The Relationship Between Simple Anthropometric Indices and C-Reactive Protein: Ethnic and Gender Differences

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C-reactive protein (CRP) is an independent risk factor for cardiovascular disease (CVD) that is strongly associated with indicators of body fat, yet the effect of potential confounders, such as ethnic background and gender has not been characterized. Our purpose was to determine the effect ethnicity and gender has on the relationship between CRP, body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR) in men and women of Chinese and European descent. BMI, WC, WHR, and CRP were measured in European (n = 91) and Chinese (n = 91) men and women recruited from local hospital staff. Pearson correlation coefficients were determined between CRP, age, and anthropometric measures for the entire cohort and stratified by ethnicity and gender. Multiple regression analyses were performed using interactions between BMI, WC, and WHR for each ethnicity and gender with CRP as the outcome. CRP levels were significantly lower in Chinese compared with Europeans, but this difference disappeared after correction for either BMI or WC. In women, BMI (r = .55, P < .01) and WC (r = .59, P < .01) correlated with CRP. Gender significantly interacted with WC to predict CRP after adjusting for age, smoking status, alcohol, and BMI (P < .05). There was a nonsignificant interaction between gender and BMI as a predictor of CRP. Differences in CRP remained significant after adjusting for WHR. The relationship between CRP levels and BMI or WC was similar between men and women of Chinese and European descent. Gender significantly modified the relationship between CRP and WC. At a WC beyond 70 cm, CRP levels increased at a greater rate in women than men.

OBESITY IS associated with numerous metabolic risk factors and is an independent predictor of cardiovascular disease (CVD).[1,2] Recently, C-reactive protein (CRP), an inflammatory marker that is an independent predictor of CVD, has been reported to be positively associated with body mass index (BMI).[3-6] This has led to the suggestion that obesity may result in low-grade inflammation. These studies indicate that CRP levels tend to be higher in women than in men, which may put women at increased risk.[3,7] However, it is not clear whether gender modifies the relationship between CRP and commonly used anthropometric measures (BMI, waist circumference [WC], and waist-to-hip ratio [WHR]).

In addition, many of these studies have been limited to men and women of European origin. Recent studies have demonstrated that the relationship between anthropometric measures and CVD risk factors differs between men and women of European and Chinese descent.[8-10] At a given BMI or WC, Chinese men and women have higher values of various CVD risk factors than their European counterparts. With the increasing prevalence of obesity in Chinese populations, there may be a concomitant increase in CVD risk.[11] Currently, no study has reported CRP values in a Chinese cohort, nor is it known whether ethnic background alters the relationship between anthropometric measures and CRP.

As BMI, WC, and WHR are routinely used to identify those at increased risk for CVD, understanding the effect of ethnicity and gender on the relationship with various CVD risk factors is essential for effective screening. We have previously reported Chinese origin to be a significant determinant of established CVD risk factors (lipids, insulin, glucose levels).[8] In the current report, we report the effect ethnicity and gender has on the relationship between CRP with BMI, WC, and WHR in men and women of Chinese and European descent.

MATERIALS AND METHODS

Apparently healthy men and women were recruited from hospital staff, students, volunteers, and their friends who answered posted study advertisements. Those over 18 years of age and either of European or Chinese descent (all known ancestors of either European or Chinese origin) were eligible. Individuals were excluded if they had increased abdominal girth not related to increased adiposity (ie, pregnancy, peritoneal dialysis, or ascites). A sample size of convenience was limited to 100 participants of each ethnicity. Participants with previous CVD, taking medications known to affect CRP levels, or using lipid-lowering therapy were excluded from analysis; those with untreated hyperlipidemia or untreated hyperglycemia were not excluded. All participants read and provided informed consent (approved by the Providence Health Care Ethics Committee).

