The Relationship Between Waist Circumference and Metabolic Risk Factors: Cohorts of European and Chinese Descent

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Waist circumference (WC) may be the best anthropometric index for identifying individuals at risk for cardiovascular disease (CVD) and diabetes mellitus (DM). The objectives of this study were to determine if the relationship between WC and metabolic risk factors is similar in men and women of Chinese and European descent, and to assess the effect of ethnicity on these relationships. Apparently healthy men and women of Chinese (n = 92) and European (n = 99) descent were recruited from hospital staff and assessed for anthropometric variables and blood pressure (BP), lipids, insulin, and glucose. The study cohort was stratified by sex, and regression analyses were performed with the various metabolic risk factors as the outcome and WC and ethnicity as predictors. Chinese men and women had significantly lower WC than European men and women. Age and metabolic risk factors were similar between the 2 ethnic groups except for BP. Metabolic risk factors significantly correlated with WC within each gender and ethnic cohort. In men, ethnicity was an independent predictor for total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), and the ratio of TC to high-density lipoprotein cholesterol (HDL-C) after controlling for WC. In women, ethnicity significantly interacted with WC as an independent predictor of TG, TC:HDL-C ratio, insulin, and glucose. As ethnic descent modifies the relationship between WC and metabolic risk factors, current WC targets derived from relationships in European populations are not applicable to Chinese men and women. Therefore, ethnic background should be considered when using WC as a marker of cardiovascular risk.

THE PREVALENCE of obesity has increased dramatically in industrialized and developing nations.[1-4] As a consequence, the cost of health care may rise as obesity imparts an increased risk for type 2 diabetes mellitus (DM) and cardiovascular disease (CVD).[5-7] Determining the best anthropometric index to identify obesity is essential for early intervention and risk reduction. Body mass index (BMI), waist-to-hip ratio (WHR), and waist circumference (WC) have been found to correlate with CVD risk factors, intra-abdominal fat, and mortality.[8,9] Of these measures, WC appears to be the best individual marker of obesity as it has a stronger correlation with risk factors and intra-abdominal fat content than either BMI or WHR[8,10,11] and is more reliable than WHR.[12] Therefore, WC targets have been proposed in order to identify individuals at risk for CVD and DM.[8,13,14] These targets are based on the relationship between WC and CVD risk factors derived from European descent populations and may be of limited value in other ethnic populations.

As Chinese populations tend to have a lower prevalence of obesity than European populations, it is believed that they are at a lower risk for obesity-related diseases. However, Amos et al estimated that with the increasing prevalence of obesity and changes in lifestyle and economic structure, the incidence of DM may increase by 2- to 3-fold in Asia by 2010.[15] In Chinese populations, as in European populations, WC has been found to correlate with CVD risk factors.[16,17] It has also been suggested that current anthropometric targets may not be appropriate for Chinese men and women.[16,18] As no study has investigated the relationship between WC and multiple metabolic risk factors in these 2 ethnic groups, the World Health Organization International Obesity Task Force has called for further investigations.[19] The objectives of this study were to determine if the relationship between WC and metabolic risk factors is similar in men and women of Chinese and European descent and to assess the effect of ethnicity on these relationships in order to determine the appropriateness of current WC targets.

MATERIALS AND METHODS

Study participants (men and women) were recruited from staff, students, volunteers, and their friends of 2 local hospitals. Participants were eligible if they were over 18 years of age and either of European or Chinese descent. Ethnicity was defined as having all known ancestors of either European or Chinese descent as determined by participant self-report. Participants were excluded if they had increased abdominal girth not related to increased adiposity (eg, pregnancy, peritoneal dialysis, or ascites). A sample size of convenience was limited to 100 participants of each ethnicity. All participants read and provided informed consent prior to commencing the study. The study was approved by the Providence Health Care Ethics Committee. Combined data from this cohort has been previously published to demonstrate the reliability of the WC measure.[12]

Participants underwent an initial assessment that included WC, BMI, blood pressure (BP), and medical history. Within 1 week, participants returned to provide fasting blood samples to be analyzed for plasma total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), insulin, and glucose at a later date. Plasma and serum samples were kept frozen at −70° C until analyzed.

