Comparison of existing skinfold equations for estimating body fat in African American and white women

L Jerome Brandon

ABSTRACT The purpose of this study was to compare seven skinfold equations with underwater weighing (UWW) for estimating body fat in 39 African American [age: 22.8 ± 3.6 y (x ± SD); weight: 59.6 ± 8.3 kg] and 39 white [age: 22.1 ± 2.9 y; weight: 61.7 ± 7.3 kg] women. The hypothesis examined was that the equations would produce more accurate body fat estimates in white women, but would be appropriate for use in African American women. Body fat estimated from two quadratic, three linear, and two logarithmic skinfold equations was compared with body fat estimated from UWW; the same procedures were used to evaluate the results in both African Americans and whites. The data were analyzed by using t tests, analysis of variance, Scheffé’s honestly significant difference tests, correlations, error assessments, and agreement. The results showed that total error, SEE, and SD values were larger in the African American women than in the white women and were not within acceptable limits listed in the literature. The correlation coefficients were lower in the African American women than in the white women. Agreement between the skinfold equations and UWW, based on deviations from mean differences, was better in the white women. In conclusion, the skinfold prediction equations evaluated in this study were more variable and produced more error when used in African American women. Therefore, population-specific equations in African American women should be used to estimate body fat because they will probably yield more accurate estimates. Am J Clin Nutr 1998;67:1155–61.

KEY WORDS Densitometry, skinfold prediction equations, body fat measurements, underwater weighing, African Americans, whites, women

INTRODUCTION African American women are reported to experience a disproportionately high prevalence of excess body fat and related diseases during middle adulthood (1, 2), the reasons for which are unclear. One reason could be the procedures used to estimate body fatness and obesity in this population. Many clinical, health, and fitness facilities use skinfold equations developed in white women to estimate body fat in African American women. Although skinfold equations have been used for several years, their accuracy in African American women has not been determined. Because the body composition of African American women may be different from that of white women, the critical assumptions on which skinfold equations were developed may be inappropriate in African American women (3, 4).

One critical assumption for accurate estimation of body fat from skinfold equations is that the density of fat-free mass (FFM) is consistent across populations. Research designed to determine the average FFM density (1.1 kg/L) for white males (5, 6) and white females (1.096 g/L (7) has been completed; however, there are limited data available on African Americans. Schutte et al (3) estimated the FFM density in 20 African American males to be 1.113 kg/L and Ortiz et al (2) estimated the FFM density in 19 African American females to be 1.106 kg/L. Findings by Pollitzer and Anderson (8) support the conclusion that FFM density is greater in African Americans than in whites because they reported that bone and muscle densities are greater in African American females than in white females. Because bone and muscle compose a significant portion of the nonfat portion of the body, the FFM density of African American females is expected to be different from that of white females.

Another critical assumption for accurate estimation of body fat, especially from skinfold thicknesses, is that the relation between the subcutaneous fat pattern and body density is constant between African Americans and whites (3, 9). Zillikens and Conway (10) reported a slightly different pattern of skinfold thickness between African American and white females, but they had no standard by which to determine whether differences were due to total body fat or to racial characteristics. African American females appear to have more truncal or centrally located fat deposits than do white women (2, 11–14). This conclusion is supported by Thomas et al (15), who found that estimates of regional fat, including the sum of truncal skinfold thicknesses, were different between African American and white females. Skinfold equations developed in white females will likely produce more error when used in African American females (3, 4, 11–13). Therefore, the purpose of this study was to evaluate the accuracy of a select group of existing skinfold equations in estimating body fatness in African American and white women. The

1 From the Department of Kinesiology and Health, Georgia State University, Atlanta.
2 Reprints not available. Address correspondence to LJ Brandon, Department of Kinesiology and Health, Georgia State University, Atlanta, GA 30303. E-mail: jbrand@gsu.edu.
Accepted for publication November 6, 1997.
hypothesis was that existing skinfold equations would produce more accurate body fat estimates in white women, but would also be appropriate in African American women.

SUBJECTS AND METHODS

A repeated-measures research design was used in this study. This design was modified from a procedure used by Sinning (14) to evaluate the effectiveness of skinfold equations in estimating body fat in female gymnasts. Sinning evaluated linear, quadratic, and logarithmic equations to determine whether the nonlinear generalized equations were more effective than linear equations. In the present study, the subjects were 78 female university students: 39 African Americans aged 22.8 ± 3.6 y (x ± SD) and 39 whites aged 22.1 ± 2.9 y. The study was approved by the University human subject review committee and subjects provided informed consent before participating in the study. Because many of the equations evaluated in this study are classified as generalized equations, a diverse cross-section of individuals who participated in a wide range of physical activities served as subjects. Body density was measured by underwater weighing and subcutaneous fat was measured at eight skinfold sites: subscapula, abdomen, suprailliac, midaxilla, chest, thigh, triceps, and biceps. All subjects received identical treatment.