Participants were assessed for BMI, WC, and hip circumference (HC) and provided a fasting blood sample (frozen at −70°C until analyzed) to be analyzed for plasma CRP, total cholesterol (TC), LDL-cholesterol (LDL-C), HDL-cholesterol (HDL-C), and triglycerides (TG). Weight was measured to the nearest 0.1 kg on a balance beam scale without shoes and pockets emptied. Height was measured at the same time to the nearest 0.5 cm. BMI was calculated by dividing weight (kilogram) by height (meter) squared. WC was measured (to the nearest 0.1 cm) over the skin at the point of maximal narrowing of the trunk following a normal expiration. HC was measured (to the nearest 0.1 cm) over undergarments at the point of greatest gluteal protuberance. WHR was calculated by dividing WC by HC. Participants were interviewed regarding medical history, smoking status (smoker or nonsmoker), alcohol consumption (yes or no), medications, activity levels (0, 1, 3, or 5 times per week), hormone replacement therapy

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Table 1. Pearson Correlations Coefficients for Age, BMI, WC, and Transformed CRP Levels for the Entire Cohort and Stratified by Gender and Ethnicity

		Women			Men		
	All (N = 182)	All (n = 99)	European (n = 52)	Chinese (n = 47)	All (n = 83)	European (n = 39)	Chinese (n = 44)
Age	0.17*	0.14	0.17	0.14	0.19	0.40*	0.01
Body mass index	0.44†	0.55†	0.62†	0.35*	0.21	0.17	0.18
Waist circumference	0.43†	0.59†	0.66†	0.40†	0.28*	0.27	0.21
Waist-to-hip ratio	0.17*	0.27†	0.42†	0.16	0.28†	0.26	0.26

*$P < .05$, †$P < .01$.

(HRT) (yes or no) and oral contraceptives (yes or no). Serum CRP was measured using high sensitivity chemi-illuminescence on an Immulite 1, with a sensitivity of 0.2 mg/L. Serum TC, HDL-C, TG, glucose, and insulin were measured using standard procedures in a certified clinical laboratory. LDL-C was calculated using the Friedewald equation.[12]

Due to skewness, CRP and TG were log transformed before statistical analyses. Comparison between ethnicity and gender was made by an independent 2-tailed *t* test. Pearson correlation coefficients were determined for CRP versus age, BMI, WC, HC, and WHR for the entire cohort and stratified by ethnicity and gender. Multiple linear regression analyses were conducted with transformed CRP as the dependent variable and interaction terms derived from pairs between ethnicity or gender with BMI, WC, or WHR as the independent variable. If the interaction term was not a significant predictor, then further regression analyses were performed with either ethnicity or gender and the anthropometric measures as separate independent variables. Adjustment was made for potential confounders (age, smoking status, and alcohol). Data are reported as means and standard deviations except for CRP and TG, which is presented as median and range. Statistics were performed using SPSS version 10.0 (SPSS, Chicago, IL) software with *P* set at .05 for significance.

RESULTS

Eleven participants were excluded as CRP levels were not available, 5 were taking either ASA or lipid-lowering therapy and 2 had pre-existing CVD resulting in 91 European (39 men and 52 women) and 91 Chinese (44 men and 47 women) participants. One participant had diagnosed diabetes and another had elevated blood glucose, as they were not taking hypoglycemic agents, they were included in the analysis. A total of 12 participants reported smoking and 113 reported drinking alcohol. There were no differences in smoking status between the Chinese and European participants or between men and women. Significantly more European participants reported drinking alcohol than Chinese, 88% versus 37%, $P <$ .001, respectively. Over 75% of participants reported being active at least once per week, and 42% reported being active more than 3 times per week. Activity levels were the similar between men and women, but there was a trend for Chinese men and women to be less active than their European counterparts (data not shown). Six women reported using HRT, 13 using oral contraceptives, and 25 were postmenopausal. The proportion of women using either HRT or oral contraceptives was similar between the Chinese and European women as was the proportion of postmenopausal women.

Table 1 shows the Pearson correlation coefficients for CRP with age, BMI, WC, and WHR for the entire cohort and stratified by ethnicity and gender. BMI and WC were strongly correlated with CRP levels, while age and WHR were only weakly correlated with CRP levels for the entire cohort. BMI and WC were strongly correlated with CRP in women regardless of ethnicity.

Chinese women had significantly lower BMI, WC, HC, and CRP levels than European women (Table 2). Levels of CRP were no longer significantly different between Chinese and European women after adjustment for either BMI or WC. Chinese men had significantly lower BMI, WC, HC, and WHR than European men. European women had significantly lower WC and WHR and greater HC than European men, while age, BMI, and CRP were similar. Chinese women had significantly lower WC and WHR and were older than Chinese men, while HC, BMI, and CRP were similar.