WC was measured (to the nearest 0.1 cm) directly over the skin at the point of maximal narrowing of the trunk as viewed from the anterior position with the participant standing upright following a normal ex-

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Table 1. Anthropometric Data and Metabolic Risk Factors for European and Chinese Men

	European (n = 42)	Chinese (n = 45)
Age, yr (range)	37.8 ± 9.7 (19-58)	36.2 ± 11.3 (19-66)
Height, m (range)	1.77 ± 0.07 (1.64-1.90)	1.71 ± 0.06 (1.57-1.82)
BMI, kg/m^2 (range)	25.5 ± 3.6 (19.6-35.8)	23.2 ± 2.9* (17.8-31.9)
WC, cm (range)	88.7 ± 9.7 (72.2-113.6)	80.0 ± 7.5† (62.0-96.1)
TC, mmol/L	4.09 ± 0.78	4.38 ± 0.98
LDL-C, mmol/L	2.38 ± 0.73	2.50 ± 0.81
HDL-C, mmol/L	1.22 ± 0.23	1.32 ± 0.25
TG, mmol/L‡	0.96 ×/÷ 1.66	1.06 ×/÷ 1.73
TC:HDL-C	3.47 ± 0.92	3.42 ± 0.89
Glucose, mmol/L	5.5 ± 0.6	5.5 ± 0.4
Insulin, μU/L	12.0 ± 4.8	11.5 ± 7.3
Systolic BP, mm Hg	120 ± 11	114 ± 11*
Diastolic BP, mm Hg	75 ± 8	71 ± 7*
Current smokers	5 (12%)	2 (4%)

*$P < .01$ compared to European.

†$P < .001$ compared to European.

‡Geometric mean with antilog of SD.

piration. Weight was measured to the nearest 0.1 kg on a balance beam scale, and participants were asked to remove their shoes and any heavy items from their pockets. Height was measured at the same time to the nearest 0.5 cm. BMI was calculated as weight (kg) divided by height (m) squared. Blood pressure was measured in the left arm following 5 minutes of seated rest using an appropriately sized cuff. A second measurement was taken 5 minutes later. The average of the 2 measures was used in analyses.

Plasma TC, HDL-C, TG, and glucose were measured using a Technicon RA-1000 analyzer (Bayer Diagnostics, Tarrytown, NY). LDL-C was calculated using the Friedewald equation; this formula is invalid when TG is greater than 4.5 mmol/L, but no subjects presented with TG at this level.[20] The percent coefficient of variation (%CV) for these procedures are 1.5% for a TC concentration of 3.70 mmol/L, 2% for a HDL-C concentration of 1.42 mmol/L, 1.9% for a TG concentration of 1.48 mmol/L, and 1.4% for a glucose concentration of 4.6 mmol/L. Plasma insulin was measured by radioimmunoassay with a commercial kit from ICN Pharmaceuticals (Costa Mesa, CA) using a Cobra Gamma Counter (Packard BioScience, Meriden, CT). The %CV for this method is less than 5% counts per minute.

Data are reported as the mean ± SD. Comparisons between groups were analyzed using an independent-samples 2-tailed *t* test. TG were log-transformed for analyses, with the geometric mean presented in the tables and the transformed data presented in the figures. Categorical data were analyzed using the Pearson chi-square test. Pearson correlation coefficients were calculated between WC and other parameters within each sex and ethnicity and adjusted by age through regression analysis. Regression analysis was performed within each sex with the various metabolic risk factors as dependent variables to identify a possible interaction between WC and ethnicity. If no interaction was found, then a second regression analysis was performed with WC and ethnicity as independent variables. The regression analyses were repeated again adjusting for age and height. All tests were conducted with *P* value set at .05 for significance using SPSS version 10.0 software (SPSS, Inc, Chicago, IL).

