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Waist Circumference Correlates with Metabolic Syndrome Indicators Better Than Percentage Fat

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Abstract

Objective—Percent fat is often considered the reference for establishing the magnitude of adipose tissue accumulation and the risk of excess adiposity. However, the increasing recognition of a strong link between central adiposity and metabolic disturbances led us to test whether waist circumference (WC) is more highly correlated with metabolic syndrome components than percent fat and other related anthropometric measures such as BMI.

Research Methods and Procedures—BMI, WC, and percent fat, measured by DXA, were evaluated in 1010 healthy white and African-American men and women [age, 48.3 ± 17.2 (standard deviation) years; BMI, 27.0 ± 5.3 kg/m^2]. The associations of BMI, WC, and percent fat with age and laboratory-adjusted health risk indicators (i.e., serum glucose, insulin, triglycerides, high-density lipoprotein cholesterol, blood pressure) in each sex and ethnicity group were examined.

Results—For 18 of 24 comparisons, the age- and laboratory-adjusted correlations were lowest for percent fat and in 16 of 24 comparisons were highest for WC. Fifteen of the between-method differences reached statistical significance. With health risk indicator as the dependent variable and anthropometric measures as the independent variable, the contribution of percent fat to the WC regression model was not statistically significant; in contrast, adding WC to the percent fat regression model did make a significant independent contribution for most health risk indicators.

Discussion—WC had the strongest associations with health risk indicators, followed by BMI. Although percent fat is a useful measure of overall adiposity, health risks are best represented by the simply measured WC.

Keywords

anthropometrics; BMI; DXA; body composition; health risk indicators

Introduction

The prevalence of obesity has reached epidemic levels worldwide, and the related health risks of excess adiposity are well recognized by the medical community (1,2). An important question

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that has not been fully answered is how best to quantify excess adiposity from the perspective of patient risk for obesity-related diseases.

The current NIH and World Health Organization's BMI ranges now in use were developed empirically to capture varying levels of morbidity and mortality risk (3,4). BMI has been criticized as a limited measure of total adiposity, particularly at the individual level (5). Accordingly, the sensitivity and specificity of BMI ranges in children and adults are often judged using percentage fat as the reference (6–8).

Although there is little challenge to the notion that percent fat is an excellent measure of relative adiposity and energy stores, increasing attention is focusing on the identification of clinically useful measures of patient risk, particularly for cardiovascular disease and diabetes. Many studies now show a link between central adiposity, notably visceral adipose tissue, and an increased risk of metabolic disturbances, morbidity, and mortality (9–13). In contrast, some large-scale studies suggest that peripheral fat depots are negatively associated with some health risk factors and are, thus, "protective" of weight-related conditions such as cardiovascular disease (14–18). These and other related observations suggest that percent fat, a global measure of adiposity, may not optimally reflect health risks among the available clinical measures.

Specifically, waist circumference (WC)1 provides a simple and practical anthropometric measure for assessing central adiposity (19–21), and an increasing number of studies are reporting strong associations between WC, visceral adipose tissue, and obesity-related health risks (22,23). Recently, it has been reported that WC is a better predictor of metabolic abnormalities than percent fat measured by bio-impedance method in elderly whites (24). In another study, waist-to-hip ratio has been shown to be a better predictor of health risks than percent fat in Japanese subjects (25). It is important to further test whether WC is a better anthropometric marker than accurately measured percent fat for adiposity-related health risks in different ethnic groups. Confirmation of this hypothesis would provide the obesity research community and the public with additional support for the use of a simple and inexpensive measuring tape to estimate a subject's weight-related health risks.

The aim of this study was to compare the strengths of the associations between three anthropometric measures, WC, BMI, and percent fat, with health risks centered on insulin resistance and the metabolic syndrome including serum lipid, insulin, and glucose levels and blood pressure in white and African-American men and women.