When combined, Chinese men and women had significantly lower CRP levels compared with European men and women: median 0.36 mg/L (range, 0.11 to 20.20) versus 0.69 mg/L (range, 0.11 to 9.91) $P < .05$, respectively). Ethnicity did not interact with BMI, WC, or WHR to predict CRP levels when stratified by gender or for the entire cohort combined. In

Table 2. Age, Anthropometry, and CRP Levels Stratified by Gender Within Each Ethnic Group

	European		Chinese	
	Women (n = 52)	Men (n = 39)	Women (n = 47)	Men (n = 44)
Age	41.0 ± 11.4	38.9 ± 9.9	41.6 ± 13.5	34.8 ± 11.1
BMI (kg/m^2)	27.1 ± 5.8	25.6 ± 3.8	23.1 ± 3.0†	23.4 ± 2.9†‡
Waist circumference (cm)	82.2 ± 12.5	89.3 ± 9.9§	74.4 ± 7.2†	80.2 ± 7.3†‖
Hip circumference (cm)	106.3 ± 10.6	99.9 ± 5.6‖	95.0 ± 6.3†	93.7 ± 5.2†
Waist-to-hip ratio	0.77 ± 0.07	0.89 ± 0.07‖	0.78 ± 0.05	0.85 ± 0.05*‖
Median CRP (mg/L) (range)	0.72 (0.17 to 9.91)	0.63 (0.11 to 7.25)	0.33 (0.11 to 8.79)*	0.36 (0.12 to 20.20)

*$P < .01$, †$P < .001$ compared with European counterparts of same gender (independent samples *t* test). ‡$P < .05$, §$P < .01$, ‖$P < .001$ compared with women of same ethnicity (independent samples *t* test).

Table 3. Age, Anthropometry, and CRP Levels of the Entire Cohort Stratified by Either Ethnicity or Gender

	Gender	
	Women (n = 99)	Men (n = 83)
Age	41.3 ± 12.4	36.7 ± 10.7*
BMI (kg/m^2)	25.2 ± 5.1	24.4 ± 3.5
Waist circumference (cm)	78.5 ± 11.0	84.5 ± 9.7†
Hip circumference (cm)	101.0 ± 10.4	96.6 ± 6.2†
Waist-to-hip ratio	0.78 ± 0.06	0.87 ± 0.06†
Median CRP (mg/L) (range)	0.44 (0.11 to 9.91)	0.48 (0.11 to 20.20)
Total cholesterol (mmol/L)	4.33 ± 0.87	4.20 ± 0.82
LDL-C (mmol/L)	2.29 ± 0.78	2.43 ± 0.73
HDL-C (mmol/L)	1.58 ± 0.32	1.25 ± 0.23†
Median triglycerides (mmol/L) (range)	0.83 (0.39 to 3.99)	1.02 (0.28 to 3.45)

*$P < .01$, †$P < .001$ compared with women (independent samples *t* test).

addition, BMI, WC, and HC were lower in the Chinese men and women (data not shown). Ethnicity was not a significant predictor of CRP levels after adjusting for either BMI or WC, but was a significant predictor independent of WHR after adjusting for age, smoking status, and alcohol in women only.

As ethnic background was not a predictor of CRP levels independent of BMI or WC, the results of men and women were combined and analyzed across gender (Table 3). Men were significantly younger, had higher WC and WHR and lower HC and HDL-C than women, but similar CRP levels. There were no differences in CRP levels between women using HRT or oral contraceptives and those who were not (data not shown). Postmenopausal women had significantly higher CRP levels than those who were not: median 0.95 mg/L (range, 0.22 to 8.79) versus 0.41 mg/L (range, 0.11 to 9.91) $P < .05$. However, this was no longer significant after adjusting for either BMI or WC.

Figure 1 displays the relationship between the anthropometric measures and CRP levels stratified by gender. The interaction between gender and WC was a significant predictor of CRP levels ($P < .05$). The interaction remained significant after adjusting for age, smoking status, and alcohol. The 2 gender curves intersected at approximately 70 cm and beyond this value, women had higher CRP levels than men. Neither the gender/BMI or gender/WHR interaction was a significant predictor of CRP levels. Both BMI ($P < .001$) and WHR ($P < .01$) were predictors of CRP levels independent of gender, age, smoking status, and alcohol.

