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Is waist circumference more strongly associated with metabolic risk factors than waist-to-height ratio in Asians?

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ABSTRACT

Objectives: Differential distribution of fats can vary among ethnic groups and thus have varying effects on metabolic risk. Measuring metabolic risk of individuals using simple anthropometric measurements is essential to replace current invasive methods of obtaining blood samples. Waist-to-height ratio (WHtR) has been advocated as the best simple anthropometric measurement, but, because of the high visceral fat of Asians, there has been speculation as to the possibility of using only waist circumference (WC) to measure metabolic risk. The aim of this study was to compare the performance of WC and WHtR in terms of their association with measures of obesity and metabolic risk factors (e.g., homeostasis model assessment for insulin resistance, low-density lipoprotein, triacylglycerol, and ratio of triacylglycerol to high-density lipoprotein) and to obtain an optimal cutoff value for one anthropometric measurement.
Methods: The study was performed on healthy Asian Chinese (N = 527) men (n = 209) and women (n = 318) who participated in a cross-sectional study conducted at the Clinical Nutrition Research Centre located in Singapore. Association of WC and WHtR with metabolic risk factors was obtained using Spearman's rank correlation coefficient. Optimal cutoff value was obtained using receiver operating characteristic curve.
Results: WC and WHtR performed equally well in both sexes in terms of their strength of association between metabolic risk factors. Receiver operating characteristic curve analysis showed that 73.5 cm (in women) and 82.5 cm (in men) were the optimal WC cutoff values to identify insulin resistance.
Conclusion: It is suggested that WC is a simpler anthropometric measurement that has strong association with an individual's metabolic risk level.

Introduction

High metabolic risk factor gives an indication of the health status of an individual and the susceptibility of the individual to metabolic diseases [1,2]. Therefore, the evaluation of one's metabolic risks is crucial. Current methods to measure metabolic risks include assessment of blood drawn from the individual in the fasted state. Such measurements are invasive, time-consuming, and require trained personnel to carry out the analysis of the blood. Therefore, using anthropometric measurements as a simple tool for assessing metabolic risks would be of interest to the general population.

A classic example is the waist-to-height ratio (WHtR) index proposed by Ashwell in 1996. The index was proposed as the best simple anthropometric predictor of intraabdominal fat for both men and women [3]. It has been suggested that WHtR is a simple anthropometric measurement that has the potential of being a global predictor of health risk in adults and children [3,4]. Ashwell's work culminates in the development of a simple yet powerful health message stating “keep your waist circumference to less than half your height” [5]. However, population groups can differ in body build. Therefore, ethnicity has been reported to affect metabolic risks because of the differences in body composition and distribution of fats [6,7].

Asians have a high tendency to deposit fat at the viscera compared with their European counterparts [7,8]. This explains why Asians have a higher fat percentage than Europeans despite having the same body mass index (BMI). Such phenomenon was identified and termed by Yajnik et al. as the *thin-fat phenotype* in Indians, where a majority of fat is deposited at the visceral and internal organs [9]. The close proximity of fat to the vital organs puts Asians at higher risk for insulin resistance (IR) and for developing type 2 diabetes (T2D) [9,10]. Higher percentage of fat in turn puts Asians at greater risk for metabolic disorders than Europeans [11].

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Recently, many studies have been conducted with Asians to compare the performance of anthropometric measurements to predict health disorders such as cardiovascular disease and metabolic syndrome [12,13]. However, given the differential body composition between Asians and Europeans [6,14], it is important to test the validity and veracity of Ashwell's WHtR criteria in Asian Chinese. Because visceral fat is related to increased metabolic risk [10,15], high visceral fat in Asians instigates the speculation that waist circumference (WC) will be the simple measurement necessary to estimate metabolic risks especially in this population. Hence, the aims of the present study were to compare the basic WC measurement with WHtR in terms of their strength of association with metabolic risk factors, especially in Asian Chinese, and to suggest a plausible cutoff value for the best anthropometric measurement that could identify at-risk individuals from those not at risk. At-risk individuals were identified as those who are at risk for T2D using the homeostasis model assessment for insulin resistance (HOMA-IR) as an estimate. Moreover, it will be advantageous to be able to have a simple anthropometric measurement that could identify individuals at risk for T2D given the escalating prevalence in Asians [16].