Research Methods and Procedures

Protocol and Subjects

The primary study aim was to evaluate the associations between BMI, WC, and percent fat with fasting serum insulin levels along with four metabolic syndrome components as defined by the Adult Treatment Panel III (26): serum glucose, triglycerides (TGs), high-density lipoprotein (HDL)-cholesterol, and systolic blood pressure (SBP) and diastolic blood pressure (DBP).

Subjects were healthy adults, >18 years of age, who completed a screening medical history, physical examination, and blood studies. Race/ethnicity was established in each subject by self-report and included whites and African Americans. Subjects who had a fasting serum glucose >140 mg/dL, serum TGs >400 mg/dL, SBP >180 mm Hg, DBP >110 mm Hg, or serum insulin >40 μIU/mL were excluded from participation. Specific lipid, insulin/glucose, and blood pressure values were excluded from analysis in patients treated with lipid-, glucose-, and blood pressure–lowering pharmacological agents, respectively. Weight, height, and body composition were evaluated on the same day as the screening examination.

Data from three sites were combined to produce the final study database: Obesity Research Center, St. Luke's-Roosevelt Hospital in New York (NYORC), University of Alabama at Birmingham (UAB), and Kaiser Permanente Northern California (KPNC), Oakland, CA. The NYORC data included two chronologically separated studies: one carried out between 1990 and 1995 and the other between 1995 and 2003 (n = 316 and 430, respectively) (27,28). The remaining data were from healthy control participants in the study of Fat Redistribution and Metabolic Change in HIV Infection (FRAM). These control participants were recruited from the UAB and KPNC sites (n = 287) of the study of Coronary Artery Risk Development in Young Adults (CARDIA) (29). All three sites evaluated white and African-American subjects.

Body Composition

Anthropometric Measurements—Body weight was measured to the nearest 0.1 kg and height to the nearest 0.1 cm using calibrated scales and stadiometers. BMI was calculated as weight divided by height squared. WC was measured by trained observers between the lower rib margin and the iliac crest (30), with subjects standing with their heels together. Subjects wore a hospital gown or a short sleeve shirt or blouse, shorts, socks, and no shoes. All staff were trained and certified for measurements.

DXA—DXA was used to estimate total body fat mass and percent fat. Two DXA systems were used as follows: NY-ORC, DPX (GE Lunar, Madison, WI) with software version 4.7e; CARDIA, QDR 2000 (Hologic, Bedford, MA) with software version 11.1. All scans were acquired by trained technologists and read at NYORC. The intraclass correlation coefficient for percent fat estimation by DXA was 0.994 with a between-measurement coefficient of variation of 3.3% (31). All systems were routinely calibrated, and quality control measures were followed as recommended by the respective manufacturers.

Blood Studies

Serum glucose, lipids (total cholesterol, TG, and HDL-cholesterol) and insulin levels were evaluated at Center for Disease Control–certified chemistry laboratories (NYORC: Hospital Laboratory, Quest Diagnostics, Teterboro, NJ; CARDIA: Covance, Princeton, NJ).

Blood Pressure Measurement

The procedure for measuring blood pressure varied according to research study centers. The procedures of the CARDIA study have been described previously (32). The blood pressure measurement at the NYORC site was taken with a sphygmomanometer on the right arm after a 5-minute rest.

Statistical Methods

Regression equations were calculated with each of the risk factors (serum glucose, TG, HDL, SBP, DBP, and insulin) as dependent variable and age, center (i.e., for DXA scanner, blood pressure measurements), blood analysis laboratory, and their interactions as potential predictor variables. Variables and interactions with significant contributions to the model were retained in the regression equation. The regression analyses were conducted within each sex and race/ethnicity group. The correlation between the residuals of each regression equation and the three anthropometric measures was calculated. For each health risk factor, we tested whether the correlation coefficients were significantly different from each other (33). We also constructed regression equations using one anthropometric measure as an independent variable and tested whether adding other anthropometric measures made significant contributions to the model for each health risk indicator.

