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Neck and waist circumference biomarkers of cardiovascular risk in a cohort of predominantly African-American college students: A preliminary study

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INTRODUCTION

Disease prevention is predicated on the identification of risk factors in asymptomatic individuals. The emergence of school-based health screening as a prevention strategy relies primarily on body mass index (BMI) to categorize body weight and health risk because it is relatively easy to obtain. However, BMI is an imprecise surrogate measure of obesity, which raises concerns that some healthy-weight individuals with large lean body mass are mislabeled as overweight or obese [1, 2]. Screening tools that include additional biomarkers may yield better predictive value for hypertension, impaired glucose tolerance and other cardiovascular disease (CVD) risk factors and help identify those individuals who may benefit from more in-depth assessment. Neck circumference (NC), waist circumference (WC), hip circumference (Hip-C) and the waist-hip ratio (WHR) are easily obtained biomarkers and may be useful in screening.

The validity of using NC as a biomarker of health risk is supported by its correlation with metabolic risk factors in adults in Brazil [3], China [4], Israel [5, 6] and the United States [7]. The use of WC and WHR as biomarkers are related to the health implications of centrally deposited fat, which is a strong risk factor for CVD and type 2 diabetes (T2D) [8–11]. However, location of the waist measure impacts the absolute value of the circumference measure and use of WC and WHR has been encumbered by lack of a common approach to measurement. More than ten different WC measurement sites are reported in the scientific literature [11–17]. Thus it is critical to use standardized procedures and report site measurement when characterizing an individual's central adiposity and assessment of CVD risk [18–21].

There are limited data available describing noninvasive biomarkers for use in screening minority adolescents and young adults for prediabetes and T2D despite the high incidence of disease in this population [22]. Screening is useful as a prevention strategy in largely healthy populations when it can identify those individuals who would benefit most from lifestyle changes. A subset of data from a study in predominantly African-American college students, *Assessing Inherited Metabolic Syndrome Markers in the Young* (ClinicalTrials.gov Identifier, redacted for peer-review), was analyzed to determine associations between circumference measures (WC, NC, WHR), and traditional biomarkers of CVD and the metabolic syndrome (MetS). Because there are distinct gender-associated variations in body composition, anthropometric measures and several clinical indicators of health (e.g., WC,

HDL cholesterol) [10, 23] [note: delete coded[10][23] the associations of sex with anthropometric and CVD risk factors were examined.

METHODS

Study Participants

The [Research institution redacted for peer-review] Institutional Review Board approved the study protocol. Students recruited at [University site redacted for peer-review] were eligible if they were 18–25 y and provided informed consent. Exclusion criteria included: pregnancy, body weight >250 kg, diagnosed eating disorder, weight loss treatment, disordered glucose metabolism, hematologic disorder, use of appetite suppressants or drugs known to alter glucose metabolism or blood pressure (BP), participation in a drug trial, alcohol dependency, cancer, neurosurgical procedure, or psychiatric disorder. Participants who withdrew prior to completion of BP measurements were excluded. Recruitment was conducted using IRB-approved flyers posted on campus, verbal descriptions announced in undergraduate and graduate classes, and advertisements in the school newspaper. Of 115 consented students, eight (7%) were excluded: one did not meet age criteria; five did not respond to calls and two had schedule conflicts.

Anthropometric Measurements

Participants were admitted to the Clinical Research Center at [institution site redacted for peer-review] after a 12-hour fast and having refrained from exercise for at least two hours. Compliance with fasting procedures was confirmed by asking the volunteer to specify the last time they had eaten or had a large drink. Intake of water was acceptable for blood testing and anthropometric measures; however, to be eligible for measures of body composition, the participant must have avoided food, all drinks and strenuous exercise for two hours prior to the measure,

Anthropometric measurements of each participant were obtained in triplicate according to standardized procedures. Weight was measured (Scale-Tronix, Wheaton, IL) in underwear and a hospital gown after the student was asked to void as needed. Gown weight was subtracted to derive net weight. After positioning the head in the Frankfort horizontal plane, standing height without shoes was measured (to 0.1 cm) using a wall-mounted stadiometer (Holtain Limited, Crymych UK). Stadiometer accuracy and precision was verified monthly using a 160 cm metal rod. The accuracy of the weight scale was verified daily using two 10-kg weights, and monthly using four 10 kg weights. Body weight categories were defined by BMI [11].