Participants and methods

Data from a cross-sectional study conducted at the Clinical Nutrition Research Centre (CNRC) located in Singapore from June 2014 to October 2017 were used for the present study. Participants were recruited from the general public in Singapore through newspaper and poster advertisements that were placed around the National University of Singapore campus, public area, and on the CNRC website. The recruited participants were between 21 and 74 y of age, men and women of all ethnic groups, not diagnosed with any major diseases, not taking any regular medication, and were not pregnant. The current analysis included 527 participants (209 men and 318 women) with both dual energy x-ray absorptiometry (DXA) and anthropometric measurements. The National Healthcare Group Domain Specific Review Board, Singapore, approved the protocol for the study. All participants provided written informed consent before study commencement.

Anthropometric and blood measurements

All participants reported to CNRC in the morning after a 10-h overnight fast. Two finger-prick capillary blood samples along with 10 mL of venous blood were collected into vacutainers (Becton Dickinson Diagnostics, Franklin Lakes, NJ, USA). The fasting blood glucose (FBG) concentration was obtained using the HemoCue 201 + RT Glucose analyser (HemoCue Ltd, Dronfield, UK) using the blood obtained from the finger prick. Fasting serum insulin (FSI; μU/mL) was measured using immunochemistry analyzer COBAS e411 (Roche, Hitachi, Indianapolis, IN, USA). HOMA-IR was calculated using these fasting values:

$$\mathrm{HOMA-IR} = \mathrm{FBG} \times \mathrm{FSI}/22.5$$

Fasting lipid parameters including low-density lipoprotein (LDL), triacylglycerols (TGs), and high-density lipoprotein (HDL) were measured using chemistry analyzer COBAS c311 (Roche, Hitachi). Using these values, the ratio of TG to HDL (TG/HDL) was obtained.

Along with the blood analysis, the anthropometric measurements of the participants were taken following standard protocols [17]. Weight (kg) was measured to the nearest 0.1 kg in light clothing without footwear by using an electronic scale (Seca Limited, Birmingham, UK), and height (cm) was measured using a stadiometer (Seca Limited, Birmingham, UK) to the nearest 0.1 cm. WC was taken at the smallest reading above the umbilicus or navel and below the xiphoid process using a standard non-elastic measuring tape (Lufkin W606 PM, Lufkin, Sparks, MD, USA). DXA (QDR 4500 A, fan-beam densitometer, Hologic, Waltham, MA, USA) was used to determine the participant's total body fat percentage (TBF%).

Statistical analysis

HOMA-IR, LDL, total body fat percentage, TG, and TG/HDL were identified as metabolic risk factors. Partial Spearman's rank correlation coefficients (adjusting for age) of WC and WHtR with the metabolic risk factors were computed to investigate their strength of association with the metabolic risk factors. Cutoff values for indicating IR (HOMA-IR $\geq$2, which was obtained based on a 15-y prospective study to discriminate T2D from normal glucose tolerance [18]) were obtained for the chosen anthropometric measurements in the initial step using receiver operating characteristic (ROC) curve. The optimal cutoff values were obtained by identifying the value that maximizes the Youden index (sensitivity + specificity − 1). All analyses were performed using SPSS version 24 (IBM, Armonk, NY, USA). Statistical Software R (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/) was used to compare the area under the ROC curve (AUC) obtained using WC and WHtR. Data was reported as median with the first and third quartiles and all statistical significance for tests in this study was set at $\alpha = 0.05$.

Results

Table 1 shows the basic characteristics of the 527 participants (209 men and 318 women) recruited for this study. There were significant differences in the anthropometric measurements and blood analysis for men and women in all variables except for age and LDL (Table 1). Hence, to remove the confounding effect of sex, correlation and ROC curve analysis were performed separately for each sex. Because age is a plausible confounding variable for many metabolic diseases, correlation analysis was performed to control for age [19]. Both WC and WHtR were significantly correlated with the various metabolic risk factors even after controlling for age, as shown in Table 2.