Levene's test was used to evaluate the equality of variance among groups, and the Shapiro-Wilk test was applied to test the normality of the residual distributions. When necessary, risk factor values were mathematically transformed to normalize the residual distributions and to equalize the residual variance across centers or laboratories. Log transformations were applied initially and followed by Box-Cox transformations if necessary (34).

When the Box-Cox transformation failed to normalize the residual distributions or to equalize the residual variance across centers, 11 African-American women and 2 white women with residuals >3 standard deviation from the group mean were excluded from the analyses. Correlation coefficients were calculated both before transformation with the outlying subjects included and after transformation without the outlying subjects. Age-adjusted correlation coefficients were also calculated within each center for the associations between anthropometric measures and health risk factors in each race/ethnicity and sex group.

All statistical analyses were carried out using SPSS (SPSS for Windows, 11.5; SPSS, Chicago, IL). Group data are presented as the mean ± standard deviation. Two-tailed (α= 0.05) tests of significance were used.

Results

Subjects

Blood glucose and lipids were available on 1010 subjects whose characteristics are presented in Table 1. Blood pressure data were available on 202 subjects at the NYORC and 241 subjects at the CARDIA study sites (Table 2). Serum insulin data were available on 178 subjects at the NYORC and 266 subjects at the CARDIA study sites (Table 3). The availability of specific measures depended on whether the measure was called for in the original study protocol.

Relationship between Percent Fat, BMI, WC, and Blood Lipids and Glucose

The adjusted correlations between anthropometric measures and serum glucose, TGs, and HDL-cholesterol are summarized in Table 4. Percent fat had the lowest correlation among the three anthropometric measures in white men and the differences between percent fat and WC and percent fat and BMI reached significance for HDL (p = 0.016 and 0.033, respectively). BMI had the lowest correlation among the three measures in African-American men and the differences between BMI and WC and BMI and percent fat reached significance for TGs (p = 0.001 and = 0.018, respectively). In African-American men, none of the differences between the association of WC or percent fat with metabolic outcomes reached significance.

WC had the highest correlation and percent fat the lowest correlation with serum glucose in African-American women and for TGs and HDL-cholesterol in African-American and white women. The differences between WC and percent fat reached significance or borderline significance for all of these variables (Table 4). The correlation between WC and TG and HDL-cholesterol was also significantly or borderline significantly higher than that of BMI for TG and HDL-cholesterol in African-American women (p = 0.008 and 0.062, respectively). The correlation between BMI and HDL-cholesterol was significantly higher than that of percent fat in white women (p = 0.012) and borderline significantly higher for glucose in African-American women (p = 0.061). BMI and percent fat had higher correlation with serum glucose than WC in white women, but the differences among all three measures did not reach statistical significance.

Relationship between Percent Fat, BMI, WC, and Blood Pressure

The adjusted correlations between anthropometric measures and SBP and DBP are presented in Table 5. WC had the highest correlation with both SBP and DBP in white men (WC vs.

percent fat, $p = 0.006$ for SBP and $p = 0.032$ for DBP; WC vs. BMI, $p = 0.018$ for SBP and $p = 0.004$ for DBP). BMI had the lowest correlation with both SBP and DBP in African-American men, although the differences among the three anthropometric measures did not reach statistical significance.

Percentage fat had the lowest correlation with both SBP and DBP in white women among the three anthropometric measures, but the difference did not reach statistical significance. The highest correlations in African-American women were between BMI and SBP and DBP, and correlation coefficient differences among the three measures reached significance or borderline significance for SBP (BMI vs. WC, $p = 0.034$; BMI vs. percent fat, $p = 0.065$).

Relationship between Percent Fat, BMI, WC, and Fasting Insulin

The adjusted correlations between anthropometric measures and serum insulin are presented in Table 6. WC had the highest correlation with serum insulin in all sex and ethnic groups, and the differences between WC and percent fat reached significance for African-American men, white women, and African-American women (WC vs. percent fat, $p = 0.032$, 0.035, and 0.014, respectively). BMI had a higher correlation with serum insulin than percent fat in African-American men, white women, and African-American women but a lower correlation with serum insulin than percent fat in white men, with the only difference in white women reaching borderline statistical significance ($p = 0.076$). WC had a higher correlation with serum insulin than BMI but only reached significance in African-American women ($p = 0.04$).

