ANTHROPOMETRIC CORRELATES OF METABOLIC SYNDROME COMPONENTS IN A DIVERSE SAMPLE OF OVERWEIGHT/OBESE WOMEN

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Objective: The purpose of this study was to determine the relationship between body mass index (BMI), waist circumference, and waist-to-hip ratio (WHR) with cardiometabolic variables that reflect the metabolic syndrome in overweight/obese premenopausal White, African American, and Hispanic women.

Methods: Two hundred and thirty four young overweight/obese women enrolled in a weight loss program were recruited for this study. Analysis of variance was used to compare means among groups, and multiple regression analyses were used to determine the relationship between anthropometric measurements and cardiometabolic variables, after controlling for age.

Results: In both White and African American women, BMI was significantly related to systolic blood pressure and diastolic blood pressure, while in Hispanic women, BMI failed to predict any cardiometabolic variables. Using waist circumference afforded the additional prediction of high density lipoprotein cholesterol ($P=.017$) and triglycerides in White women and serum glucose in African American women. In Hispanic women, waist circumference significantly predicted serum glucose. WHR was the strongest predictor of metabolic syndrome components in White women; however, it failed to predict any cardiometabolic variables in Hispanic women.

Conclusions: Both waist circumference and WHR were better correlates of metabolic syndrome components than was BMI. While WHR appeared optimal for predicting components of the metabolic syndrome in White women, our findings showed that waist circumference was the most global anthropometric indicator of metabolic syndrome components in a diverse racial and ethnic sample of overweight/obese women. (*Ethn Dis*. 2008;18:163–168)

Key Words: Obesity, Fat Distribution, Metabolic Syndrome, Health Risk, Minority Women

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INTRODUCTION

An estimated $117 billion is spent treating overweight and obesity[1] in the United States, and an estimated 112,000 US adult deaths are related to obesity each year.[2] Furthermore, the prevalence of obesity is highest among minorities in the United States; African American and Hispanic women have the highest rates.[3]

The distribution of body fat rather than total adiposity, however, may be more relevant in predicting a clustering of cardiometabolic variables. These include increased fasting glucose, blood pressure, triglycerides, and decreased high-density lipoprotein (HDL) cholesterol, collectively known as metabolic syndrome.[5] Thus, body mass index (BMI), which is used as a surrogate measure of adiposity, may not be as closely related to components of the metabolic syndrome as a more central obesity pattern.[6]

The National Cholesterol Education Program (NCEP)[7] favors use of waist circumference (WC) as a metabolic syndrome component, while the World Health Organization[8] uses either BMI, WC, or waist-to-hip ratio (WHR) to identify risk factors for metabolic syndrome. Using NCEP guidelines, the prevalence rates of those with metabolic syndrome have been steadily rising,[9] are greater in older populations,[9] and in minority women.[3] To further extend the utility of fat distribution measures in relation to metabolic syndrome components, we must examine this relationship in different racial and ethnic populations. Since overweight and obese women constitute a population who may be at greater health risk in the future,[10] this is an important group to target for further study.

The purpose of this study was to examine the relationship between anthropometric variables (BMI, WC, and WHR) and cardiometabolic variables that reflect the metabolic syndrome in overweight/obese premenopausal White, African American, and Hispanic women.

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SUBJECTS AND METHODS

Subjects

All participants were apparently healthy premenopausal women free from known coronary heart disease, diabetes, hypertension, or metabolic disease. Women taking oral contraceptives, hormones, or any medication that would affect serum lipids and lipoproteins, blood pressure, or carbohydrate metabolism were excluded from the study. All medical records were obtained, and information was abstracted from participants in a larger program designed to evaluate the effects of a very low calorie diet on weight loss. All women were required to have a BMI

≥25 kg/m^2. Demographic information, including race, was self-reported.

Most Hispanic subjects were from Cuba, and the rest were from Venezuela, Columbia, and Puerto Rico. All participants were fluent in English, since patient forms were completed in English only. During the course of three years, 650 women were enrolled in the weight loss program. The final data collection and analysis included 234 premenopausal women: 105 White (44.9%), 90 African American (38.5%), and 39 Hispanic (16.7%) women. Major reasons for the reduced number of participants in this analysis included postmenopausal status, use of hormones, use of medications excluded for this study, or failure to provide complete medical information. Eligible participants completed consent forms, and all testing procedures were conducted in accordance with the protocol set forth and approved by the Office of Research Standards at the University of Miami.

