Original Article

Waist Circumference is a Potential Indicator of Metabolic Syndrome in Singaporean Chinese

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Abstract

Introduction: Metabolic Syndrome (MetS) is associated with cardiovascular morbidity and mortality. Studies proposed that waist circumference (WC) and body mass index (BMI) are good indicators of MetS. In this study, we examined and compared the predictive utility of clinical measures such as WC, blood pressure and BMI and determined the cut-off points in which these measures are most reliable in identifying MetS in Singaporean Chinese. Materials and Methods: Two hundred and forty-four subjects aged between 21 and 50 years of Chinese ethnicity were recruited into the study. Sociodemographic, height, weight and blood pressure information were obtained. High-density lipoprotein cholesterol (HDL-C), triglycerides (TG) and glucose levels were evaluated. Presence of MetS was examined according to American Heart Association (AHA)/National Heart, Lung and Blood Institute (NHLBI) guidelines. Predictive utility of BP, WC and BMI was examined using receiver operating curve and discriminant indices were determined accordingly. Results: Forty-one (16.8%) subjects were identified to have MetS. Our analysis revealed that waist circumference was most accurate in identifying MetS (area under the curve (AUC) = 0.88, 95% confidence interval (CI), 0.83 to 0.93, *P* <0.001) followed by BMI (AUC = 0.84, 95% CI, 0.77 to 0.91, *P* = 0.035), systolic BP (AUC = 0.83, 95% CI, 0.76 to 0.90, *P* = 0.036) and diastolic BP (AUC = 0.80, 95% CI, 0.71 to 0.88, *P* = 0.042). Waist circumference cut-off values of >92.5 cm in males and >86.5 cm in females were found to be most sensitive and specific in discriminating MetS. Conclusion: Our finding has immediate and significant clinical implications as WC can be easily obtained. However, as the study included only Singaporean Chinese, findings cannot be generalised for other ethnic groups.

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Key words: Chinese, Metabolic syndrome, Waist circumference

Introduction

Metabolic Syndrome (MetS), as characterised by increased visceral adiposity, hyperglycaemia, hypertension and hyperlipidaemia has been consistently reported to be a risk factor for the development of type 2 diabetes and cardiovascular diseases and contribute significantly to the increase prevalence of cardiovascular mortality.[1-3] In Singapore, the prevalence of MetS, depending on the criteria adopted, had been reported to range from 17.7% to 26.2%.[4,5] The criteria set by the American Heart Association (AHA)/National Heart, Lung and Blood Institute (NHLBI) has been suggested to be most sensitive in predicting MetS in the Singaporean population[6] and had been associated with a 3-fold increase in cardiovascular mortality.[4,5]

The criterion symptoms of MetS are potentially modifiable through changes in lifestyle and diet, or pharmacological management of hyperglycaemia, hyperlipidaemia and obesity. Therefore, MetS has attracted much clinical attention with the aims of early identification and intervention.

Identification of MetS through laboratory screening presents some limitations as blood tests are considerably invasive and expensive. Thus, alternative reliable and easily obtainable screening tools for MetS have been examined. Body Mass Index (BMI), a measure of body fat, and waist circumference (WC), a measure of central adiposity, have been proposed to be the 2 most accurate and useful in identifying MetS in various populations.[7-11]

This study aims to examine and compare the predictive utility of commonly and easily obtainable clinical measures; namely blood pressure (BP), WC and BMI in detecting MetS within Singaporean Chinese and suggest optimal

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cut-off values for the detection.

Materials and Methods

Subjects and Assessments

Subjects aged between 21 and 50 years of Chinese ethnicity residing in Singapore were recruited through advertisements and referrals. We did not use any specific exclusion criteria in this study. The study received ethics approval from the Domain Specific Review Board of the National Healthcare Group. Information related to the study was explained to eligible study subjects and only subjects capable of providing informed consent were recruited.

