Relation between Body Mass Index and Body Fat in Black Population Samples from Nigeria, Jamaica, and the United States


Body mass index (BMI) is the most commonly used measure of obesity. Recently, some investigators have advocated direct measurement of adiposity rather than use of the BMI. This study was undertaken to determine the ability of BMI to predict body fat levels in three populations of West African heritage living in different environments. A total of 1,054 black men and women were examined in Nigeria, Jamaica, and the United States during 1994 and 1995. A standardized protocol was used to measure height, weight, waist and hip circumferences, and blood pressure at all sites; percentage of body fat was estimated using bioelectrical impedance analysis. Percentage of body fat and BMI were highly correlated within site- and sex-specific groups, and the resulting $r^2$ ranged from 0.61 to 0.85. The relation was quadratic in all groups except Nigerian men, in whom it was linear. The regression coefficients were similar across sites, yet the mean body fat levels differed significantly ($p < 0.001$) as estimated by the intercept, making intersite comparison difficult. Compared with BMI, percentage of body fat was not a better predictor of blood pressure or waist or hip circumference.

The prevalence of obesity is increasing in both industrialized nations and those undergoing alterations in diet and activity patterns as a result of increasing westernization (1). It has been shown that increases in the prevalence of obesity within a population often precede a rise in the occurrence of chronic diseases, such as diabetes mellitus and hypertension (2). Also of concern to public health researchers in developing countries is the decrease in body weight and body fat associated with inadequate food and energy supplies on a national level (3). To reliably measure and monitor levels of obesity and/or undernutrition within and between populations, easy-to-use methods of determining body composition are needed.

To date, the most commonly used method of determining relative fatness has been the body mass index (BMI). Although an often-cited definition of obesity is the 95th percentile of BMI from the First National Health and Nutrition Examination Survey (NHANES I) (4), the use of BMI in this context has been controversial, because the correlation between BMI and body fat typically is less than 0.60 (5–9). BMI, expressed as weight/height$^2$, was not originally intended as a measure of adiposity but rather as a means of comparing body weights independently of height (10). Adiposity, however, irrespective of weight, is believed to be a primary risk factor for diabetes and cardiovascular disease (11), providing a rationale for the use of methods which measure body composition directly.

Debate over the value of BMI for the estimation of body fat has recently led some investigators to recommend the use of new technologies for the direct measurement of body fat levels in epidemiologic research (8). For epidemiologic studies with large samples, bioelectrical impedance analysis (BIA) appears to be an ideal tool. Based on the principles governing the electrical impedance of body tissues, BIA provides a rapid, noninvasive, and relatively accurate and precise estimation of total body water, from which body composition is derived (12).

The purpose of this study was to compare the relations between BMI and percentage of body fat, as measured by BIA, in populations with similar genetic backgrounds but different environments. BIA was validated and subsequently used to estimate body com-

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position among three distinct populations of West African descent, and the relation between BMI and body fat content was determined for each site- and sex-specific group.

Well-described relations exist between BMI and blood pressure (13, 14) and between BMI and measures of regional fat distribution (15, 16). It is not obvious, however, whether it is weight or adiposity which influences these relations. For this reason, we also assessed the degree to which BMI and percentage of body fat explained the between-person variance observed in blood pressure and anthropometric measurements in these populations.

**MATERIALS AND METHODS**

**Sampling procedure**

The study was conducted at three field sites of the International Collaborative Study on Hypertension in Blacks: Idikan, Ibadan, Nigeria (n = 314); Spanish Town, Jamaica (n = 242); and Maywood, Illinois, United States (n = 335). An additional 181 individuals (65 men and 116 women) from the US site were participants in a clinical trial of the reduction of dietary fat, the Fat Reduction Intervention Trial in African Americans. Data presented here were obtained at baseline, prior to the intervention. Participant recruitment for the intervention trial was conducted using the same sampling strategy as that used in the hypertension survey.

The cluster sampling technique—probability proportional to size—was used at all sites to recruit equal proportions of adult men and women aged 25 years or over. Clusters (e.g., city blocks in the United States, enumeration districts in Jamaica, and villages in rural Nigeria) were identified, and the approximate sizes of the populations were ascertained. After random selection of appropriate clusters, all black adults residing within the clusters were asked to participate in the survey. The final number of clusters selected was determined by the sizes of the clusters and the participation rate at each site. Details on the sampling strategy are given elsewhere (17).