ROC curve analysis was used to obtain the optimal cutoff value of WC to predict IR. The optimal cutoff value obtained for women and men were 73.5 cm (sensitivity = 57%, specificity = 80.4%) and 82.5 cm (sensitivity = 75.5%, specificity = 78.1%), respectively (Fig. 1A, B). AUC of the ROC curves obtained using WC and WHtR were tested using DeLong's method for two correlated ROC curves to compare the performance of the two anthropometric variables as potential biomarkers. WHtR did not outperform WC as a biomarker as indicated by the insignificant difference in the AUC for both men ($P = 0.50$) and women ($P = 0.55$).

Discussion

Correlation analysis of the metabolic risk factors with the anthropometric variables (i.e., WC and WHtR) demonstrated that both WC and WHtR were significantly correlated with the

Table 1
Characteristics of the participants (N = 527) used for correlation and ROC curve analysis

Variables	Women (n = 318)		Men (n = 209)		*P*-value*
	Median	Q1, Q3	Median	Q1, Q3	
Age (y)	34.3	24.9, 53	32	24.7, 52	0.94
Weight (kg)	53.0	48.7, 59.8	68.4	61.5, 74.8	<0.001
Height (cm)	159.7	155.7, 163.5	171.3	167.4, 175.6	<0.001
BMI (kg/m^2)	21.1	19.5, 23.1	23.1	21.2, 25.5	<0.001
Waist (cm)	69.0	64.4, 74.4	78.2	73.4, 85.3	<0.001
DXA fat (%)	35.0	30.9, 38.9	24.9	20.7, 28.6	<0.001
LDL (mmol/L)	3.2	2.7, 3.8	3.2	2.7, 3.8	0.67
TG (mmol/L)	0.8	0.6, 1.1	0.9	0.7, 1.2	0.008
TG/HDL	0.5	0.3, 0.6	0.6	0.4, 0.9	<0.001

BMI, body mass index; DXA, dual-energy x-ray absorptiometry; HDL, high-density lipoprotein; LDL, low-density lipoprotein; ROC, receiver operative characteristic; Q, quartile; TG, triacylglycerol.
**P*-value from non-parametric *t* test testing the difference in men and women.

metabolic risk factors even after controlling for age (Table 2). The numerical difference in strength of correlation of metabolic risk factors with WC and WHtR was minor (a maximum difference of 0.05), which was not considered to have clinical importance. Furthermore, bootstrap confidence intervals for the correlations involving WC and WHtR were overlapping, suggesting that there was no significant difference in the strength of association between the metabolic risk factors and the two anthropometric variables. Therefore, WHtR may not outperform WC in terms of its strength of association with the metabolic risk factors in Asians. The implication of this result was that WC alone could be a simple anthropometric measurement used to determine an individual's metabolic risk. This is probably because Asians, despite having similar BMI, are prone to have fat deposited at the viscera area compared with Westerners [7,8]. As a result, WC will be expected to be a crucial measurement to be made in Asians instead of the height measurement or calculation of their ratio.

As T2D is prevalent in Asians [16] and is escalating, identifying those at risk using a simpler method is essential. HOMA-IR is the widely used method for estimating an individual's IR. However, the calculation of HOMA-IR requires the analysis of the individual's blood profile in the fasted state, which is both invasive and time-consuming. Hence, a simpler and noninvasive method for identifying IR is necessary. Previously, many studies reported that visceral fat (determined by WC) is associated with IR [20–22]. Therefore, identifying a cutoff value of WC for Asian Chinese was necessary for identifying IR. Previous studies have established that the best cutoff value of HOMA-IR indicating IR is 2 [18]. In the present study, we found that cutoff values of WC were 82.5 and 73.5 cm in men and women, respectively. The significant AUC of the ROC curve for both sexes ($P < 0.001$) suggests that WC has predictive ability to discriminate IR. Moreover, there was no significant difference in the AUC obtained using WHtR and WC to predict IR for both men ($P = 0.50$) and women ($P = 0.55$). Hence, WC alone is a simpler anthropometric measurement that can be used to discriminate IR because WHtR does not outperform WC.