A fiberglass tape measure (GulickII® model # 4192G, Country Technologies, Gays Mill, WI) was used by one trained researcher for NC, WC, and Hip-C, in sequence from neck to hip. Removable stickers were used to mark locations for tape placement and locations were reestablished for each repeated sequence. NC was measured between the mid-cervical spine and mid-anterior neck just below the laryngeal prominence with the head in the Frankfurt plane [6, 13]. WC was measured at: (a) the mid-point, half-way between the right iliac crest and the lower costal region (WC-MP) [15]; (c) the narrowest waist as viewed from the back

(WC-narrowest); and, (c) the right superior iliac crest (WC-suprailiac) [12]. Hip-C was measured at the maximum extension of the buttocks as viewed from the right side [12].

Body composition was assessed via whole-body air displacement plethysmography (ADP; BOD POD®, Life Measurement, Concord, CA) in tight-fitting spandex clothing (swim suit or shorts and sports top for women, and swim cap), using race and gender specific equations [24–26]. For purposes of analyses, two categories were constructed using body fat percentage (%BF): lean to moderate fat accumulation (males <25 %BF, females <35 %BF) and higher body fat (males ≥ 25 %BF, females ≥ 35 %BF) [23, 27–29].

Clinical and Laboratory Measures of Metabolic Syndrome

While the participant was seated, BP was measured in duplicate using a random zero sphygmomanometer (model/serial number 53STO/JA096584, 53STO/JA096585, Welch Allyn Inc, Skaneateles Falls, NY) Measurements were repeated later during the study visit and twice more during a second visit approximately one week later [30]. Each student's BP was categorized using the average value of eight measures [30].

Fasting blood samples (20 mL) were collected, processed and shipped by research nurses according to standardized protocols in order to measure serum glucose, insulin, triglycerides, HDL cholesterol, LDL cholesterol (calculated), and total cholesterol. Blood samples were collected into tubes containing heparin sodium, stored on ice, and centrifuged at 4°C immediately after each draw. Whole blood was collected to measure HbA_{1c}. A blood pregnancy test (serum hCG level) was administered on samples from female participants. Specimens were either picked up by the laboratory courier or shipped through FEDEX/UPS to the testing facility. Assays on de-identified blood samples were performed by Quest Diagnostics® (Chantilly, VA).

The following clinical determinants of MetS [8] were recorded: a) WC: >102 cm men; >88 cm women; b) triglycerides: ≥ 150 mg/dL; c) HDL cholesterol: <40 mg/dL men; <50 mg/dL women; d) BP: ≥ 130 mmHg systolic (SBP) or ≥ 85 mmHg diastolic (DBP); and, e) ≥ 110 mg/dL fasting glucose

Prior to study completion, each participant was provided with educational information and materials to increase their awareness of obesity and CVD risk, and to encourage them to maintain a healthy lifestyle. Participants were also given their laboratory values, BMI measurement, and anthropometric results with instruction to contact their physician and/or the university student health department for more in depth discussions of their results. Participants were compensated \$25 per visit.

Data Analysis

The normality of continuous variables was analyzed using Shapiro-Wilks test, qq plots, and histograms. Non-normal variables were log transformed. Associations of circumference measures with continuous variables were assessed using partial Pearson's correlations and Spearman correlations controlling for sex. Fisher's z transformations were used to test if the correlation coefficients of WC and WHR with BMI, weight, and %BF significantly differed by site of WC measurement.