**Body measurements**

BIA, anthropometric data, and blood pressure were measured using standardized procedures by field staff local to each site who had been trained by centrally certified supervisors (17). Body composition was determined by BIA. BIA measures the impedance of body tissues to the flow of an applied mild alternating current. Impedance is a function of two components, the resistance of the tissues and the additional opposition, called reactance, due to the capacitant effect of cell membranes, tissue interfaces, and nonionic tissues (12). The measured impedance of body tissues provides an estimate of total body water from which fat-free mass and fat mass can be calculated.

All BIA measurements were performed using a single-frequency (50-kHz) battery-operated bioimpedance analyzer (model BIA 101Q; RJL Systems, Clinton Township, Michigan). A tetrapolar placement of electrodes was used, with current electrodes placed on the dorsal surfaces of the right hand and foot at the distal metacarpals and metatarsals, respectively, and the detector electrodes placed at the pisiform prominence of the right wrist and between the medial and lateral malleoli at the right ankle (18).

The deuterium dilution method (19) was used for validation of BIA estimation of body fat levels. In a separate sample of 15 adults in Nigeria, 21 in Jamaica, and 8 in the United States, representing a BMI range of 16 to 39, total body water was determined using BIA and previously published predictive equations (20) and was compared with total body water measured using deuterium dilution. With the deuterium dilution method, an oral dose of deuterium oxide (0.08 g per kg of body weight, 99.9 percent deuterium; Cambridge Isotopes, Worcester, Massachusetts) was administered and was allowed to equilibrate with body water. Urine was sampled before deuterium oxide administration and following equilibration, 4–6 hours after dosing, and was analyzed for deuterium content. Using simple dilution principles, total body water was calculated from the increase in the deuterium content of the urine from baseline to equilibration. Stable isotopic analyses were performed by the Clinical Nutrition Research Unit of the University of Chicago. For the BIA measurements, total body water was calculated from resistance, height, weight, and sex using published equations. Although several of the most commonly cited equations provided good estimates of total body water, the best fit was obtained using the equations of Kushner and Schoeller (20). The mean deviation of the BIA-derived total body water from the isotopically determined body water was −0.2 kg (95 percent confidence interval (CI) −0.7 to 0.3), corresponding to +0.2 percent (95 percent CI −1.2 to 0.8) body fat, for all sites combined. (Data for the individual sites were: +0.4 percent (95 percent CI −1.2 to 2.0) fat in Nigeria, 0 percent (95 percent CI −1.5 to 1.5) in Jamaica, and +0.3 percent (95 percent CI −1.3 to 1.9) in the United States.) No BIA-derived total body water × site interaction was observed (p > 0.50). Thus, the same equations were used for all data collected at the three field sites, with subsequent extrapolation to fat-free mass, fat mass, and percentage of fat mass.
Of the original 314 participants in Nigeria, 16 (one woman and 15 men) were omitted from data analysis because the BIA resistance values obtained resulted in negative values for percentage of body fat. The mean BMI of the 16 omitted participants was 3.9 units lower than the mean for that population, and several had total cholesterol levels less than 2.8 mmol/liter; thus, these individuals were extremely lean and were probably chronically undernourished (21). Data on two male participants from Jamaica were omitted because of negative BIA values, and no data were omitted from the United States (n = 516). The equations that best fitted our validation population and were subsequently used for all three sites overestimated total body water somewhat in extremely lean persons, resulting in implausibly low levels of body fat. In our validation group, six men had extremely low levels of body fat as measured using deuterium dilution (less than 10 percent, with a minimum of 4 percent). In these men, the applied BIA equations estimated total body water with the same accuracy as in the validation group as a whole, and mean deviation from the isotopically determined total body water was only —0.3 kg. Thus, it was not possible to determine the exact level of body fat or the corresponding BMI at which overestimation of total body water occurred among the Nigerian and Jamaican participants. Because of the lack of individuals with extremely low levels of body fat at the US site, further testing of the prediction equation could not be carried out. Equations developed for a clinically malnourished population, i.e., patients with Crohn’s disease (22), could not be validated in our population, and thus were not used for the extremely lean individuals.