Moreover, the cutoff values of WC were 83.5 and 72.5 cm for men and women, respectively (detailed results are not shown), using elevated TG concentration (≥1.7 mM) as the diagnostic criteria [23]. These results, when combined, suggest the consistency of using WC cutoff values for different diagnostic criteria based on the metabolic risk factors. This further supports the view that the current cutoff values suggested in this study should be proposed to be the WC values for Asian Chinese in this region in general.

The Singapore Health Promotion Board (HPB) currently suggests 90 and 80 cm as the healthy WC cutoff values for men and women, respectively. The cutoff values found in present study are lower than those suggested by the Singapore Health Promotion Board for both sexes, which will be helpful in clinical setting to easily identify at-risk individuals at an earlier stage. It is suggested that Asian Chinese women with WC in the range of 73.5 to 80 cm are at moderate risk and WC >80 cm are at a very high risk for IR. Similarly, Asian Chinese men with WC in the range of 82.5 to 90 cm are at moderate risk, whereas those with WC >90 cm are at very high risk (summarized in Table 3). The results of the study suggest that individuals with WC in the high-risk category should seek medical advice, whereas those in the moderate-risk category should start increasing their physical activity and monitoring their health.

We acknowledge the limitations of the present study such as the use of only healthy Chinese participants. Further studies on different ethnic and racial groups with different health status are necessary to be able to generalize the results obtained in this study. The present study is cross-sectional and thus a causal relationship cannot be established. The cutoff values were obtained by combining the age groups, but the values might change in individual age groups. Finally, the menopausal status of the women in the study was not taken into account, and this could affect their accumulation of fat in the viscera [24].

Conclusion

The results of the present study show that Ashwell's WHtR index does not outperform WC in strength of association with metabolic risk factors in Asian Chinese men and women. Hence, in many busy clinics and health centers, where a requirement to estimate the metabolic risks of patients is essential, this study proposes that WC alone is a simple, easy-to-measure and minimally time-consuming activity that provides prediction as good as WHtR.

Table 2
Spearman's rank partial correlation coefficients (controlling for age) between biomarkers and two anthropometric measurements along with the bootstrap percentile confidence interval (95%) evaluated separately for each sex*

	Anthropometric variable	HOMA-IR (95% CI)	LDL (95% CI)	DXA fat% (95% CI)	TG (95% CI)	TG/HDL (95% CI)
Women (n = 318)	WC (cm)	0.412† (0.322–0.494)	0.147† (0.030–0.253)	0.664† (0.595–0.728)	0.334† (0.216–0.433)	0.419† (0.321–0.509)
	WHtR	0.418† (0.323–0.498)	0.145‡ (0.028–0.256)	0.683† (0.617–0.745)	0.321† (0.202–0.433)	0.413† (0.304–0.505)
Men (n = 209)	WC (cm)	0.534† (0.431–0.627)	0.145‡ (0.000–0.278)	0.771† (0.719–0.820)	0.402† (0.278–0.512)	0.470† (0.362–0.568)
	WHtR	0.518† (0.404, –0.611)	0.171‡ (0.037–0.303)	0.784† (0.724–0.828)	0.370† (0.243v0.484)	0.421† (0.296–0.524)

CI, confidence interval; DXA, dual-energy x-ray absorptiometry; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triacylglycerol; WC, waist circumference; WHtR, waist-to-hip ratio.
*All partial correlation coefficients reported in the table were significant at $\alpha = 0.05$.
†Indicates $P < 0.01$ (2-tailed).
‡Indicates $P < 0.05$ (2-tailed).