When the data analyses were run without excluding outliers and without normalizing transformations on the dependent variables, the correlation coefficient ranking of WC did not change (data not shown). The significance levels of the correlation coefficient differences between percent fat, BMI, and WC did not change except for two instances: the difference between percent fat and WC for HDL-cholesterol in white men (p values with and without transformation, 0.036 and 0.053, respectively), and the difference between percent fat and BMI for insulin in white women (p values with and without transformation, 0.076 and <0.001, respectively).

The within-center correlations between anthropometric measures and health risk factors after adjusting for age were lowest for percent fat and highest for WC for most endpoints (data not shown), consistent with the pattern seen in the merged sample.

Improvement of Association with Health Risks by Adding Other Anthropometric Measures in Regression Models

In testing whether additional anthropometric measures improve the prediction after one has already been entered, we found that percent fat made a statistically significant contribution to WC regression models in only two instances: serum glucose in white women and SBP in African-American men (R^2 improvement: 0.013 and 0.006, respectively). In contrast, WC made statistically significant contributions to the percent fat regression models in 14 instances: serum glucose in white men and African-American women; TG and HDL-cholesterol in white men, white women, and African-American women; SBP and DBP in white men; and serum insulin in all groups (R^2 improvement, 0.020 to 0.144).

BMI made a statistically significant contribution to the WC regression models in four instances: for TG in African-American men; serum glucose in white women; and SBP in white men and African-American women (R^2 improvement: 0.012 to 0.041). In contrast, WC made a statistically significant contribution to the BMI regression models in 14 instances: serum glucose in African-American and white men; TG and HDL-cholesterol in African-American

men and white and African-American women; SBP and DBP in white men; and serum insulin in all groups (R^2 improvement: 0.009 to 0.124).

Percentage fat made a statistically significant contribution to the BMI regression models in only seven instances: serum glucose, TG, and HDL-cholesterol in African-American men; DBP in African-American men; and serum insulin in white men, African American-men, and African-American women (R^2 improvement: 0.011 to 0.123). In contrast, BMI made a statistically significant contribution to the percent fat regression models in 12 instances: serum glucose in African-American women; TG and HDL-cholesterol in white men and white and African-American women; SBP in African-American women; and serum insulin in all groups (R^2 improvement: 0.011 to 0.124).

Discussion

Anthropometric Measurements and Associated Health Risks

In this study, we carefully distinguished between two often inappropriately related concepts in the weight control field: total body mass and adipose tissue as markers of energy storage and weight-related markers of cardiovascular disease risk. Many earlier studies have examined the validity of BMI and WC as proxies for adiposity (20,21,35). Our focus was not on these associations but on the health risks that accompany excess adiposity.

The main finding in this large-scale study is that accurately measured percent fat overall is not associated as strongly as WC with indicators of obesity-related health risks. Among the 24 comparisons of adiposity measurements, WC had higher correlations with health risk indicators than percent fat in 20 instances, with 10 of the comparisons reaching statistical significance. Because we did not adjust for multiple comparisons, there is a chance of a type I error occurring in some of the comparisons, favoring either percent fat or WC. However, because our study focus was on the overall trend in the comparisons rather than an individual comparison, our conclusion would not be influenced by the presence of type I error in particular cases.

This observation is consistent with the substantial literature on the health risks now well associated with fat distribution patterns. Central obesity, notably the relatively small visceral adipose tissue compartment, is considered a more important marker of the physiological disturbances that accompany excess weight gain than total body adipose tissue. On the other hand, peripheral fat depots in cross-sectional studies show either low contribution to health risks (36,37) or even a protective effect (14–18). The limited performance of percent fat as a marker of the metabolic syndrome components may, thus, be attributed to the mixed contribution of various adipose tissue compartments to metabolic dysregulation. Our findings support the growing evidence that WC can serve as a practical screening method for the metabolic risks that often accompany overweight and obesity.