Standing height was measured without shoes to the nearest 0.1 cm at all sites. In the United States, weight was measured to the nearest 0.25 pound (0.1 kg) using a balance scale (Health-o-Meter, Inc., Bridgeview, Illinois). In both Jamaica and Nigeria, weights were measured to the nearest 0.1 kg using a calibrated electronic scale with digital readout (Seca Corporation, Columbia, Maryland). BMI was calculated as weight (kg)/height (m)². Waist circumference was measured to the nearest 0.1 cm at the narrowest part of the torso as seen from the anterior aspect. In obese subjects for whom it was difficult to identify a narrowing of the torso, the smallest horizontal circumference in the area between the lowest rib and the iliac crest was utilized. Hip circumference was measured to the nearest 0.1 cm at the point of maximum extension of the buttocks. Repeat measurements were obtained for waist and hip circumferences, and a third measurement was made if the difference between the first two readings was more than 0.5 cm.

Blood pressure was measured three times using a standard mercury manometer with the participant seated (17). A 30-second radial pulse was taken and, with the antecubital fossa at heart level, an initial systolic pulse disappearance level was measured. Three subsequent auscultatory readings were taken, with additional pulse measurements made between readings.

Statistical methods

Basic descriptive statistics, including mean values, proportions, and Pearson’s correlation coefficients, were calculated. Multivariate linear regression was performed taking percentage of body fat as the response variable and BMI as the explanatory variable. The model was also fitted with additional covariates to test for interactions. First, a dummy variable for sex was considered for each site to study the interaction between sex and BMI. Second, two dummy variables for site were defined, which in turn were used to test the interaction between site and BMI (23). All statistical analyses were carried out using Stata for Windows (24).

The study protocol was approved by the Institutional Review Board of Loyola University’s Stritch School of Medicine; by the University of the West Indies, Kingston, Jamaica; and by University College Hospital, Ibadan, Nigeria.

RESULTS

An obvious trend was observed for all anthropometric variables across sites (table 1). For both sexes, height, weight, waist and hip circumference, BMI, and percent body fat were lowest in Nigeria and greatest in the United States, with intermediate values in Jamaica.

The relation between BMI and percent body fat is presented for men and women in figure 1. Among women, BMI and BMI² were both determined to be significant, irrespective of site (table 2). Among the men, however, the relation varied by site. In the United States and Jamaica, the relation between BMI and percent body fat was also quadratic. In Nigeria, where there was only one male with a BMI greater than 35, the best-fitting mathematical relation was linear. In addition, because of questions concerning the validity of BIA at the extremes of BMI (25), we also truncated the data from all sites at BMI = 35 and reanalyzed the regression models. The quadratic relation was maintained among women in all populations and among the Jamaican and US men; the levels of correlation were maintained to within 5 percent for all site- and sex-specific groups. Utilizing the quadratic model for the full range of data explains 75 percent, 82
TABLE 1. Sex- and site-specific characteristics of participants in a study of body fat measures, 1994–1995

<table>
<thead>
<tr>
<th>Sex and site</th>
<th>No. of participants</th>
<th>Age* (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI†</th>
<th>Waist (cm)</th>
<th>Hip (cm)</th>
<th>Body fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SD</td>
<td>Mean SD</td>
<td>Mean SD</td>
<td>Mean SD</td>
<td>Mean SD</td>
<td>Mean SD</td>
<td>Mean SD</td>
<td>Mean SD</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>137</td>
<td>48.7 17.8</td>
<td>169.6 7.1</td>
<td>63.0 12.3</td>
<td>21.7 3.9</td>
<td>78.4 11.0</td>
<td>87.8 9.8</td>
<td>11.4 7.5</td>
</tr>
<tr>
<td>Jamaica</td>
<td>94</td>
<td>43.2 13.8</td>
<td>172.7 8.2</td>
<td>70.2 11.5</td>
<td>23.6 4.4</td>
<td>79.1 9.3</td>
<td>94.7 7.4</td>
<td>19.2 7.6</td>
</tr>
<tr>
<td>United States</td>
<td>189</td>
<td>41.2 13.3</td>
<td>177.1 6.6</td>
<td>85.0 18.7</td>
<td>27.0 5.7</td>
<td>92.1 14.4</td>
<td>104.2 11.0</td>
<td>27.1 7.8</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>161</td>
<td>43.4 15.3</td>
<td>158.4 6.6</td>
<td>59.6 13.3</td>
<td>23.6 5.0</td>
<td>79.1 11.7</td>
<td>95.0 11.4</td>
<td>25.1 10.4</td>
</tr>
<tr>
<td>Jamaica</td>
<td>146</td>
<td>43.0 14.9</td>
<td>161.3 7.0</td>
<td>70.2 15.5</td>
<td>27.0 6.0</td>
<td>82.7 9.7</td>
<td>104.7 10.4</td>
<td>35.3 8.4</td>
</tr>
<tr>
<td>United States</td>
<td>327</td>
<td>43.2 14.5</td>
<td>163.8 6.2</td>
<td>83.1 21.5</td>
<td>30.9 7.9</td>
<td>91.9 16.3</td>
<td>112.6 15.8</td>
<td>42.2 7.9</td>
</tr>
</tbody>
</table>