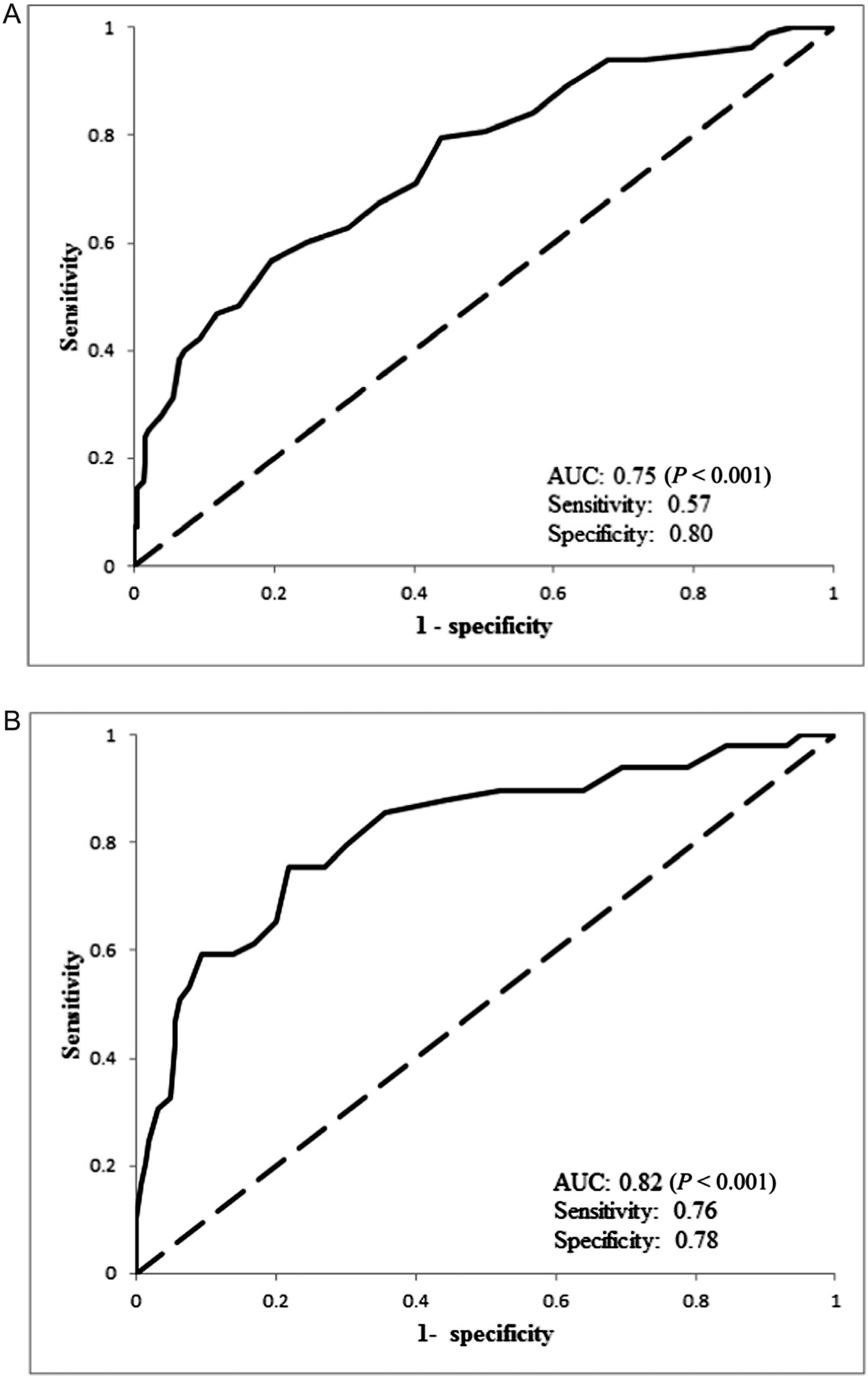

Fig. 1. (**A**) Receiver operative characteristic (ROC) curve for WC to predict insulin resistance (using HOMA-IR ≥2) in women (n = 318); 95% CI for the AUC is (0.69–0.81). (**B**) ROC curve for WC to predict insulin resistance (using HOMA-IR ≥2) in men (n = 209); 95% CI for the AUC is (0.75– 0.89). AUC, area under the curve; CI, confidence interval; HOMA-IR, homeostasis model assessment for insulin resistance; WC, waist circumference.

Table 3
Representing the summary of the waist circumference cutoff value in men and women and their proposed associated risk level*

Sex	Risk level for diabetes status		
	Low risk	Moderate risk	High risk
Woman	<73.5	73.5–80	≥80
Men	<82.5	82.5–90	≥90

The optimal cutoff value of WC recommended from the study is 73.4 cm for women and 82.5 cm for men. These results are not surprising because the measurement of visceral fat is crucial in Asians who tend to have higher fat accumulation at the abdomen.

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