Sociodemographic information and medical history were collected into a standardised data collection form. Height and weight were measured in a standing position with subjects wearing light clothing and without shoes using an automated height and weight machine. BMI was calculated accordingly. Waist circumference was measured in a standing position using a measuring tape around subjects' waist to the nearest 0.5 cm. BP was measured with the subjects seated to the nearest 1 mmHg. Venous blood was collected into serum separating tube (SST) after an overnight fast. High-density lipoprotein cholesterol (HDL-C), triglycerides and glucose levels were measured using analyser LX-20PRO (Beckman Coulter, Germany) from the serum content of subjects using a standardised protocol.

Metabolic Syndrome Classification

This study adopted the criteria set by the AHA/NHLBI to identify individuals with MetS. This set of guidelines had been previously reported to be most sensitive in predicting the prevalence of cardiovascular disorders in a Singapore cohort.[4,5,12] These criteria include elevated triglycerides (≥1.7 mmol/L or on drug treatment for elevated triglycerides), reduced HDL-C (<1.03 mmol/L in males and <1.3 mmol/L in females or on drug treatment for reduced HDL-C), elevated BP (≥130 mmHg systolic blood pressure or 85 mmHg diastolic blood pressure or previously diagnosed as hypertensive and on treatment), elevated fasting glucose (≥5.6 mmol/L or known diabetic on treatment) and central obesity characterised by Asian waist circumference cut-offs of ≥90 cm for males and ≥80 cm for females.[6] Individuals were considered to suffer from MetS if they fulfilled at least 3 of the criteria.

Statistical Analysis

Statistical analyses were performed using Predictive Analytics Software Statistics (PASW) version 18. Descriptive statistics were tabulated for subjects with and without MetS. Statistical significance was examined with the chi-square test for categorical variables. For continuous variables, student t-test was used if normality assumptions were fulfilled, and non-parametric test if the assumptions were not fulfilled. Statistical significance was set at $P<0.05$. Prediction accuracy and optimal predictive values of BP, WC and BMI for MetS were examined using receiver operating characteristic (ROC) curve. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) at optimal predictive values as identified from the ROC were tabulated. In addition, discriminant indices at BMI cut-off of 23 kg/m^2 was also examined as this indicated moderate cardiovascular risk according to the World Health Organisation (WHO) public health action points for Asians.[13] Subsequently, analysis was further stratified into gender and age groups.

Results

Two hundred and forty-four subjects were recruited into the study. Forty-one (16.8%) subjects were identified to have MetS according to the AHA/NHLBI criteria. Table 1 summarises the characteristics of study subjects with and without MetS. Besides the criteria variables for MetS, individuals with MetS were significantly older ($P = 0.009$) with greatest proportion within the age group of 41 to 50 years old ($P = 0.012$). There were also significantly more males than females ($P = 0.039$). Predictive utility of WC, BP and BMI for MetS were evaluated using ROC curves. Predictive power as defined by the area under the curve (AUC) was found to be highest for waist circumference (AUC = 0.88, 95% CI, 0.83 to 0.93, $P<0.001$) followed by BMI (AUC = 0.84, 95% CI, 0.77 to 0.91, $P = 0.035$), systolic BP (AUC = 0.83, 95% CI, 0.76 to 0.90, $P = 0.036$) and diastolic BP (AUC = 0.80, 95% CI, 0.71 to 0.88, $P = 0.042$) as depicted in Figure 1.

The optimal cut-off values for WC and BP were determined from the ROC coordinates with the greatest Youden's index value (sensitivity + 1- specificity).[14] The optimal cut-off values were established to be >130 mmHg for systolic BP, >86 mmHg for diastolic BP and BMI ≥24 kg/m^2. WC measurements were further stratified according to gender and optimal cut-off values were found to be >90.5 cm for males and >86.5 cm for females. Sensitivity, specificity, PPV and NPV were calculated for the various variables at ROC determined cut-offs. In addition, discriminant indices for WHO pre-established public health action point of BMI ≥23 kg/m^2 for Asians was also examined in the aim to determine which cut-off will be most appropriate. The discriminant indices are summarised in Table 2.