* Age was unknown for 45 individuals (32 men and 13 women) at the Nigerian site.
† Weight (kg)/height (m)².
‡ SD, standard deviation.
TABLE 2. Sex- and site-specific regression coefficients for the relation between body mass index* (BMI) and percentage of body fat, 1994-1995†

<table>
<thead>
<tr>
<th>Sex and site</th>
<th>Intercept</th>
<th>β₁ (BMI)</th>
<th>β₂ (BMI²)</th>
<th>SEE†</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>-21.39</td>
<td>1.51</td>
<td>-0.018§</td>
<td>4.7</td>
<td>0.61</td>
</tr>
<tr>
<td>Jamaica</td>
<td>-19.74</td>
<td>1.66</td>
<td></td>
<td>3.7</td>
<td>0.73</td>
</tr>
<tr>
<td>United States</td>
<td>-2.64</td>
<td>1.11</td>
<td>-0.028</td>
<td>4.6</td>
<td>0.66</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>-17.00</td>
<td>1.78</td>
<td>-0.043</td>
<td>5.4</td>
<td>0.74</td>
</tr>
<tr>
<td>Jamaica</td>
<td>2.70</td>
<td>1.21</td>
<td></td>
<td>4.2</td>
<td>0.75</td>
</tr>
<tr>
<td>United States</td>
<td>14.83</td>
<td>0.88</td>
<td>-0.042</td>
<td>3.7</td>
<td>0.78</td>
</tr>
</tbody>
</table>

* Weight (kg)/height (m)²  
† All p values were less than 0.001.  
‡ SEE, standard error of the estimate  
§ BMI² was not a significant covariate in the model.

percent, and 85 percent of the variance in percent body fat in Nigerian, Jamaican, and US women, respectively. Among Jamaican and US men, 78 percent and 70 percent of the variance was explained by BMI and BMI², respectively. Sixty-one percent of the variance in percent body fat among Nigerian men was described by BMI. Standard errors for the prediction of percent body fat ranged from 3.6 percent to 4.7 percent among the men and from 3.0 percent and 5.4 percent among the women (table 2).

Age was not consistently found to be a significant variable in the regression of percent body fat on BMI. This observation did not change with the truncated data (maximum BMI = 35). Age was found to be a significant predictor among Nigerian men (p < 0.01), where the relation was positive, and among Jamaican women (p < 0.05), where the relation was negative. In neither case, however, was r² changed by the addition of age. Therefore, age was not included in any of the results presented here.

Sex was a significant predictor variable at each site (p < 0.001). Regression coefficients for the combined data from men and women are presented in table 3. The mean levels of percent body fat varied across BMI values uniformly for each sex at a given site (figure 1); i.e., within each site, the difference in percent body fat for men and women was approximately constant across the range of BMI values. The shape of the relation between percent body fat and BMI was not modified by sex, which implies that there was no sex × BMI interaction within each site. Women, on average, had 11 percent higher percent body fat values than men at any given level of BMI (p < 0.001).

There was a clear trend across levels of BMI. US men and women had the greatest mean percentage of body fat, followed by Jamaicans; Nigerians had the lowest mean (p < 0.001) (figure 2). It is apparent from figure 2 that the sex-specific functional relation between percent body fat and BMI was modified by site. That is, there was a BMI × site interaction across the sexes. However, this finding was shown to be statistically significant for women but not for men—i.e., we had enough power to detect an interaction between site and BMI for women only. The model containing BMI, BMI², sex, and site explained over 90 percent of the variance at all sites combined (table 3).

Percent body fat did not account for more of the variance in waist circumference, hip circumference, waist:hip ratio, or blood pressure than did BMI (table 4).