DISCUSSION

This is the first investigation comparing CRP levels in a group of healthy Chinese men and women to those of European origin. BMI and WC were strongly correlated with CRP levels in Chinese women, but not men. We found CRP levels to be significantly lower in Chinese than European men and women, however this difference was no longer significant after adjusting for either BMI or WC. After adjustment for WHR, CRP levels remained lower in the Chinese men and women independent of age, smoking status, and alcohol. This is explained by lower WC and HC in the Chinese participants yet similar WHR to the Europeans.

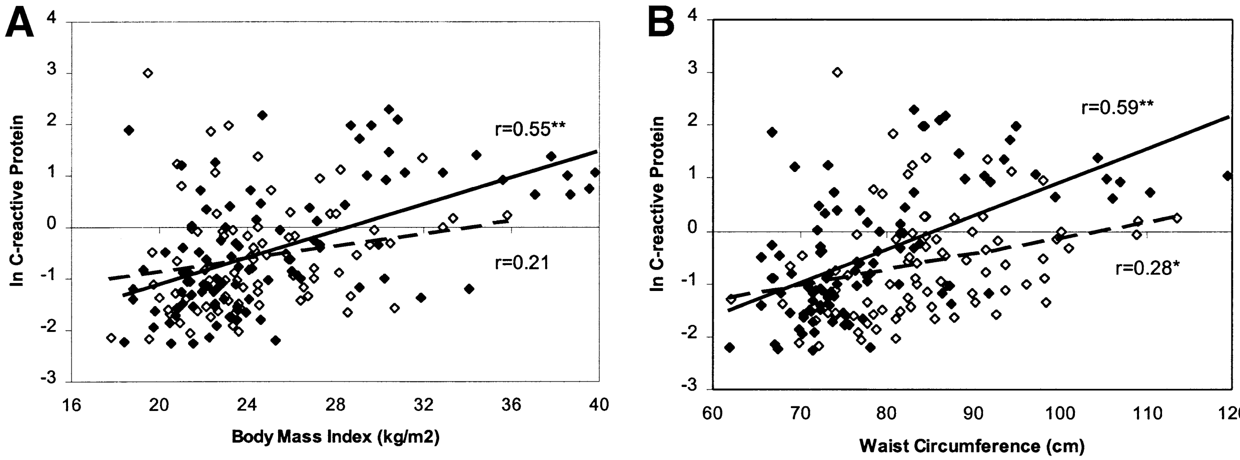
These findings are in contrast to earlier reports implicating ethnicity as a significant predictor of lipids, blood glucose, and insulin after adjusting for WC.[8-11] This has led to the suggestion that BMI and WC targets should be lower for Chinese men and women to minimize CVD risk. Even though CRP levels were correlated with BMI, WC, and WHR, ethnic background did not appear to modify this relationship as it does with other CVD risk factors.

As ethnic background reflects both environmental and physiologic differences, differences in lifestyle must be considered. Smoking status, HRT, and oral contraceptives use, potential confounders of CRP levels, were no different between the Chinese and European participants. Despite greater active alcohol consumption in Europeans, adjustment by alcohol did not affect the difference in CRP levels between the 2 ethnic groups. These results indicate that the observed differences in CRP levels can be attributed to differences in BMI or WC, indicators of body fat. While no other study has reported CRP levels in those of Chinese descent, CRP levels between men of European and South Asian descent were no longer significantly different after adjustment for differences in WHR.[13]

Comparison across gender indicated a stronger association of CRP levels with BMI and WC in women than men, accounting for 30% and 35% of the variance, respectively. Gender significantly interacted with WC to predict CRP levels such that the slope for this relationship was steeper in women than in men. The interaction remained significant after adjusting for age, smoking status, and alcohol. Based on these results, a WC beyond approximately 70 cm was associated with higher levels of CRP in women than in men. Gender was an independent predictor of CRP levels after adjusting for WHR, age, smoking status, and alcohol, indicating that at a given WHR, women have higher CRP levels than men.