When stratified by gender as described in Table 3A, ROC curves revealed the same order of accuracy of the potential indicators as the overall sample. WC has highest AUC, followed by BMI, systolic BP and diastolic BP.

Table 1. Description of Subjects with and Without MetS

	MetS Present (n = 41)	MetS Absent (n = 203)	*P* Value
Age in Years, Mean (SD)	37.8 (8.1)	34.0 (8.1)	0.009
Age - Categorisation, n (%)			0.012
21 to 30 years old	10 (24.4)	79 (38.9)	
31 to 40 years old	11 (26.8)	72 (35.5)	
41 to 50 years old	20 (48.8)	52 (25.6)	
Gender, n (%)			0.039
Male	29 (70.7)	108 (53.2)	
Female	12 (29.3)	95 (46.8)	
Smokers, n (%)	2 (4.9)	15 (7.4)	0.073
Systolic Blood Pressure, mmHg, Mean (SD)	139.1 (19.2)	118.7 (14.8)	<0.001
Diastolic Blood Pressure, mmHg, Mean (SD)	88.9 (12.9)	76.1 (10.6)	<0.001
Body Mass Index in kg/m^2, Mean (SD)	28.3 (4.8)	22.7 (3.55)	<0.001
Fasting Glucose , mmol/L, Mean (SD)	6.1 (2.03)	5.02 (0.48)	<0.001
Fasting Triglycerides , mmol/L, Mean (SD)	2.2 (0.22)	0.9 (0.49)	<0.001
Fasting HDL-C,* mmol/L, Mean (SD)	1.2 (0.35)	1.4 (0.34)	<0.001
Elevated Waist Circumference,† n (%)	39 (95.1)	71 (35.1)	<0.001
Elevated Blood Pressure,‡ n (%)	35 (85.4)	46 (22.7)	<0.001
Elevated Fasting Glucose,§ n (%)	21 (50)	21 (10.3)	<0.001
Elevated Fasting Triglycerides,‖ n (%)	10 (26.3)	4 (2)	<0.001
Reduced HDL-C,¶ n (%)	28 (68.3)	67 (33)	<0.001

*High density lipoprotein-C

†Defined by waist circumference ≥90 cm for males and ≥80 cm for females following Asian cut-offs

‡≥130 mmHg systolic blood pressure or 85 mmHg diastolic blood pressure or on drug treatment for hypertension

§>5.6 mmol/L of fasting glucose or on drug treatment for elevated glucose

‖>1.7 mmo/L of fasting triglycerides or on drug treatment for elevated triglycerides

¶≤1.034 mmol/L in males and ≤1.293 mmol/L of HDL-C in females or on drug treatment for reduced HDL-C

Lower optimal cut-off values were identified in females. However, when analysis was stratified by various age groups, the ranking of the predictive accuracy as measured by the AUC of the measures were found to be different. Within the 21 to 30 years old group, WC was found to have the highest AUC followed by systolic BP, BMI and diastolic BP. Within the 31 to 40 and 41 to 50 years old groups, BMI was found to have the highest AUC. It was followed by waist circumference, systolic BP and diastolic BP in the 31 to 40 years old group and diastolic BP, waist circumference and systolic BP in the 41 to 50 years old group. The optimal cut-off values were found to be >93 cm and >95 cm in the 21 to 30 years old group, >90 cm and >85 cm in 31 to 40 years old group and >91 cm and >89 cm in the 41 to 50 years old group for males and females respectively. Results are described in Table 3B.