Associations between circumference and independent variables (sex, year in school, glucose level, hypertension risk, weight, triglycerides, LDL cholesterol level, and HDL cholesterol level) were examined with analysis of covariance (ANCOVA). These ANCOVA models were used to identify the variables predicting variability of circumference. Significant relationships were identified using a backward elimination selection procedure. Receiver operating characteristic (ROC) analysis was used to assess the accuracy of binary predictions of event or no event for risk factors of disease (%BF, BP and MetS) using the specificity and sensitivity of the predictor biomarkers (NC, WC-MP, WC-suprailiac, WHR-MP, and WHR-suprailiac) and their respective cutoff values with the best fit. A best fit variable was defined as [sensitivity + specificity - 1] and the cutoff value was associated with the largest best fit value. For multiple measures that shared an identical best fit value (e.g., 87 cm and 88 cm WC), the greater measured value was selected as the cutoff in order to decrease the potential for false positive predictions. Because there are distinct gender-associated variations in body composition, anthropometric measures and several clinical indicators of health (e.g., WC, HDL cholesterol) [10, 27] data were reported by gender. Differences between males and females were tested by applying a stepdown bootstrap approach with Proc Multtest for continuous variables and applying a median test for non-continuous variables. Data were analyzed using SAS® software, Version 9.2 of the SAS System for Windows. Copyright © 2008 SAS Institute Inc. (Cary, NC) and reported as mean (standard deviation) and median (IQR). All statistical comparisons were made at the 0.05 significance level.

RESULTS AND DISCUSSION

Participant demographics, weight status, and clinical measures

Participants ($n=109$; 19.5 ± 1.5 y) were 92% black, and 62.4% female, reflecting the 2:1 female/male ratio on campus [31]. A greater proportion of freshmen were female, whereas males reflected the broader college population (Table 1). On average, as expected, men were leaner, taller, heavier, and had wider NC but narrower waists (suprailiac) and hips than women ($P < 0.05$; Table 1). Overall, 30 (44%) women and 11 (27%) men had at least one risk factor for MetS, including ten students (80% female) having 2 risk factors for MetS.

Eighty-four (77%) students were 20 y or younger. Because we plan to follow a cohort over time, the adult criteria for BMI [11] was used to define the weight status of all participants rather than use sex-and age-specific BMI percentiles for those 18–20 years of age [32]. In contrast to BMI, which has standardized cut-offs for interpretation of weight status, specific cut-off values of %BF (by ADP) to delineate categories of fatness are not yet defined by consensus and %BF (by ADP, bioelectrical impedance or skinfold) has yet to be widely applied in health screening. Laurson et al. [29] calculated %BF from triceps and subscapular skinfold thickness and reported that %BF percentiles among non-Hispanic whites, non-Hispanic blacks, and Mexican American youth were similar. In that sample, 30.3 %BF and 36.3 %BF delineated the 85th percentiles respectively, defining overweight for 18 year old boys and girls. Laurson et al. [29] pointed out, as supported by the current study, there are distinct age-and gender-associated variations in %BF. Laurson et al. [29] suggested that their reported cut-off values for overweight may be inflated because they used a regression

equation to calculate %BF from skinfolds that was derived from a cohort who were leaner and older than their sample. By comparison, the cut-off used to delineate higher body fat (males ≥ 25 %BF, females ≥ 35 %BF) in the current study may introduce less false negatives but generate more false positives, consistent with thresholds generally selected for biomarkers used in health screening.