This study included pooled data from three DXA scanners manufactured by two different companies. We did not cross-calibrate the scanners, and instead, between-instrument differences were considered as part of our developed regression models. Also, earlier studies indicate good agreement on percent fat measurements between the Lunar and Hologic DXA scanners (38). Thus, it is unlikely that the limited performance of percent fat as evaluated in this study can be attributed to the use of different DXA scanners, especially because the results within each center agreed with the results of the merged data.

We also found that WC had higher correlations with health risks than BMI in 18 of 24 comparisons**,** with 5 of the comparisons reaching statistical significance. This observation is consistent with previous findings (11,39), and the likely underlying basis is that WC has higher correlations with visceral adipose tissue than does BMI (40). WC may, therefore, provide a

better anthropometric representation than BMI of body compartments most associated with the adverse metabolic profile that accompanies excess adiposity.

While there were some sex and race/ethnicity differences, our results do not support the view that percent fat is a better indicator of metabolic syndrome components than BMI, although the differences between percent fat and BMI in these correlations were not as large as those observed between percent fat and WC. Thus, when a major objective of study is phenotyping subjects for weight-related health risks, there is little justification for evaluating the sensitivity and specificity of BMI cut-off points against reference percent fat measurements. Referencing BMI against percent fat would only be appropriate when considering stature-adjusted body mass as a measure of energy stores.

Race/Ethnicity and Sex Effects

The observed study relationships were somewhat more evident in women than in men. One possible explanation for the higher association between WC and risk factors in women is that sex differences are present in the proportion of total fat as peripheral and central fat. Women have relatively more peripheral and less central fat than men. Hence, WC in women may be an even more sensitive marker for detecting between-individual differences in central obesity than measures of total fatness (22,23).

Another noteworthy finding in this study is that BMI had the lowest correlation among the three metabolic syndrome anthropometric measures in African-American men. A possible explanation for this finding is that African-American men have a relatively large skeletal muscle mass compared with women and white men (41,42). More of the individual variation in BMI among African-American men may, therefore, be caused by between-subject differences in skeletal muscle mass than in total body fat.

Both total adiposity as percent fat and fat distribution as WC in the evaluated African-American women showed low correlations with blood pressure. Because the correlation coefficients for BMI and blood pressure in the African-American women were higher than those for WC and percent fat, one possible speculation is that lean tissue mass is the major tissue component that contributes to between-individual variation in blood pressure in African-American women.

Study Limitations

Even though we evaluated a relatively large number of subjects, our convenience sample may not be representative of the general population. Although the bioimpedance analysis data from population studies such as NHANES III are now available, we did not view the derived percent fat estimates as sufficiently accurate for a critical test of our study hypothesis. The most recent NHANES study with DXA data has not yet been released, and this database will provide a new and important follow-up to this study. Our findings should also be validated in race and ethnic samples other than African Americans and whites as in this study.

Because the present study was conducted in a healthy subject sample and about one half of the subjects did not have blood pressure measurements, we did not examine how well WC can detect the metabolic syndrome. Instead, we studied the correlation of each component of metabolic syndrome with adiposity measurements. Future studies would need to test different adiposity measurements for their ability to detect metabolic syndrome in a population sample of the patients who did have blood pressure measurements. Those at the NYORC were based on a single reading.

Another limitation is that our study is based on a cross-sectional data set, and studies are needed to confirm our findings in longitudinally monitored subjects. An important question is whether our findings will be validated with other obesity-related health risks, diseases, and mortality.

While this study focused on components of the metabolic syndrome, it is possible that health conditions associated with load bearing, such as osteoarthritis, may show a stronger association with total body mass than with the other two anthropometric measures. Similarly, adipose tissue stores fat-soluble toxins, and also, through aromatase, is a source of estrogen production. Some conditions other than those evaluated in this study may, thus, be mechanistically linked with total fat mass and percent fat independent of central obesity.