RESULTS

A total of 99 European (42 men and 57 women) and 92 Chinese (45 men and 47 women) were recruited from 2 hospital communities. Tables 1 and 2 outline the age, anthropometric values, and metabolic risk factors for men and women, respectively. Ages were similar between European and Chinese men and European and Chinese women. The Chinese men and women had significantly lower BMI and WC values compared to their European counterparts. Systolic and diastolic BP were significantly lower in Chinese men than European men, while all other risk factors were similar between the 2 ethnic groups. There were no differences in metabolic risk factors between European and Chinese women.

Table 3 outlines the Pearson correlation coefficients between WC and the metabolic risk factors stratified by sex and ethnicity. WC correlated significantly with most of the metabolic risk factors for European and Chinese men, except for systolic BP in European men, LDL-C and insulin in Chinese men, and glucose for both European and Chinese men. WC correlated significantly with all metabolic risk factors for European and Chinese women, except for TC and LDL-C in European women. WC remained a significant predictor for many of the metabolic risk factors after adjusting for age. Correlations were strongest for those risk factors most commonly associated with WC:TG, insulin, and BMI.

In men, there was no interaction between WC and ethnicity for any of the outcome variables. Ethnicity was an independent predictor for TC ($P < .01$), LDL-C ($P < .05$), TG ($P < .01$), and TC:HDL-C ($P < .05$) after adjusting for WC (Fig 1). As a result, TC, LDL-C, TG, and TC:HDL-C were, on average, greater by 0.61 mmo/L, 0.39 mmol/L, 0.45 mmol/L, and 0.40 mmol/L, respectively, in this population of Chinese men compared to European men for a given WC. Ethnicity remained a significant predictor for TC ($P < .01$), LDL-C ($P < .05$), and TG ($P < .01$) after adjusting for age. After adjusting for both age and height, ethnicity remained a significant predictor for TG ($P < .05$).

In women, the interaction between ethnicity and WC and ethnicity itself were independent predictors of TG ($P < .01$), TC:HDL-C ($P < .01$), insulin ($P < .05$), and glucose ($P < .05$) (Fig 2) and remained a significant predictor after adjusting for height ($P < .05$ for all). No interaction was apparent between WC and ethnicity for TC, HDL-C, LDL-C, and BP, and ethnicity was not an independent predictor of these variables.

Table 2. Anthropometric Data and Metabolic Risk Factors for European and Chinese Women

	European (n = 57)	Chinese (n = 47)
Age, yr (range)	41.5 ± 11.4 (22-65)	41.6 ± 13.8 (20-72)
Height, m (range)	1.65 ± 0.07 (1.53-1.88)	1.59 ± 0.05 (1.47-1.73)
BMI, kg/m^2 (range)	26.6 ± 5.6 (18.8-39.1)	22.9 ± 3.1† (18.4-34.4)
WC, cm (range)	81.3 ± 12.2 (65.5-119.4)	74.3 ± 7.5* (61.9-104.4)
TC, mmol/L	4.27 ± 0.91	4.34 ± 0.79
LDL-C, mmol/L	2.25 ± 0.85	2.25 ± 0.65
HDL-C, mmol/L	1.60 ± 0.33	1.61 ± 0.31
Triglycerides, mmol/L‡	0.86 ×/÷ 1.53	0.94 ×/÷ 1.66
TC:HDL-C	2.78 ± 0.76	2.79 ± 0.74
Glucose, mmol/L	5.3 ± 0.4	5.4 ± 0.6
Insulin, μU/L	10.6 ± 3.9	11.1 ± 5.2
Systolic BP, mm Hg	115 ± 16	110 ± 15
Diastolic BP, mm Hg	71 ± 10	68 ± 9
Current smokers	3 (5%)	1 (2%)
Postmenopausal	15 (26%)	14 (30%)

*$P < .01$ compared to European.
†$P < .001$ compared to European.
‡Geometric mean with antilog of SD.

Comparing a WC range between 70 and 90 cm, values of TG, TC:HDL-C ratio, insulin, and glucose increased more in the Chinese than the European women: by 0.64 mmol/L, 0.82, 4.16 pmol/L, and 0.44 mmol/L, respectively. The interaction between WC and ethnicity remained significant for TC:HDL-C and insulin after adjusting for both age and height ($P < .05$ for all).