Physical and Anthropometric Measures

Body weight was measured to the nearest 0.1 kg with the subjects dressed in light clothing and no shoes. Body height was measured to the nearest 0.5 cm with a wall-mounted stadiometer. WC was measured midway between the lower rib and iliac crest, whereas hip circumference was measured at the outermost points of the greater trochanters;[11] WHR was the ratio calculated between these two circumferences. All anthropometric measurements were performed by the same technician, who recorded the mean of two measurements to the nearest 0.5 cm.

Subjects' systolic and diastolic blood pressures (SBP and DBP, respectively) were taken from the left upper arm by trained personnel with a mercury sphygmomanometer and stethoscope. All measurements were recorded after participants had been seated for ≥5 minutes, in accordance with the recommendations outlined by the American Heart Association.[15] Duplicate measurements were taken after a 5-minute interval, and mean values were recorded. All measurements were recorded to the nearest 1.0 mm Hg.

All blood sampling was performed as part of the initial medical examination. One venous sample was taken from all participants after an overnight fast. Serum lipids were measured according to a standardized protocol reported by the Lipid Research Clinic Program.[12] Total cholesterol was measured accordingly, after several enzymatic steps. HDL cholesterol was measured in the supernatant fraction of serum after removal of low-density lipoprotein (LDL) cholesterol and very low-density lipoprotein (VLDL) cholesterol by precipitation with heparin and manganese chloride.[13] Triglyceride concentrations were determined enzymatically after treatment with a lipase and subsequently measuring glycerol release,[14] while VLDL cholesterol was estimated by dividing the triglyceride level by five. The LDL cholesterol level was calculated by subtracting HDL and VLDL levels from total cholesterol.[12] The cardiac risk ratio was obtained after dividing total cholesterol by HDL.

Fasting glucose levels were determined spectrophotometrically at a wavelength of 340 nm by using a hexokinase reaction developed by Roche (Roche Diagnostic System, Nutley, NJ).

Statistical Analyses

The Statistical Package for the Social Sciences (SPSS) for Windows version 10.0 was used for all statistical analyses.[16] Descriptive statistics (means, standard deviations) were calculated to describe characteristics of the study sample. Natural log transformations were performed on triglyceride and glucose values to achieve normality of distribution. Since normality of distribution could not be obtained for serum glucose, nonparametric (Kruskal-Wallis) tests were performed. Results for glucose were the same using either Kruskal-Wallis tests or log transformation. Thus, log-transformed data were presented for both glucose and triglyceride analyses. Analysis of variance for the total sample was performed to determine whether significant differences existed in anthropometric measurements, serum lipids, lipoproteins, glucose, and blood pressure among the three racial/ethnic groups. If significance was found, Tukey's post hoc test with a Bonferroni adjustment was used to determine where significance occurred. Multiple regression analyses were conducted to examine the relationship between anthropometric measures (BMI, WC, WHR) and metabolic syndrome components using NCEP guidelines. This was done for the entire sample and by race/ethnicity. Since age was significantly different among groups and significantly related to several cardiometabolic variables, all multiple regression analyses were conducted after controlling for age. An α level of .05 was used to denote significance.

RESULTS

White women in our study were significantly older than both African American and Hispanic women (Table 1). Hispanic women had a significantly higher BMI than both White and African American groups. Hispanic women also had a significantly higher WC and WHR than did African American women; White women were somewhere in the middle and had no significant differences from the other two groups. Three percent of the sample had HDL cholesterol values <35 mg/dL, 22.6% had triglyceride levels >150 mg/dL, and 9.8% had glucose levels ≥110 mg/dL, which is consistent with impaired glucose tolerance. A total of 16.7% of women in our sample had SBP ≥130 mm Hg and DBP ≥85 mm Hg. Since the mean WC exceeded 0.88 in each group, many of our

Table 1. Characteristics of a sample of overweight/obese White, African American, and Hispanic women (all values are mean±standard deviation)