DISCUSSION

Some investigators have recommended the abandonment of BMI as a measure of obesity in favor of more direct measures of body fat (6, 8), and several published reports have provided evidence to support this contention (5-9, 26-31). We found, however, that within populations of American, Jamaican, and Nigerian blacks, BMI was a relatively good predictor of level of body fat. At the same time, mean levels of body fat varied substantially at similar levels of BMI.
TABLE 3. Regression coefficients for the relation between body mass index* (BMI) and percentage of body fat, adjusted for sex and site, 1994-1995†

<table>
<thead>
<tr>
<th>Site</th>
<th>No. of participants</th>
<th>Intercept_BMI</th>
<th>$\beta_1$ (BMI)</th>
<th>$\beta_2$ (BMP)</th>
<th>$\beta_3$ (Site)</th>
<th>$\beta_4$ (Sex)</th>
<th>SEE† (%fat)</th>
<th>SEE*</th>
<th>$r^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>298</td>
<td>-45.17</td>
<td>3.59</td>
<td>-0.033</td>
<td>-0.030</td>
<td>10.34</td>
<td>7.1</td>
<td>0.62</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>-43.86</td>
<td>3.23</td>
<td>-0.030</td>
<td>10.34</td>
<td>5.0</td>
<td>0.81</td>
<td></td>
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</tr>
<tr>
<td>Jamaica</td>
<td>240</td>
<td>-45.70</td>
<td>4.11</td>
<td>-0.044</td>
<td>-0.038</td>
<td>11.48</td>
<td>6.5</td>
<td>0.67</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>-40.18</td>
<td>3.44</td>
<td>-0.038</td>
<td>11.48</td>
<td>3.6</td>
<td>0.90</td>
<td></td>
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</tr>
<tr>
<td>United States</td>
<td>516</td>
<td>-22.58</td>
<td>2.81</td>
<td>-0.026</td>
<td>-0.025</td>
<td>11.47</td>
<td>6.4</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-24.04</td>
<td>2.61</td>
<td>-0.026</td>
<td>11.47</td>
<td>3.5</td>
<td>0.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All sites combined</td>
<td>1,054</td>
<td>-47.98</td>
<td>4.11</td>
<td>-0.042</td>
<td>-0.033</td>
<td>11.20</td>
<td>7.3</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-47.38</td>
<td>3.79</td>
<td>-0.040</td>
<td>10.96</td>
<td>5.1</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-40.75</td>
<td>3.15</td>
<td>-0.033</td>
<td>11.20</td>
<td>4.02</td>
<td>4.1</td>
<td>0.91</td>
<td></td>
</tr>
</tbody>
</table>

* Weight (kg)/height (m)^2.  
† All p values were less than 0.001.  
‡ Men = 0, woman = 1.  
§ Nigeria = 0, Jamaica = 1, United States = 2.  
¶ SEE, standard error of the estimate

between populations. The differences observed between populations were directly analogous to the difference observed between men and women at each site. At any level of BMI, women had greater mean levels of body fat than did men ($p < 0.001$). At any BMI, the mean level of body fat increased with increasing industrialization ($p < 0.001$). Although age was not a significant predictor of percent body fat after data were adjusted for BMI, this finding has been observed previously (9, 28, 31–33).

The cross-group differences observed in the present study are clearly the result of population- and sex-specific differences in the ratio of fat-free mass to fat mass at any given weight. Men have a greater proportion of fat-free mass than women, Nigerians have a greater proportion than Jamaicans, and Jamaicans have a greater proportion than African Americans. Body composition is strongly influenced by both genetic and environmental factors (11). While the difference in body composition between men and women is due in large part to genetic and hormonal differences between the sexes, the differences observed between sites among these genetically similar populations must be due primarily to environment. The environmental factors most responsible for the determination of body composition are energy intake and energy expenditure in the form of physical activity level (34).

Between 61 percent and 85 percent of the variance in percent body fat could be explained by BMI for each of the six site- and sex-specific groups in the present study. The finding of a quadratic relation between BMI and percent body fat has been described

FIGURE 2. Regression lines for the relations between body mass index and percentage of body fat in Nigeria (—), Jamaica (—), and the United States (—), by sex, 1994-1995. The relations differ significantly within each sex across the sites ($p < 0.001$).

before (7, 8); however, the strength of the relations in the present study for the most part exceeds that of those reported from these studies. We recognize, however, that the correlations were somewhat inflated by the inclusion of height and weight in the calculation of percent body fat. In studies of primarily nonblack populations, \( r^2 \) has ranged from 0.35 to 0.71 (5–8, 27, 31). Gallagher et al. (9) recently reported coefficients of determination of 0.44 and 0.58 for black men and women, respectively. In their linear model, both BMI and age were significant coefficients. Most studies to date have utilized methods of determining body composition that are considerably more accurate than BIA but are unavailable to most institutions, are quite costly, and are virtually impossible to use at remote field sites—i.e., hydrodensitometry, isotope dilution, or dual photon absorptiometry. While the measurement of skinfold thickness for the estimation of body fat is a viable alternative to BIA, it is subject to significant inter- and intraobserver variability (32, 35). Using isotope dilution, we were able to validate the less well established BIA method in the field settings of the three international sites. It seems reasonable to conclude, therefore, that BMI is a valid proxy for measures of adiposity within these black populations.