DISCUSSION

The relationship between metabolic risk factors and WC has been studied mostly in subjects of European descent, with few investigations of other ethnic populations. These studies have established the proposed WC targets.[8,14,21] To date, no other trial has examined the relationship of WC with a variety of metabolic risk factors (lipids, insulin, glucose, and BP) between men and women of European and Chinese descent.

As expected, Chinese men and women were significantly thinner than their European counterparts despite a similar age and height. WC correlated with many metabolic risk factors, regardless of sex or ethnic background, indicating that increased abdominal girth is associated with increased likelihood of the presence of metabolic risk factors for Chinese as well as European individuals.

Table 3. Pearson Correlation Coefficients Between WC and the Metabolic Risk Factors

	European Men	Chinese Men	European Women	Chinese Women
TC	0.452†‡	0.298*	0.233	0.425†
LDL-C	0.400†‡	0.285	0.209	0.404†
HDL-C	−0.369*†	−0.339*	−0.273*	−0.365*
Log TG	0.532†‡	0.522†‡	0.602†	0.592†‡
TC:HDL-C	0.550†‡	0.454†‡	0.378†‡	0.655†‡
Glucose	−0.030	0.234	0.363†	0.475†
Insulin	0.563†‡	0.279	0.662†	0.612†
Systolic BP	0.229	0.458†‡	0.445†	0.385†
Diastolic BP	0.599†‡	0.478†‡	0.520†	0.365*

*$P = .05$.
†$P = .01$.
‡WC a significant predictor independent of age.

Our data demonstrate elevated levels of lipids, glucose, and insulin for the same WC in Chinese men and women compared to European men and women. While no interactions between WC and ethnicity were found in men, ethnicity was an independent predictor of TC, LDL-C, TG, and TC:HDL-C. For women, a significant interaction between WC and ethnicity was identified for TG, TC:HDL-C ratio, insulin, and glucose, suggesting these values may increase to a greater extent in Chinese women than in European women for the same incremental increase in WC. While it is difficult to draw conclusions as to the reason for our observation of an ethnic-WC interaction in women only, this is consistent with an earlier investigation in which the ethnicity-WC interaction was a significant predictor for HDL-C and TG in women only.[18] Previous reports have identified differences in the metabolism of sex hormones between European and Chinese women.[22] If this interaction is apparent in longitudinal studies, then Chinese women who increase their WC may experience more marked changes in their metabolic risk factors and be at greater cardiovascular risk.

Ko et al studied 1,513 Hong Kong Chinese men and women, and proposed a BMI of 24 kg/m^2 for both men and women and a WC of 82 cm in men and 76 cm in women in this population.[16] Our data would concur with the conclusion that Chinese men and women require lower WC targets. However, Ko et al studied a population exclusively in Hong Kong and did not directly compare the relationship between WC and metabolic risk factors between other ethnic groups.

Only 2 other studies have compared the relationship between BMI and WC in Chinese descendants to indigenous Europeans.[18,23] Unwin et al reported WCs of Chinese men (87.1 ± 6.5 cm) and women (82.2 ± 8.8 cm) living in Europe to be significantly smaller than of European men (98.3 ± 14.7 cm) and women (94.8 ± 13.1 cm), despite a similar prevalence of