Variable	Total Sample (*N*=234) Mean±s.d.	White (*n*=105) Mean±s.d.	African American (*n*=90) Mean±s.d.	Hispanic (*n*=39) Mean±s.d.	*P* value*
Age (years)	37.6±7.8	39.7±7.6[a]	36.6±7.9	34.1±6.8	<.001
BMI (kg/m^2)	35.3±6.4	35.1±6.7	34.1±5.6	38.8±6.2[b]	<.001
Waist (cm)	94.2±14.8	95.2±15.0	90.8±14.4	99.3±13.9[c]	.007
WHR	.85±.07	.85±0.0	0.83±0.0	.8±.1[c]	.008
Total cholesterol (mg/dL)	197.9±39.7	198.4±36.0	199.7±43.6	192.7±40.0	.652
HDL cholesterol (mg/dL)	53.7±11.8	53.6±13.1	52.5±10.8	56.4±10.2	.234
LDL cholesterol (mg/dL)	117.1±35.5	117.4±33.4	120.2±38.1	108.6±34.4	.232
Glucose (mg/dL)	95.3±29.4	92.1±13.6	99.2±44.4	95.0±18.1	.318
Triglyceride (mg/dL)	114.3±60.7	123.1±64.1	110.7±61.4	98.5±44.6	.075
SBP (mm Hg)	123.1±16.1	125.1±14.9	119.8±14.0	125.1±22.2	.025
DBP (mm Hg)	80.1±9.3	80.1±9.0	79.7±9.2	80.8±10.8	.837

BMI=body mass index, WHR=waist-to-hip ratio, HDL=high-density lipoprotein, LDL=low-density lipoprotein, SBP=systolic blood pressure, DBP=diastolic blood pressure.

* Derived from analysis of variance conducted across groups.

Tukey's post hoc test for significant *P* values

Notes:

White women>African American and Hispanic women, *P*≤.01.

Hispanic women>African American and White women, *P*≤.001.

Hispanic women>African American women, *P*=.004.

subjects already possessed multiple components of the metabolic syndrome. Furthermore, 30.3% had LDL cholesterol values >130 mg/dL which exceeds recommendations for those with preexisting risk factors.[17]

For the total sample, BMI significantly predicted 2.0%–7.6% of the variance for serum glucose, TG, and BP (Table 2). In White women, SBP and DBP were the only cardiometabolic variables significantly predicted by BMI, accounting for 4%–6% of the variance in blood pressure. In African American women, BMI significantly predicted 7%–11% of the variance in SBP and DBP. In Hispanic women, no components of the metabolic syndrome were predicted by BMI.

Table 2. Significant cardiometabolic variables predicted by body mass index, after adjusting for age, in a sample of overweight/obese White, African American, and Hispanic women

Cardiometabolic Variables	*B*	SE	Partial *r*	Partial r^2	*P* value
Total Sample (*N*=234)					
SBP	.476	.161	.191	.036	.004
DBP	.395	.091	.276	.076	<.00
Glucose*	2.289	.001	.162	.026	.002
Triglyceride*	4.522	.002	.142	.020	.030
White (*n*=105)					
SBP	.449	.217	.201	.040	.041
DBP	.330	.128	.247	.061	.011
African American (*n*=90)					
SBP	.648	.252	.266	.071	.012
DBP	.506	.158	.325	.106	.002
Hispanic (*n*=39)	-	-	-	-	-

SE=standard error, SBP=systolic blood pressure, DBP=diastolic blood pressure.

* Natural log transformation performed.

For the total sample, WC significantly predicted 3.8% and 6.2% of the variance for serum glucose and triglyceride, respectively, while accounting for 5.8% and 12.2% of the variance in SBP and DBP, respectively (Table 3). In White women, WC significantly predicted HDL and triglyceride as well as SBP and DBP. In African American women and in addition to blood pressure, WC significantly predicted serum glucose, accounting for >7% of its variance. In Hispanic women, waist significantly predicted >17% of the variance in serum glucose.

For the entire sample, WHR significantly predicted 4.0%–7.8% of the variance in serum glucose, triglyceride, HDL cholesterol, SBP, and DBP. In both White and African American women, WHR significantly predicted the same variables as WC. In contrast, for Hispanic women, WHR failed to predict any cardiometabolic variables.