Mean and median values for most clinical and laboratory variables were within the normal range with the exception of SBP among men and several students had elevated HbA_{1c} and insulin values (Table 1). Three male students (one freshman and two sophomores) had BP measurements in the range (140–159/90–99 mm Hg) for Stage I hypertension [30]. According to recent guidelines [30], these students demonstrate risk for heart attack, stroke, and kidney disease; however, each considered themselves to be generally healthy. Individuals with HbA_{1c} in the range of 5.7% to 6.4% are considered at high risk for developing diabetes [33]. Despite a normal range of fasting glucose, many participants had HbA_{1c} values between 5.7% and 6.0% [17 of 66 (25.8%) women and 16 of 40 (40.0%) men], and six students (4 women and 2 men) had elevated insulin levels (>17 IU/mL). Findings from the Diabetes Prevention Program Outcomes Study suggest that early identification of individuals at a high risk for T2D who gain control of glucose regulation through lifestyle interventions and/or medication are 56 percent less likely to develop the disease 10 years later [34]. The long-term upward trend in prevalence of prediabetes/T2D among US adolescents aged 12 to 19 years [22] coupled with the findings of substantially elevated BP and the prevalence of overweight in otherwise healthy students underscores the need for early and periodic health screening during college with options for referral and intervention.

Circumference Measures

NC was highly associated with measures taken at all three sites of WC ($r = .75$, $p < .0001$) and was significantly correlated with weight, BMI and %BF ($r = .85$, $r = .78$, $r = .51$; $p < .0001$, respectively). The ease by which a circumference measurement is taken can have bearing on its reliability and usefulness in health screening. NC is measured fairly rapidly and is less prone to privacy concerns than are WC and Hip-C. Moreover, WC measured at the mid-point (WC-MP) is particularly laborious to obtain because it requires skillful identification of two bony landmarks, measuring the distance between them, and then calculating the mid-point. However, in general, body circumference measures may be particularly useful when counseling young adults about disease risk because they de-emphasize the terms “overweight” and “obese,” which can be perceived as a subjective judgment of body appearance. Although BMI is typically used to categorize weight status, it is WC as a marker of abdominal obesity (weight distribution) that is included among the five risk factors of MetS [8].

The data in Table 2 describing within-subject variability in repeated circumference measures are presented to emphasize that obtaining repeat waist and hip measures even for one subject by one trained investigator is highly variable under conditions when the location of the subsequent measures are not simply placed over a mark of the location of the site of the first measure, but must be re-located on the body. The purpose of re-locating the site of measure

per protocol each time and sacrificing precision is to improve the probability of obtaining an accurate measure of the “true” circumference of the neck, waist, and hip. In contrast to WC and Hip-C, triplicate NC measures for individual participants yielded relatively low variability (Table 2), which was anticipated [13]. Lohman et al. [13] concluded that when following standardized protocols, the true value of the WC and Hip-C will be within 1 cm of that measured and the true value of the NC will be within 0.3 cm of the measured value. Among the sites selected to measure WC, those obtained at the narrowest point (WC-narrowest) were the most precise. When calculating median WC and WHR, the values varied depending on which WC site was measured ($p < 0.0001$, Wilcoxon signed rank test): WC-narrowest < WC-MP < WC-suprailiac, which is consistent with published literature [17].

The variation in WC measure by site means that disease risk classifications that include a component based on WC may vary depending on where the waist is measured. For example, the NHLBI cardiovascular disease risk parameters specify use of WC-suprailiac [11], and if applied to this study sample, 31 of 109 (28%) students would be categorized at increased risk for CVD, T2D and hypertension. Whereas using the WC-MP or WC-narrowest sites instead of WC-suprailiac, 23 of 109 (21%) and 19 of 109 (17%) students, respectively, would be identified to be at risk for these conditions, which are both statistically different from the 28% using WC-suprailiac ($P < 0.05$). Thus, given the variability in screening outcomes depending on the site of the waist measure, clinicians and researchers should use standardized procedures when measuring circumference and report their methods so that the results can be accurately interpreted.

Prediction variables

An ideal screening test would classify disease risk so that very few people would be mischaracterized. In practice, however, this is not possible when screening large numbers of individuals, so that achieving an acceptable balance between sensitivity and specificity is necessary. ROC curves determine the cutoff value with the best possible combination of specificity and sensitivity for the selected screening measure to identify at-risk individuals. In this study, ROC analyses were used to determine the optimal cutoff values for grouping students based %BF and MetS.