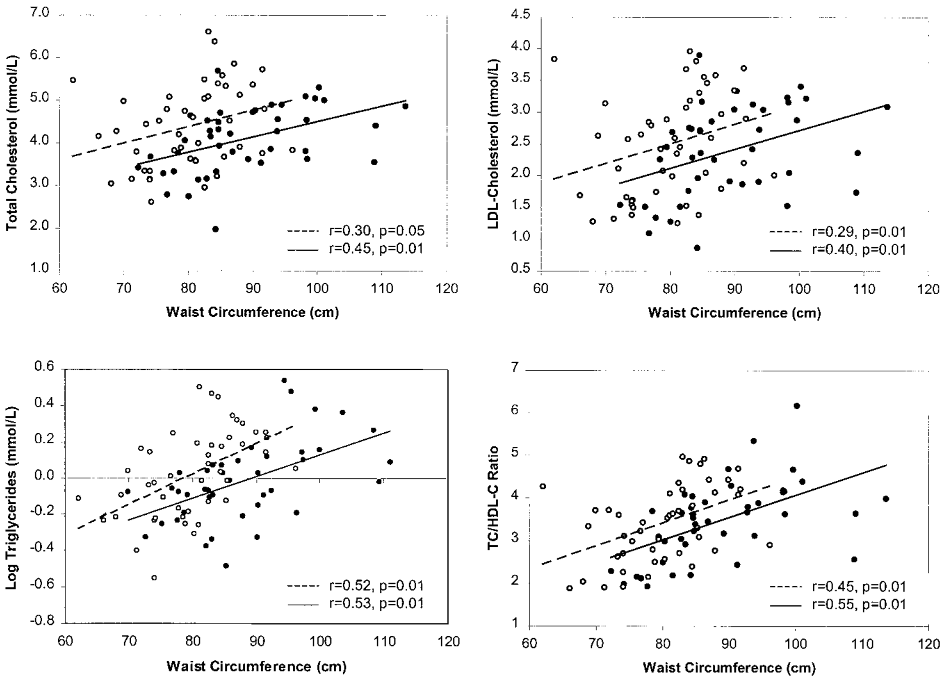

Fig 1. Comparison of the relationship of metabolic risk factors (TC, LDL-C, TG, and TC: HDL-C ratio) and WC between European and Chinese men. (European, ● and —; Chinese, ○ and – – –.)

glucose intolerance.[23] They concluded that an increase in WC in Chinese men and women to values similar to their European counterparts would result in a substantial increase in glucose intolerance and diabetes in this population. In the other study, Patel et al investigated men and women of European and Chinese descent and compared the relationship between WC and HDL-C, TG, and glucose from an oral glucose tolerance test.[18] They reported a significant interaction between ethnicity and WC as a predictor for HDL-C and TG in women, but not in men. Our results confirm these findings and in addition report the results of numerous other CVD and DM metabolic risk factors, thus providing a more comprehensive investigation.

The physiologic basis for the observed differences between Chinese and European men and women is not known. Possible cultural differences must be considered, as well as diet and

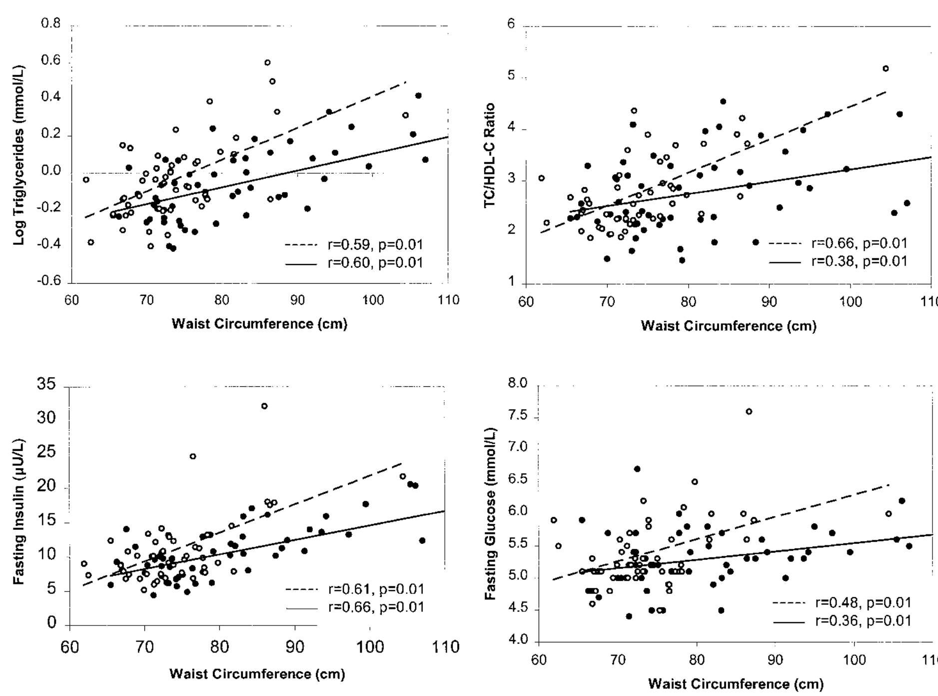

Fig 2. Comparison of the relationship of various metabolic risk factors (TG, TC:HDL-C ratio, insulin, and glucose) and WC between European and Chinese women. *P* values refer to the interaction between ethnicity and WC as an independent predictor after adjusting for WC. (European, ● and —; Chinese, ○ and – – –.)