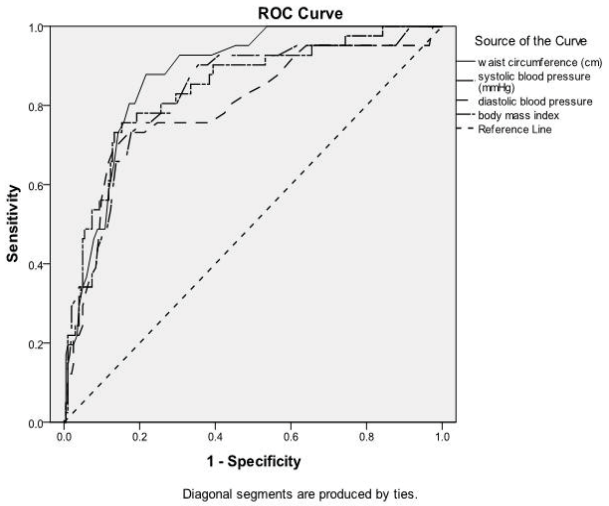

Fig. 1. Graph showing the ROC curves of BP, WC and BMI in the prediction of MetS.

Discussion

MetS has been found to be closely associated with cardiovascular diseases and has been suggested be the intermediate step to the occurrences of cardiovascular diseases. This study found a slightly lower prevalence of MetS (16.8%) compared to previous reports.[4,5] This is likely attributed by the inclusion of only Chinese subjects in the study. Indians and Malays have been reported to have higher prevalence of MetS compared to their Chinese counterparts and have shown to contribute significantly to the overall prevalence.[4,15]

At the WHO pre-established public health action point of BMI ≥23 kg/m^2 for Asians, BMI was found to be more sensitive and had higher PPV value in predicting MetS in comparison to the optimal cut-off value of ≥24 kg/m^2 as determined by the ROC curve. This finding suggests that a cut-off of BMI ≥23 kg/m^2 is more appropriate to screen for cases of MetS. However, the predictive power of BMI was observed to be reduced significantly in individuals between 21 and 30 years old. This observation suggests that BMI may not be an accurate measure of body fat as previously reported.[16,17] As young people are generally more physically active compared to their older counterparts, a larger proportion of their weight is attributed to muscle

Table 2. Discriminant Indices in Prediction of Metabolic Syndrome

	AUC (95%CI)	*P* Value	Cut-off Point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Likelihood Ratio (+)	Likelihood Ratio (-)
Systolic Blood Pressure (mmHg)	0.83 (0.76 to 0.90)	0.036	>130	65.9	83.7	45	92.4	4	0.41
Diastolic Blood Pressure (mmHg)	0.80 (0.71 to 0.88)	0.042	>86	70.7	85.2	49.2	93.5	4.8	0.35
Waist Circumference (Males) (cm)	0.87 (0.81 to 0.94)	0.032	>90.5	93.1	75.9	50.9	97.6	3.9	0.09
Waist Circumference (Females) (cm)	0.87 (0.79 to 0.95)	<0.001	>86.5	83.3	76.8	31.3	97.3	3.6	0.22
BMI (kg/m^2)	0.84 (0.77 to 0.91)	0.035	≥23	91.1	52.9	40	94.5	1.9	0.17
			≥24	82.9	69.5	35.4	95.3	2.7	0.25

AUC: area under the curve; BMI: body mass index; CI: confidence interval; NPV: negative predictive value; PPV: positive predictive value

Table 3A. Predictive Power Stratified by Gender

	Males, n = 137			Females, n = 107		
	AUC (95% CI)	*P* Value	Cut-off Point	AUC (95% CI)	*P* Value	Cut-off Point
Systolic Blood Pressure (mmHg)	0.806 (0.72 to 0.89)	<0.001	>132	0.817 (0.65 to 0.98)	<0.001	>125
Diastolic Blood Pressure (mmHg)	0.791 (0.70 to 0.89)	<0.001	>85	0.738 (0.54 to 0.94)	<0.001	>87
Waist Circumference (cm)	0.875 (0.81 to 0.94)	<0.001	>90.5	0.871 (0.79 to 0.95)	<0.001	>86.5
BMI (kg/m^2)	0.828 (0.73 to 0.92)	<0.001	≥25	0.864 (0.77 to 0.96)	<0.001	≥25