Measuring NC in association with biomarkers of disease risk is novel [7] and these data represent some of the first US measurements obtained in college-aged adults. NC correlated with LDL cholesterol ($p = 0.02$), insulin ($p = .001$) and triglycerides ($p = .002$), similar to results obtained in older men and women in which NC was associated with increased odds of hypertension, low HDL cholesterol, high triglycerides, diabetes, and MetS [7]. Despite these encouraging biochemical associations and that NC was relatively specific as a biomarker for obesity and MetS, NC lacked sufficient sensitivity to achieve even moderate best fit ROC (Table 3). This could be the result of measuring only a small number of participants. The predictive validity of NC for body composition and disease risk should be further tested with larger numbers of participants, including those with MetS risk factors.

WC measured at all sites was highly correlated with weight, BMI ($r = .90$ to $r = .92$, $p < 0.0001$) and %BF ($r = .73$ to $r = .76$, $p < 0.0001$). Similarly, WHR (using waist measures at

each site) was significantly correlated with weight, BMI and %BF ($r=.34$ to $r=.60$, $p < 0.0001$), which was expected given that cutoff values for WHR have been assigned to indicate central obesity and its respective co-morbidity for health screening [11, 35–37]. Our study lends support for sex-specific differences in using WC to predict %BF (i.e. total body fatness). Both WC-MP and WC-suprailiac site measures had robust predictive value for categorizing body fatness in men, using cutoffs of 83 cm and 88 cm respectively (Table 3). When used to calculate WHR, the WHR-MP and WHR-suprailiac were moderately predictive of %BF, but neither WC site was predictive of %BF in women (Table 3).

WC is an independent predictor of disease risk separate from BMI [38]. The InterAct case-cohort study [38] found that WC-narrowest and WC-MP (corrected for measures over clothing) were independently and strongly associated with T2D among older adults, particularly in women. Consistent with those results, our study determined that WC-MP correlated with insulin ($p .001$) and triglycerides ($p .002$) and emerged as a sensitive and specific biomarker for categorizing MetS risk in women. Rather than using WC-MP, the NHLBI recommends WC-suprailiac in conjunction with BMI to classify risk for CVD, T2D, and hypertension in adults [11]. The National Cholesterol Education Program Expert Panel [8] also specifies use of WC (i.e., WC-suprailiac) to define abdominal obesity and for inclusion as a clinical determinant of MetS [8]. However in our study, best fit ROC identified WC-MP as having higher predictive value than WC-suprailiac for risk of MetS (Table 3). In addition to highlighting the importance of WC site selection for predictive power in MetS, our finding that WC-MP had predictive value for MetS in women but not in men (Table 3) lends support for sex-specific differences in using WC to predict disease risk. Moreover, the National Cholesterol Education Program Expert Panel [8] considered that some men can develop multiple metabolic risk factors when the WC is only marginally increased (i.e., falls below the >102 cm cutoff). Thus, these experts concluded that WC or any of the other risk factors alone is not sufficient to identify the MetS, but rather, three or more cutoffs must be exceeded of WC, triglycerides, HDL cholesterol, BP and/or fasting glucose for clinical identification. In our sample, WC had stronger predictive value than WHR in that WHR-MP and WHR-suprailiac lacked sufficient sensitivity to distinguish health outcomes (Table 3).

None of the sites of circumference measurement achieved even moderate best-fit values for distinguishing abnormal BP. The incidence of overweight and prehypertension among self-described healthy students underscores the need for health screening in college. The American College Health Association (ACHA) has renewed enthusiasm for advocating that college campuses establish wellness and health promotion programs [39, 40]. ACHA recently published planning guidelines and health objectives that include baseline values and targets for healthy body weight. Such efforts can be synchronized with low-cost screening measures that are validated for the identification and referral of college-aged students who would most benefit from in-depth nutrition assessment and health education. Further research is needed to identify which circumference measures would be most valuable for screening college students.