activity status. While these factors were not assessed in the present study, we anticipate that any differences in these lifestyle behaviors would have a minimal effect given that both the European and Chinese cohorts reside in the same vicinity and were recruited from the same working environment. The cohorts were also a mix of first, second, third, and greater generations of Canadians and lifestyle behaviors are more likely to reflect North American habits than either Asian or European. Another consideration is the importance of height, which has commonly been questioned as Chinese men and women tend to be shorter than European men and women. Our cohort of Chinese men and women tended to be nonsignificantly shorter than their European counterparts. However, adjustment of WC by height has been found to be of less predictive value than WC alone in other cohorts.[24] In our regression analyses, we adjusted for height as a possible confounding factor and found that ethnicity was still an independent predictor of TG in men and the interaction between ethnicity and WC remained an independent predictor of TG, TC:HDL-C, insulin, and glucose in women. It is possible that there may be a difference in the accumulation or percentage of intra-abdominal fat between these 2 ethnic groups at a similar WC. To date, no study has compared intra-abdominal fat accumulation between these 2 ethnic groups and this is an area for future research.

Our study population was recruited from staff, students, and volunteers of a hospital community and therefore may be more health conscious and educated. Indeed, many subjects had an elevated WC by current standards, yet metabolic factors within appropriate targets for people without CVD or DM and with a lower than expected prevalence of smokers. However, a recent study has reported that TG levels above 2 mmol/L in the presence of a WC above 90 cm are indicative of an atherogenic metabolic profile in healthy men.[11] Compared to other cohorts,[17,25] the anthropometric and metabolic values were remarkably similar. The Chinese men and women of our study had nearly identical WC and BMI values to those observed by Ko et al (age, 36.7 $\pm$ 9.2 and 38.6 $\pm$ 9.1 years; WC, 80.8 $\pm$ 0.3 and 74.9 $\pm$ 0.3 cm; BMI, 23.4 $\pm$ 0.1 and 23.3 $\pm$ 0.1 kg/m^2; all values for men and women, respectively).[17] Metabolic risk factor values were also similar between these studies, with the exception of lower LDL-C values observed in our cohort. Likewise, the European men and women in our study had, apart from lower LDL-C, similar anthropometric and metabolic factors to the values reported by the Canadian Heart Health Surveys for the 35 to 54 years old age range.[25] The difference in LDL-C may be explained in part by the younger age of our cohort. Based on these similarities, our cohorts of Chinese and European men and women are not remarkably different from that reported elsewhere.

Despite demonstrating a clear influence of ethnicity on the relationship between WC and many of the metabolic risk factors, this was not consistent for all metabolic risk factors. It is possible that the sample size may have limited the ability to detect ethnicity as a predictor for the other metabolic risk factors and therefore draw definitive conclusions about these factors. Also, these results do not address what effect ethnicity may have on the predictive value of WC with respect to mortality; instead, we demonstrate the effect of ethnicity on the usefulness of WC as a marker for various metabolic risk factors that each have their own independent relationship with mortality. This is not unlike other studies that have investigated the use of WC as a marker of metabolic risk factors.[11,26]

Conclusion

These results demonstrate that the relationship between WC and metabolic risk factors is dependent on ethnic background, and that current WC targets and guidelines derived from relationships in European populations are not applicable to Chinese men and women. If men and women of Chinese descent are assessed based on the current WC targets, some of individuals may present with adverse levels of several metabolic risk factors. Therefore, ethnic background should be considered when using WC as a marker of cardiovascular risk. Future investigations should aim to determine WC targets for populations of different ethnic backgrounds.

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