While a number of reports have described the relationship between BMI and/or WC and CRP,[5,6,14,15] only 2 previous studies have directly compared CRP levels in men and women to address the effect of gender.[3,7] McConnell et al[7] reported CRP levels were higher in women than men independent of age, but failed to take into account differences in anthropometric measures. Visser et al[3] observed a greater proportion of women than men with elevated CRP levels when stratified by BMI. However, CRP values were not reported, and the impact that BMI had on CRP levels between genders was not characterized.

Our observations may be explained by women having a



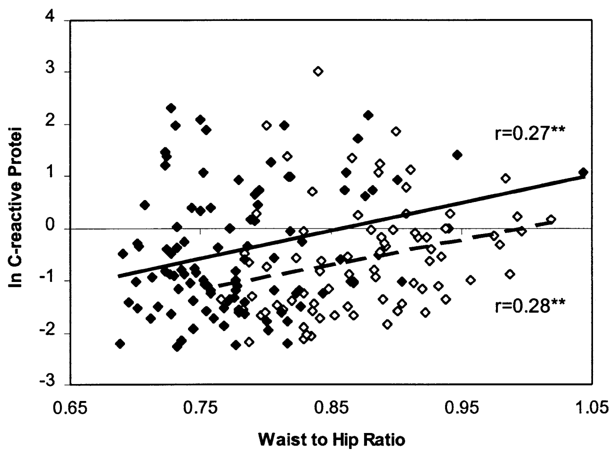


Fig 1. Comparison of the relationship of transformed CRP levels with BMI, WC, and WHR stratified by gender (women, ● and solid line; men, ○ and dashed line). *$P < .05$,$P < .01$ for Pearson correlation coefficients.**

higher percent body fat compared with men at a given BMI.[16] As the strong association between CRP levels and BMI is speculated to be due to interleukin (IL)-6 released from adipocytes, which promote CRP production by the liver,[17] excess body fat in women at a given BMI may account for the higher CRP levels. However, the gender-BMI interaction was no longer a significant contributor after adjustment for differences in age. In contrast, the gender-WC interaction remained a significant predictor of CRP levels after adjusting for known confounders. As with BMI, our cohort of women likely has a higher percent body fat than men for a given WC. In addition, differences in WC are invariably due to changes in body fat, while BMI does not discriminate between differences in muscle, bone, or body fat. A point supported by the slightly stronger correlations of WC with CRP levels than BMI.

A number of studies have indicated that women using HRT have higher CRP levels than age-matched counterparts.[5,18] In our results, we did not find a difference in CRP levels between the women taking oral contraceptives or HRT compared with those who were not.

A number of possible limitations of this study exist that must be addressed. First, we have drawn conclusions between body fat accumulation and CRP levels based on anthropometric measures that do not exclusively assess body fat. Previous reports, however, have found BMI and WC to have similarly strong correlations with CRP levels than direct measures of body fat, such as dual energy x-ray absorptiometry and computed tomography scans.[5,6,14] Lemieux et al[15] reported that correlations with CRP were stronger for WC and BMI than measures of visceral adipose tissue, but not as strong as total fat mass in men, such that those with the highest WC or BMI had the highest CRP levels. As BMI and WC are routinely used in clinical settings for identifying individuals at increased CVD risk, it is important to determine potential confounders to ensure proper screening methods. Second, our study population was recruited from hospital staff, students, and volunteers and therefore, may be subject to a healthy volunteer bias. However, this should not affect the internal validity of the study. In addition, the anthropometric values of both the Chinese and European cohorts are similar to those reported in previous populations of a similar age,[19,20] and our previous report of this cohort indicated that other CVD risk factors were consistent with reported norms.[8] Third, these comparisons were made with a relatively small sample size, and confirmation of these findings is needed in a larger sample. Fourth, as this is a cross-sectional study, we cannot address whether the observed phenomenon also relates to changes in body fat accumulation over time.

Unlike other CVD risk factors, ethnicity does not appear to modify the relationship between BMI, WC, or WHR with CRP levels. We found gender to be a significant modifier, such that women with elevated WC had the highest CRP levels and may be at greater risk for CVD. Based on this relationship with CRP, women should maintain a lower WC than men. Indeed, long-term epidemiologic studies suggest this and recommend that women have a lower WC target than men.[21,22]

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