Limitations

The primary purpose of this study was to determine whether significant associations could be detected between circumference measures and traditional biomarkers of CVD and MetS using a relatively small cohort of approximately 100 students who participated by donating blood samples and agreed to BP measures. Considering that there are distinct gender-associated variations in body composition, anthropometric measures and several clinical indicators of health (e.g., WC, HDL cholesterol) [10, 23] that further limit the sample size, we were unsure whether the association between circumference measures and disease risk would emerge. Despite the small sample, significant correlations were detected for NC with LDL cholesterol, for NC and WC-MP with insulin and triglycerides, and for WC-MP as a robust predictor of MetS in women. These findings in a predominantly African-American cohort may not be generalizable to other racial or ethnic groups.

Although these preliminary results are encouraging, a small number of true positives within the two risk factors reported (%BF and MetS criteria) form the basis of the biomarker cutoff values (Table 3). Thus, more robust evidence is needed from independent larger-scale studies that enroll socio-economically diverse students across a wide spectrum of pre-existing health conditions to improve the selection of sensitive and specific cutoffs for screening measures, as well as to determine which if any predictive variables are impacted by ethnicity and sex. Following students long term would enable testing of predictive measurements on outcomes of obesity and disease. Moreover, future studies could determine whether the predictive value of BMI, commonly used in nutrition screening and other health screening, can be increased by supplementing the BMI with circumference measures [38].

Despite the limitations of this preliminary study, the identification of WC-MP as having predictive value for MetS in women raises the potential for incorporating this relatively non-invasive and inexpensive measure into nutrition screening tools and other health screening if its value can be confirmed by other studies, including confirmation of a specific cutoff value. Measures such as WC-MP that require some training and experience to execute [15] and that fall squarely within the scope of dietetic practice, help to provide further recognition for the unique role and contributions of registered dietitians in public health.

CONCLUSIONS

This study investigated the correlation of NC and measures of central obesity (WC and WHR) with biomarkers of glucose dysregulation and dyslipidemia in a cohort of predominantly African American college students. The finding of substantially elevated BP and the prevalence of overweight in otherwise healthy college students underscores the need for registered dietitians working in university and public health settings to consider screening tools that identify higher-risk individuals in this 18–25 y age group who would benefit from more in-depth assessment and tailored interventions. However, such screening efforts require institutional support. There are state-required health screenings for students in public education through 12th grade and we raise the question of whether institutions of higher education might also play a public health role and routinely offer health screenings on campus.

The use of NC is novel for health screening and these data represent some of the first US measurements obtained in young adults. NC correlated with LDL cholesterol ($p = 0.02$) and both NC and WC-MP correlated with insulin ($p = .001$) and triglycerides ($p = .002$). Further studies are needed of college students that include those with MetS or MetS risk factors to establish possible NC predictors for MetS risk. WC-suprailiac, the measurement site used by NHLBI for adults [11–12], was not capable of distinguishing MetS risk in this young sample but a cutoff of 88 cm was determined to categorize men as having lower or higher levels of total body fat. In contrast, a cutoff of 75 cm for WC-MP was a sensitive and specific indicator of MetS risk in women. Further studies are needed to confirm these specific cutoffs and their usefulness in nutrition screening and other health screening.

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Table 1

Demographic characteristics, anthropometric measures, and cardiovascular risk factors by sex in a cohort of predominantly African American college students.