DISCUSSION

We examined anthropometric correlates of cardiometabolic variables associated with the metabolic syndrome in a diverse sample of overweight/obese premenopausal women. We found that 40.2% of our apparently healthy sample had at least two cardiometabolic variables associated with coronary heart disease risk, and 26.9% satisfied NCEP criteria for the metabolic syndrome.[7]

We found that 40.2% of our apparently healthy sample had at least two cardiometabolic variables associated with coronary heart disease risk

Table 3. Significant cardiometabolic variables predicted by waist circumference, after adjusting for age, in a sample of overweight/obese White, African American, and Hispanic women

Cardiometabolic Variables	*B*	SE	Partial *r*	Partial r^2	*P* value
Total Sample (*N*=234)					
SBP	.262	.069	.241	.058	<.001
DBP	.218	.038	.350	.122	<.001
Glucose*	1.206	<.001	.196	.038	.005
Triglyceride*	3.460	.001	.250	.062	<.001
White (*n*=105)					
SBP	.223	.097	.222	.049	.023
DBP	.197	.056	.328	.108	.001
HDL cholesterol	−.201	.083	−.234	.055	.017
Triglyceride*	.005	.001	.351	.123	<.001
African American (*n*=90)					
SBP	.394	.093	.415	.172	<.001
DBP	.267	.059	.440	.194	<.001
Glucose*	.002	.001	.271	.073	.021
Hispanic (*n*=39)					
Glucose*	.002	.001	.415	.172	.010

SE=standard error, SBP=systolic blood pressure, DBP=diastolic blood pressure, HDL=high-density lipoprotein.
* Natural log transformation performed.

Other than the ability to predict BP in White and African American women, BMI was not a useful predictor of variables associated with metabolic syndrome. Even after pooling the entire sample, BMI contributed to <3% of the variance in serum glucose and triglyceride. Thus, the clinical utility of using BMI in this sample was limited. Furthermore, use of BMI failed to assess any components of the metabolic syndrome in Hispanic women.

Table 4. Significant cardiometabolic variables predicted by waist-to-hip ratio, after adjusting for age, in a sample of overweight/obese White, African American, and Hispanic women

Cardiometabolic Variables	*B*	SE	Partial *r*	Partial r^2	*P* value
Total Sample (*N*=234)					
SBP	53.442	13.502	.253	.064	<.001
DBP	33.983	7.683	.280	.078	<.001
HDL cholesterol	–34.927	10.050	–.223	.049	.001
Glucose*	.295	.082	.246	.060	<.001
Triglyceride*	.581	.173	.216	.046	.001
White (*n*=105)					
SBP	52.67	19.46	.260	.068	.008
DBP	33.58	11.54	.276	.076	.005
HDL cholesterol	–73.87	15.52	–.426	.181	<.001
Triglyceride*	1.057	.24	.390	.152	<.001
African American (*n*=90)					
SBP	74.01	21.79	.344	.118	.001
DBP	48.15	13.88	.350	.123	.001
Glucose*	.604	.227	.302	.091	.010
Hispanic (*n*=39)	-	-	-	-	-

SE=standard error, SBP=systolic blood pressure, DBP=diastolic blood pressure, HDL=high-density lipoprotein.
* Natural log transformation performed.

In contrast, measures of central obesity, including WC and WHR, added substantial information to the prediction of the metabolic syndrome. For the entire sample and for each group, WC intensified the prediction of metabolic syndrome components compared to BMI. In White women, WC significantly predicted SBP, DBP, the cardioprotective HDL, and triglycerides, all of which can help predict coronary heart disease[18] and metabolic syndrome.[4–5,7] In African American women, WC accounted for more than 17%–19% of the variance in SBP and DBP, respectively, an amount considerably greater than that predicted by BMI. In addition, WC significantly predicted serum glucose, another key component of the metabolic syndrome.[4–5] Given the fact that diabetes is 2.4-fold greater in African American women than in White women,[19] the use of WC rather than BMI alone takes on added clinical significance. Finally, WC was the only anthropometric variable that predicted fasting glucose in Hispanic women. Since diabetes is the fourth leading cause of death in Hispanic women, who have a twofold greater complication rate and an earlier age of onset than does any other group,[20] this finding is clinically relevant for Hispanic women.

