the various obesity indices to define obesity for Asians.[11,22]

All four indices appear to complement one another, as evinced by the strong inter-correlations. In relation to predicting at least one CVD risk factor, the WSR and WC were the two indices with an AUC greater than 0.70. In contrast, BMI was consistently amongst the poorer indices in ROC curve analyses, which is compatible with the notion that abdominal obesity as measured by WC and WSR is more closely associated with cardiovascular risks than does BMI, a measurement of overall obesity.[5] Although no statistical significant difference in AUCs was found between WSR and WC for all risk factors, logistic regression analyses revealed the relatively strong and independent association of WSR with all the risk factors. Taken together, the results of the ROC and regression analyses indicate that greater confidence could be placed on WSR as the best screening tool for CVD risk factors in our subjects. Our results were also similar to other studies from Asia that indicate that WSR corresponds better to metabolic risk than WHR, WC or BMI.[5,9,13] Several investigators have reported that WSR offers several advantages as a screening tool for cardiovascular risks.[5,9,13,23,24] First, a number of papers have demonstrated that central obesity is closely associated with cardiovascular risk factors,[25,26] and WSR has been shown to be a good indicator of abdominal obesity.[27] Second, unlike other indices, a "unisex" cut-off value for WSR has been found and proposed in several studies,[5,9,23] which implies that a common and universal cut-off value may be used. Third, an index such as the WHR suffers from the drawback as a ratio of two changeable measure-ments (waist and hip), where it can remain relatively constant if both the waist and hip circumferences increase simultaneously.[5] In contrast, as one's stature is relatively fixed, the WSR allows individuals to have their indivi-dualized cut-off waist circumference.[5]

Limitations

We acknowledge several potential limitations in the present study. First, our sample was not population based and was limited to Singaporean females who were in their working ages. Hence, our results need to be interpreted with caution, and the case for WSR as the most appropriate screening tool for Singaporeans would be further strengthened if there were supporting data from Singaporean men. Second, as the regression analysis indicated that age was independently associated with the various cardiovascular risk factors, future studies are warranted to examine the anthropometric cut-off values amongst the different age groups.

Conclusion

The cut-off values of the various anthropometric indices in Singaporean female adults were lower than the criteria suggested by the WHO, but were in agreement with those reported for Asians. The WSR may be the best screening tool for Singaporean adult females, and such a conclusion awaits further verification in prospective or longitudinal epidemiological studies on morbidity and mortality.

Acknowledgement

The authors are grateful to Dr. Wei-Keong Wee, Director, Health for Life Centre, Alexandra Hospital, for his data support, and to Ms. Yen-Ling Low and Mr. Yik-Ying Teo for their constructive feedback to this manuscript.

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