Continuous Variables	Women ^a (n=68)	Men (n=41)	Classification Variables		Women ^a (n=68)	Men (n=41)
Normally Distributed Variables						
Age (y)	Mean (SD) 19.3 (1.6)	Mean (SD) 19.7 (1.5)	Race	Black African, African American	n (%) 61 (89.7)	n (%) 39 (95.1)
Height (cm)	164.1 (6.2)	176.4 (5.6) ^c		Multiracial	6 (8.8)	1 (2.4)
Neck Circumference (cm)	33.7 (2.5)	38.6 (2.3) ^c		Other	1 (1.5)	1 (2.4)
WHR-waist at mid-point	0.81 (0.06)	0.85 (0.06)		Freshman	31 (45.6)	7 (17.1)
%BF	31.7 (8.4)	20.6 (8.3) ^c		Sophomore	13 (19.1)	13 (31.7)
SBP (mmHg) ^b	109.1 (7.0)	120.1 (8.8) ^c	Junior	12 (17.6)	12 (29.3)	
DBP (mmHg)	64.2 (6.0)	67.3 (6.2)	Senior	11 (16.2)	7 (17.1)	
Glucose (mg/dL)	84.4 (7.0)	87.3 (7.3)	Not Specified	1 (1.5)	2 (4.9)	
Total Cholesterol (mg/dL)	157.5 (28.5)	148.6 (30.3)	Body Fat Status (%)	Lean to Moderate Fat Accumulation (males <25%, females <35%)	35 (59%)	27 (75%)
HDL Cholesterol (mg/dL)	62.9 (13.1)	54.5 (12.8) ^d		High Fat Accumulation (males 25%, females 35%)	24 (41%)	9 (25%)
LDL Cholesterol (mg/dL)	81.3 (24.1)	81.2 (23.8)	Weight Status (BMI kg/m ²)	Underweight (<18.5)	3 (4.4)	0 (0)
Non-Normally Distributed Variables						
Weight (kg)	Median (IQR) 66.7 (20.3)	Median (IQR) 74.0 (17.9) ^d		Normal (18.5, <25)	32 (47.1)	24 (58.5)
Body Mass Index (kg/m ²)	24.7 (5.9)	24.3 (5.0)		Overweight (25, <30)	20 (29.4)	11 (26.8)
WC-at narrowest curve (cm)	75.0 (14.3)	78.1 (9.2)		Obese (30)	13 (19.1)	6 (14.6)
WC-at mid-point (cm)	78.7 (15.9)	79.1 (10.4)	Blood Pressure Status	Normal (<120 SBP and <80 DBP mmHg)	63 (94.0)	23 (56.1)
WC-at superior iliac crest (cm)	84.9 (13.0)	79.6 (14.2) ^e		Prehypertension (120–139 SBP or 80–89 DBP mmHg)	4 (6.0)	15 (36.6)
Hip Circumference (cm)	99.2 (14.3)	95.1 (12.1) ^e	LDL Cholesterol Status	Stage I Hypertension (140–159 SBP or 90–99 DBP mmHg)	0 (0)	3 (7.3)
WHR-waist at superior iliac crest	0.85 (0.07)	0.85 (0.06)		Normal (<130 mg/dL)	64 (97.1)	40 (97.6)
Insulin (IU/mL)	8.0 (6.0)	5.0 (5.5)	Metabolic Syndrome Risk Factors	Elevated (130 mg/dL)	2 (2.9)	1 (2.4)
				One or more metabolic syndrome risk factors	30 (44.1)	11 (26.8)
				Abdominal Obesity (WC- Suprailiac > 88 cm, women; >102 cm, men	27 (39.7)	4 (9.8)

Continuous Variables		Women ^a (n=68)	Men (n=41)	Classification Variables		Women ^a (n=68)	Men (n=41)
Normally Distributed Variables		Mean (SD)	Mean (SD)			n (%)	n (%)
Hemoglobin A1c		5.5 (0.4)	5.5 (0.5)	HDL Cholesterol (< 50 mg/dL, women; <40 mg/dL, men)		11 (16.7)	4 (9.8)
Triglyceride (mg/dL)		60.0 (27.0)	63.0 (32.0)	Triglyceride (150 mg/dL) Glucose (110 mg/dL)		1 (1.5)	0 (0)
				Blood Pressure (130 SBP/ 85 DBP mm Hg)		0 (0)	0 (0)
						0 (0)	5 (12.2)

^aWomen: blood pressure, WC-at narrowest curve, hip circumference n=67; WC-at mid-point, WC-at superior iliac crest, laboratory specimens except insulin, n=66; %BF and insulin, n=59. Men: hip circumference and all WC, fasting glucose, n=40; %BF, n=36; insulin, n=28.