Finally, additional studies are needed to establish whether accurately measured central adiposity (e.g., trunk fat by DXA, visceral adipose tissue by imaging methods), instead of percent fat, can be used as reference methods for validating anthropometric measurements.

In summary, among the three widely used weight-related anthropometric measures, WC had the highest cross-sectional correlation with components of the metabolic syndrome. A critical question emerging from our observations is how best to define and screen for obesity, considering energy stores on the one hand and health risks on the other. Additional follow-up is also needed in longitudinally monitored populations, in other race/ethnic and age groups, and considering health risks other than components of the metabolic syndrome.

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Nonstandard abbreviations

WC
waist circumference

TG
triglyceride

HDL
high-density lipoprotein

SBP
systolic blood pressure

DBP
diastolic blood pressure

NYORC
Obesity Research Center, St. Luke's-Roosevelt Hospital in New York

UAB
University of Alabama at Birmingham

KPNC
Kaiser Permanente Northern California

CARDIA
Coronary Artery Risk Development in Young Adults

Table 1

Subject characteristics for total study group

Group	Men		Women	
	White	African-American	White	African-American
Sample size	206	207	292	305
Age (years)	46.2 ± 16.0 (42.0, 36.0, 56.3)	46.7 ± 17.3 (42.0, 36.0, 58.0)	47.2 ± 16.5 (43.0, 36.0, 57.8)	51.5 ± 18.2 (45.0, 37.0, 69.0)
BMI (kg/m^2)	26.5 ± 4.0 (25.9, 24.1, 28.4)	26.7 ± 4.4 (26.5, 23.9, 29.4)	25.5 ± 5.9 (24.1, 21.0, 28.4)	28.8 ± 5.6 (28.4, 24.2, 32.8)
WC (cm)	92.0 ± 11.2 (91.3, 84.2, 97.4)	90.7 ± 10.9 (90.2, 82.9, 98.0)	80.0 ± 13.5 (77.2, 69.5, 89.0)	87.4 ± 13. (87.0, 78.1, 96.3) 0
Percent fat	24.3 ± 8.1 (24.7, 19.0, 30.7)	22.7 ± 8.4 (23.2, 18.1, 27.8)	34.6 ± 10.4 (34.9, 25.8, 42.7)	38.7 ± 9.1 (40.0, 33.1, 45.5)
Serum glucose (mg/dL)	92.7 ± 11.2 (91.0, 86.0, 99.0)	94.3 ± 12.6 (93.0, 87.0, 102.0)	88.6 ± 9.7 (88.0, 83.0, 94.0)	91.6 ± 10.5 (90.0, 85.0. 98.0)
TGs (mg/dL)	111.6 ± 67.7 (94.5, 62.8, 138.5)	99.0 ± 60.7 (86.0, 56.0, 126.0)	91.2 ± 54.6 (77.0, 52.2, 113.5)	81.5 ± 43.6 (69.0, 51.0, 103.0)
HDL-cholesterol (mg/dL)	45.6 ± 11.2 (45.0, 39.0, 52.0)	51.4 ± 14.8 (49.0, 41.0, 60.0)	58.5 ± 15.2 (57.0, 47.0, 68.0)	58.3 ± 16.1 (56.0, 47.0, 67.0)

WC, waist circumference; TG, triglyceride; HDL, high density lipoprotein cholesterol; SD, standard deviation. Age, BMI, WC, percent fat, fasting glucose, serum TGs, and HDL-cholesterol are presented as mean ± SD (median, 25th percentile, 75th percentile). Because not all variables are normally distributed, we present median, 25th percentile, and 75th percentile for each variable.