Table 3B. Predictive Power Stratified by Age Groups as Defined by ROC

	21 to 30 years old, n = 89			31 to 40 years old, n = 83			41 to 50 years old, n = 72		
	AUC (95% CI)	*P* Value	Cut-off Point	AUC (95% CI)	*P* Value	Cut-off Point	AUC (95% CI)	*P* Value	Cut-off Point
Systolic Blood Pressure (mmHg)	0.71 (0.50 to 0.91)	0.035	>124	0.83 (0.71 to 0.95)	<0.001	>124	0.89 (0.81 to 0.96)	<0.001	>129
Diastolic Blood Pressure (mmHg)	0.61 (0.38 to 0.83)	0.267	>86	0.81 (0.69 to 0.94)	0.001	>87	0.90 (0.81 to 0.99)	<0.001	>83
Waist Circumference (Males) (cm)	0.74 (0.58 to 0.91)	0.056	>93	0.94 (0.88 to 1)	<0.001	>90	0.91 (0.81 to 1.00)	<0.001	>91
Waist Circumference (Females) (cm)	0.88 (0.66 to 1.00)	0.014	>95	0.83 (0.67 to 0.98)	0.129	>85	0.86 (0.70 to 1.00)	0.006	>89
BMI (kg/m^2)	0.65 (0.46 to 0.84)	0.125	≥28	0.93 (0.86 to 0.99)	<0.001	≥25	0.91 (0.83 to 0.99)	<0.001	≥25

AUC: area under the curve; BMI: body mass index; CI: confidence interval; ROC: receiver operating characteristic

mass rather than fat. Therefore, BMI might not be a valid measurement of body fat composition in this age group and most likely not reliable as a screener for MetS in a young population.

Similar to previous report for a large Chinese population,[8] results from ROC analysis proposed that waist circumference with cut-off values of >92.5 cm in males and >86.5 cm in females to be most accurate and in detecting MetS as supported with consistently high AUC even when analysis was stratified by gender. WC with the highest sensitivity, specificity and NPV was the most favourable compared to the other potential predictors as a screener for MetS. In addition, higher positive likelihood ratios of waist circumference as described in Table 2 compared to BMI, which has been commonly used as a gold standard for identifying MetS, further suggests that waist circumference is a better measure for identification of MetS compared to BMI.

On the other hand, it is interesting to note that the positive likelihood ratio of waist circumference is lower compared to blood pressure. While the higher positive likelihood ratios suggests that blood pressure is a better tool to use to identify MetS, the low sensitivity of blood pressure makes it not favourable as a screener of MetS as screener is required to have high sensitivity. This finding has important clinical significance as WC can be easily obtained in a community setting and is relatively inexpensive as a screening measure.

This is the first study conducted in Singapore to examine and compare the predictive utility of BP, WC and BMI in the prediction of MetS. It was carried out at a single site with reliable measurements and venous sample collections which eliminates any potential inter-site variation related to measurements and laboratory processes. Furthermore, this study adopted the AHA/NHLBI guidelines, which has been reported to be the most sensitive in predicting subsequent cardiovascular disorder in a large Singaporean cohort.[6] Therefore, the results have relevant clinical significance and implications in the local setting. However, as this study has a relatively small sample size and made up of generally young individuals, further study with larger group of study subjects of all age groups needs to be conducted to confirm this finding. In addition, as this study included only Chinese subjects and those who responded to the advertisements, findings cannot be generalised.

Conclusion

In conclusion, this study provides evidence to suggest waist circumference with cut-off values of >92.5 cm in males and >86.5 cm in females to be most accurate and reliable in identifying cases of MetS in the Chinese population in Singapore.

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