While the relation between BMI and percent body fat is strong within populations, average body composition differed substantially across sites, making intersite comparisons of BMI difficult to interpret. For example, a BMI of 25 represented mean body fat levels of 25.8 percent, 22.2 percent, and 16.4 percent among US, Jamaican, and Nigerian men, respectively (\( p < 0.001 \)). Although comprehensive studies using informative genetic markers which are currently available have yet to be carried out, the historical record indicates that the populations we studied share a common West African ancestry (36). In contrast, the current environments of the three populations are very different in terms of the level of industrialization and its consequences for individual lifestyles. While food availability was not an issue for most participants from the US and Jamaican sites, a decrease in food supply had occurred over the previous 3 years in Nigeria (3, 37). Not only did food resources differ between the US, Jamaican, and Nigerian populations but physical activity patterns varied enormously. Energy intake and physical activity are both crucial determinants of body composition (34) and most likely explain the shift in the relation between BMI and body fat.

The question of the value of BMI in predicting adiposity is further confused by the fact that percent body fat is not necessarily a better predictor of blood pressure or anthropometric variables associated with chronic illness. Our results support previous findings that BMI is similarly or better correlated with blood pressure and plasma glucose levels than is body fat level (38).

One of the advantages of using BMI to define obesity was the availability of national data sets which could be used to establish standards, such as the 85th percentile of BMI in NHANES I designating overweight and the 95th percentile designating obesity (4). Currently, there are no large national data sets with data on body composition and no consensus on acceptable levels of body fat; suggested upper limits range from 25 percent to 33 percent for women and from 20 percent to 25 percent for men (39–42). BIA was used to estimate body composition in NHANES III (1988–1991); however, as of this writing those data have not yet been published.

In addition to the question of whether or not to directly measure adiposity in epidemiologic research, there is the issue of which method to use for its estimation. BIA appears to be a good method for estimating body fat at the population level. While it is a relatively accurate and inexpensive method to employ, there are questions about the reliability of BIA-derived estimates of body composition at the extremes of body fat distribution. Clearly, in the present study we were confronted with erroneous estimates of body fat among extremely lean individuals in the Nigerian and Jamaican samples. While we cannot be totally

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**TABLE 4. Estimated correlations of body mass index (BMI) and percentage of body fat with blood pressure and waist and hip circumference, by sex and site, 1984–1995**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nigeria</td>
<td>Jamaica</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>% fat</td>
</tr>
<tr>
<td>Waist circumference</td>
<td>0.90**</td>
<td>0.77**</td>
</tr>
<tr>
<td>Hip circumference</td>
<td>0.63**</td>
<td>0.81**</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>0.16</td>
<td>0.14</td>
</tr>
</tbody>
</table>

* \( p < 0.05; ** p < 0.01. 
† Weight (kg)/height (m). 
‡ Data were adjusted for age. 
§ No significant difference was found between correlation coefficients for body mass index and percentage of body fat.
confident of the validity of the technique and the predictive model used in the very lean or the very obese, we believe the method to be reliable across the normal range of BMI values found in most healthy populations. Thus, while some investigators have raised concerns about the use of BIA in epidemiologic research (43–45)—i.e., requirements for the standardization of protocols (46), the profusion of predictive equations in the literature (43), and inconsistencies between analyzers from different manufacturers (47, 48)—we believe it is currently the best option for measuring body composition in the field.

In summary, BMI is the most commonly used measure of obesity in epidemiologic research. In three different populations of West African heritage from the United States, Jamaica, and Nigeria, BMI was shown to provide good within-population estimates of body fat levels. However, the relations between BMI and body fat levels differed significantly across the three populations, making it impossible to compare the prevalence of obesity based on BMI between populations. In addition to sex, current environment, probably including dietary patterns and level of physical activity, can strongly influence the relation between BMI and body fat at the population level.

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REFERENCES