Table 2

Subject characteristics for the blood pressure subgroup

Group	Men		Women	
	White	African-American	White	African-American
Sample size	122	97	127	97
Age (years)	41.6 ± 10.3 (41.0, 36.0, 44.0)	36.8 ± 7.5 (38.0, 34.0, 40.5)	42.2 ± 12.0 (41.5, 36.0, 45.0)	41.0 ± 11.3 (39.0, 35.0, 45.0)
BMI (kg/m^2)	26.4 ± 3.7 (26.0, 24.4, 27.6)	26.9 ± 4.6 (26.5, 24.0, 30.1)	24.7 ± 5.2 (23.2, 21.1, 27.4)	29.3 ± 5.8 (28.8, 24.0, 33.2)
WC (cm)	91.4 ± 10.0 (90.9, 85.0, 95.6)	89.0 ± 10.3 (88.6, 81.7, 94.8)	76.9 ± 11.7 (73.9, 68.5, 83.5)	87.4 ± 12.9 (87.3, 78.8, 96.3)
Percent fat	24.5 ± 7.6 (24.3, 19.6, 30.0)	21.6 ± 8.6 (22.3, 16.7, 26.1)	33.9 ± 10.5 (32.7, 25.5, 42.0)	39.9 ± 9.7 (41.6, 31.6, 46.6)
SBP (mm Hg)	117.8 ± 10.3 (117.3, 110.0, 124.0)	120.7 ± 12.2 (118.0, 112.0, 128.0)	110.4 ± 12.9 (109.3, 100.0, 118.0)	118.8 ± 16.9 (114.7, 107.2, 128.0)
DBP (mm Hg)	77.8 ± 8.3 (78.3, 70.6, 83.5)	79.7 ± 9.6 (80.0, 72.5, 84.7)	73.5 ± 8.3 (73.0, 68.0, 79.3)	78.2 ± 10.2 (80.0, 70.0, 86.0)

WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; SD, standard deviation. Age, BMI, WC, percent fat, SBP and DBP are presented as mean ± SD (median, 25th percentile, 75th percentile). Because not all variables are normally distributed, we present median, 25th percentile, and 75th percentile for each variable.

Table 3

Subject characteristics for the insulin subgroup

Group	Men		Women	
	White	African-American	White	African-American
Sample size	111	97	126	110
Age (years)	42.4 ± 9.4 (41.0, 37.0, 44.0)	37.6 ± 7.5 (38.0, 34.5, 42.0)	40.1 ± 10.7 (42.0, 36.0, 44.3)	41.0 ± 11.3 (41.0, 35.0, 45.0)
BMI (kg/m^2)	27.1 ± 4.0 (26.6, 24.5, 28.7)	27.5 ± 4.8 (26.7, 24.3, 30.3)	26.7 ± 6.5 (25.2, 21.5, 30.6)	29.8 ± 6.2 (29.5, 24.4, 33.8)
WC (cm)	93.2 ± 10.7 (91.3, 86.6, 99.3)	90.9 ± 11.2 (89.9, 82.9, 96.9)	81.8 ± 14.7 (77.8, 70.2, 91.3)	89.3 ± 13.4 (91.0, 79.3, 100.4)
Percent fat	25.6 ± 7.5 (26.2, 20.0, 31.4)	23.1 ± 8.4 (23.0, 18.8, 27.6)	37.2 ± 9.6 (38.0, 28.4, 44.5)	39.2 ± 9.7 (41.1, 32.2, 46.6)
Insulin (uIU/mL)	9.5 ± 5.6 (8.0, 5.5, 11.7)	9.3 ± 6.4 (7.8, 5.4, 11.2)	8.4 ± 5.6 (7.0, 4.5, 10.9)	11.2 ± 6.1 (9.9, 6.7, 15.4)

WC, waist circumference; SD, standard deviation. Age, BMI, WC, percent fat, and insulin are presented as mean ± SD (median, 25th percentile, 75th percentile). Because not all variables are normally distributed, we present median, 25th percentile, and 75th percentile for each variable.