In support of previous research, WC more clearly defines central or intra-abdominal fat.[10,21,22] This fact may have accounted for its stronger relationship with cardiometabolic variables that reflect the metabolic syndrome. Thus, it is not surprising that in comparison to BMI, WC provided more clinically useful information in predicting components of the metabolic syndrome.

For the entire sample, it appeared that WHR was more closely related to serum lipids and lipoproteins than was WC. Furthermore, WHR was also the only variable to predict the total cholesterol/HDL cholesterol cardiac risk ratio for the total sample (r=.199, P=.002). Upon further analysis, how-

ever, these findings were driven by the stronger relationship between WHR and cardiometabolic variables in White women and the greater number of White participants in the total sample.

Interestingly, WHR predicted the same variables as WC in White and African American women. However, in White women, WHR accounted for three times the variance in the cardioprotective HDL and a considerably greater amount of variance in triglycerides and SBP than WC. Hartz et al[23] indicated WHR to be the best predictor of coronary risk factors independent of obesity in White women. In Australian women, WHR was also found to be most closely related to coronary risk factors.[24] Although WHR is not as strong a measure as WC for quantifying abdominal adipose tissue, it is also not as highly correlated with BMI as WC is. Thus, WHR could add to the strength of BMI and WC in its relationship with cardiometabolic variables in White women.

The correlation between WC and BMI has been reported to lie between $r = .84–.88$.[22] In our study, the relationship between WC and BMI was weaker than typically observed ($r=.679$). However, the association between WC and WHR was higher than expected ($r=.653$, $P<.001$). Thus, it is not surprising that both WC and WHR had a significant relationship with the same variables in White and African American women and both were better predictors than BMI of variables that make up metabolic syndrome.

WHR failed to predict any cardiometabolic variables in Hispanic women. Since these women also had the highest BMI and the highest levels of central obesity, researchers must find better anthropometric surrogates of health risk in Hispanic women of Cuban and South American descent. While WC appeared to be the optimal anthropometric measure for use in Hispanic women, WHR appeared to be the most favorable anthropometric measure for use in White women. In a diverse group of young overweight/obese women, our results clearly favored either measure of fat distribution above that of BMI.

Given these findings, certain limitations should be noted. First, subjects were limited to women willing to pay for a weight loss program. Women who were taking medications that would affect metabolic syndrome components or using hormones were excluded from the data analysis, which may have skewed the sample. White women were older, while Hispanic women had greater BMI, WC, and WHR. Although adjustments were made for variations in age, differences in subject characteristics may have influenced significant relationships reported and may have obscured relationships that were not observed. Thus our findings may not be applicable to the overweight/obese population at large. Although only 36% of the entire sample were included in the final analysis, the relative percentage of eligible White, African American, and Hispanic women remained similar to the racial/ethnic composition of participants in the weight loss program. The significantly lower number of Hispanic women represents a more significant concern. Hispanic women may constitute a group of women less interested in entering a weight loss program. Since the program was conducted entirely in English, this may have presented a sampling bias.

We did not evaluate acculturation. Although all women were required to understand and speak English to participate in the study, acculturation status is significantly related to obesity and health risk in the United States.[25] Furthermore, this was a cross-sectional study, and all measurements were taken at one time point. Limited conclusions may be drawn from relationships observed at a single point in time in cross-sectional studies.

Within the context of these limitations, WC and WHR were better predictors of metabolic syndrome components than was BMI. Furthermore, clinically relevant differences by race/ethnicity were found in anthropometric correlates of metabolic syndrome components. WHR provided more valuable information regarding risk factors for coronary heart disease and metabolic syndrome in White women. In contrast, WC provided a broader, more global assessment of metabolic syndrome components in a diverse racial and ethnic sample of overweight/obese women. Since these anthropometric indices are relatively quick, easy, and inexpensive to perform, clinicians should take the time to routinely measure them in the assessment of health risk.

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AUTHOR CONTRIBUTIONS

Design concept of study: Perry
Acquisition of data: Perry, Wang, Kuo
Data analysis and interpretation: Perry, Wang, Kuo
Manuscript draft: Perry, Wang, Kuo
Statistical expertise: Wang, Kuo
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