^b%BF, total body fat percentage; BMI, body mass index; CHD, coronary heart disease; DBP, diastolic blood pressure; HDL, high density lipoprotein cholesterol; IQR, interquartile range; LDL, low density lipoprotein; SBP, systolic blood pressure; WC, waist circumference; Mid-point, half-way between lower rib and superior iliac crest, WHR, waist hip ratio; all circumference measures from right side, except WC-at narrowest curve was viewed from the back.

^cWomen vs. men, P<.0001;

^dP<.01;

^eP<.05.

Table 2

Repeat variability (within subject variation) of circumferences in a cohort of predominantly African American students measured three times per participant during one visit.

	Women (n=68)	Men (n=41)
Circumference^a	Coefficient of Variation (%)	
Neck	7.5	6.1
Waist-at narrowest curve	15.8	13.7
Waist-at mid-point, half-way between lower rib and superior iliac crest	16.0	18.0
Waist-at superior iliac crest	14.9	17.7
Hip	10.2	11.2

^a All measures by standardized protocols on right side, except the narrowest curve of the waist was viewed from the back.

Table 3

Best fit in receiver operating characteristic (ROC) analysis of NC, WC and WHR to distinguish categories of body fatness and presence of MetS risk factors by sex in a cohort of predominantly African American college students. *

	Risk Factor	Predictive Biomarker	Biomarker Cut-offs (cm)	Sensitivity (TP/(TP+FN))	Specificity (TN/(TN+FP))	ROC Best Fit	Selected Biomarker Cut-offs (cm)
Women (n=68; age 18–25 y)	Body Fatness (lower fat vs. higher fat)	NC	35.5	0.417	0.971	0.388	
		WC-MP	86	0.667	0.971	0.638	
	MetS Criteria (no positive risk vs. 1 risk factor)	WC-Suprailiac	88	0.750	0.829	0.579	
		WHR-MP	0.87	0.417	0.971	0.388	
		WHR-Suprailiac	0.87	0.542	0.800	0.342	
		NC	33.5	0.580	1.000	0.580	
Men (n=41; age 18–25 y)	Body Fatness (lower fat vs. higher fat)	WC-MP	75	0.900	1.000	0.900	75
		WC-Suprailiac	88	0.667	0.667	0.333	
	MetS Criteria (no risk vs. 1 risk factor)	WHR-MP	0.79	0.620	0.875	0.495	
		WHR-Suprailiac	0.93	0.417	0.889	0.306	
		NC	38.0	0.889	0.654	0.543	
		WC-MP	83	1.000	0.885	0.885	83
		WC-Suprailiac	88	1.000	0.923	0.923	88
		WHR-MP	0.88	0.778	0.962	0.739	
		WHR-Suprailiac	0.90	0.778	0.962	0.739	
		NC	41.5	0.222	0.903	0.125	
	MetS Criteria (no risk vs. 1 risk factor)	WC-MP	92	0.571	1.000	0.571	
		WC-Suprailiac	88	0.444	0.774	0.219	
		WHR-MP	0.88	0.500	0.962	0.462	
		WHR-Suprailiac	0.93	0.333	0.935	0.269	

* FN, false negative; MetS, metabolic syndrome; MP, waist measured at the mid-point, half-way between the lower rib and superior iliac crest; NC, neck circumference; Suprailiac, waist measured at the superior iliac crest; TP, true positive; WC, waist circumference; WHR, waist-hip ratio. A perfect classification prediction method would yield a ROC coordinate of 0.1 (a best fit value of 1.0).