Table 4

Adjusted correlation coefficients between anthropometric measurements and blood results

Group			Glu	TGs	HDL	Adjustment
Men	White (n = 206)	Percent fat	0.234	0.308	−0.225	Glu: age, center; TGs: age, center; HDL: none
		BMI	0.269	0.351	−0.342*	
		WC	0.291	0.345	−0.335*	
	African-American (n = 207)	Percent fat	0.254	0.267†	−0.262	Glu: age, center, age*center; TGs: age, center, age*center; HDL: none
		BMI	0.244	0.125	−0.222	
		WC	0.263	0.267†	−0.277	
Women	White (n = 292)	Percent fat	0.258	0.396	−0.350	Glu: age, center, lab; TGs: age, center, age*center; HDL: age, center, age*center, lab
		BMI	0.259	0.440	−0.427*	
		WC	0.224	0.461§	−0.438*	
	African-American (n = 305)	Percent fat	0.178	0.258	−0.192	Glu: age, center, lab, center*age; TGs: age, center; HDL: age, lab
		BMI	0.249‡	0.279	−0.228	
		WC	0.267*	0.356*†	−0.286*¶	

Glu, serum glucose; TG, triglyceride; HDL, high density lipoprotein cholesterol; WC, waist circumference. Glu, TGs, and HDL were either log or Box-Cox transformed to normalize the distribution of the residuals and to equalize the residual variance among groups; Glu, TGs, and HDL in all male subjects, Glu and HDL in white women, and Glu in African-American women were log-transformed. Box-Cox transformation was applied to TGs in white women, TGs, and HDL in African-American women (λ = −0.5, −0.4, and −0.2, respectively).

*Significantly higher ($p < 0.05$) than percent fat.

†Significantly higher ($p < 0.05$) than BMI.

‡Higher than percent fat at $p = 0.061$.

§Higher than percent fat at $p = 0.055$.

¶Higher than BMI at $p = 0.062$.

Table 5

Adjusted correlation coefficients between anthropometric measurements and blood pressure

Group			SBP	DBP	Adjustment
Men	White (n = 122)	Percent fat	0.199	0.271	SBP: age; DBP: none
		BMI	0.267	0.274	
		WC	0.373*†	0.404*†	
	African-American (n = 97)	Percent fat	0.259	0.323	SBP: none; DBP: age
		BMI	0.231	0.250	
		WC	0.290	0.286	
Women	White (n = 127)	Percent fat	0.178	0.152	SBP: age; DBP: none
		BMI	0.207	0.157	
		WC	0.195	0.196	
	African-American (n = 97)	Percent fat	0.020	0.049	SBP: age, center; DBP: age, center
		BMI	0.169‡§	0.163	
		WC	0.041	0.090	

SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference. SBP and DBP were either log or Box-Cox transformed when needed to normalize the distribution of the residuals and to equalize the residual variance among groups. SBP in African-American women was log-transformed. SBP in African-American men and SBP and DBP in white women were Box-Cox transformed ($\lambda = -2.8$, -1.8, and -1.5, respectively).

* Significantly higher than percent fat.

† Significantly higher than BMI.

‡ Significantly higher than WC.

§ Higher than percent fat at $p = 0.065$.

Table 6

Adjusted correlation coefficients between anthropometric measurements and insulin

Group			Insulin	Adjustment
Men	White (n = 111)	Percent fat	0.530	None
		BMI	0.459	
		WC	0.590	
	African-American (n = 97)	Percent fat	0.475	None
		BMI	0.536	
		WC	0.598*	
Women	White (n = 126)	Percent fat	0.541	Lab
		BMI	0.618‡	
		WC	0.643*	
	African-American (n = 110)	Percent fat	0.547	None
		BMI	0.587	
		WC	0.669*†	

WC, waist circumference. Insulin was either log or Box-Cox transformed when needed to normalize the distribution of the residuals and to equalize the residual variance among groups. Insulin in white men and African-American men and women was log transformed. Insulin in white women was Box-Cox transformed ($\lambda = 0.2$).

*Significantly higher than percent fat.

†Significantly higher than BMI.

‡Higher than percent fat at $p = 0.076$.