Underwater weighing

Body density was estimated by underwater weighing (UWW). The subjects were weighed underwater while sitting in a chair attached to a Chatillon spring gauge scale (Vacu-Med, Ventura, CA) that was supported by the frame of the tank. The pulmonary residual volume was measured simultaneously with the underwater weight by using an oxygen-dilution procedure with a 505 Nitrolyzer Gas Meter (Med Science, St Louis). The procedure was described previously (9). Body density was calculated according to the procedures of Buskirk (16). Two trials were completed on the same day for each subject and a mean of the trials that were within 0.004 kg/L of each other was used as the body density value. If the two trials of a subject’s body density were not within 0.004 kg/L, the data for that subject were not included in the study. Percentage body fat (%fat) was calculated from body density with Lohman’s (7) equation for whites and Ortiz et al’s (2) equation for African Americans.

Skinfold-thickness measurements

All subjects were measured on the right side of the body with a Lange skinfold caliper (Cambridge Scientific Instruments, Cambridge, MA) by the same investigator. Skinfolds were measured at eight sites and the procedure was repeated three times. For a given site, the mean of three measurements was used for the skinfold-thickness value, and the skinfold sites measured were generally consistent with those recommended by Lohman et al (17). A specific description of site selections follows: 1) the subscapular skinfold was measured diagonally just inferior to the inferior angle of the scapula; 2) the abdominal skinfold was a vertical fold ∼3 cm laterally at the level of the umbilicus; 3) the suprailliac skinfold was measured at two locations, one diagonally at the midaxillary line immediately superior to the iliac crest and the other at the anterior-superior iliac spine; 4) the midaxillary skinfold was measured vertically at the level of the xiphosternal junction along the midaxillary line; 5) the chest skinfold was a diagonally measured fold along an axis from the anterior axillary line near the anterior axillary crease; 6) the thigh skinfold was measured vertically at the midline of the anterior aspect of the thigh midway between the inguinal crease and the proximal border of the patella; 7) the triceps skinfold was measured vertically at a point midway between the lateral projection of the acromion process and the inferior margin of the olecranon process of the ulna; and 8) the biceps skinfold was measured vertically over the belly at the mid length of the biceps.

Treatment and data analysis

Seven skinfold equations (two quadratic, three linear, and two logarithmic) were used to estimate body density (Table 1). Skinfolds were evaluated for differences between the African American and white women with a group t test. A repeated-measures analysis of variance (ANOVA) was used to determine whether %fat estimated with the skinfold equations (skinfold %fat) was different from %fat estimated by UWW (UWW %fat). Scheffé’s honestly significant difference test was used to determine which of the skinfold equations produced %fat values significantly different from those by UWW. A method of Bland and Altman (23) for assessing agreement between two methods was used on linear, quadratic, and logarithmic equations to further assess the accuracy of the skinfold prediction equations. Differences between individual UWW %fat values and individual skinfold %fat values were plotted against the mean of the two measures (UWW + skinfold/2). The scatter plot was evaluated by assessing the variability included in 2 SDs above and below the mean differences in fat measurements by the skinfold and UWW procedures. Product-moment correlations, SEEs [SEE = (SD)√1−r2, where SD is the SD of the UWW procedure], percentage of subjects whose skinfold %fat values were within 3.5% of UWW %fat values, and total errors [E = √(UWW−X)2/n, where UWW is %fat by UWW and X is %fat estimated by the skinfold equations] were determined. SPSS-X (SPSS Inc, Chicago) was used for the statistical analyses.

RESULTS

The physical characteristics of the subjects are listed in Table 2. Height and weight of the African American and white subjects were not significantly different. The African Americans had higher %fat values and tended to have larger central trunk measurements. The subscapular skinfold was the only skinfold that was significantly different between African American and white women (Table 3). Mean upper-body skinfold-thickness measurements were not significantly different according to race nor were the means for the sum of all skinfolds sites.

The results of an ANOVA of all possible comparisons showed that skinfold %fat values were different from UWW %fat values. Scheffé’s honestly significant difference test (Table 4), used to identify the nature of the differences revealed by the ANOVA, showed that %fat measured by Jackson et al’s (18) seven-sites equation and Durin and Womersley’s (22) four-sites equations produced average %fat values significantly greater than average UWW %fat values, whereas Sloan et al’s (19) equation produced an average %fat value that was significantly smaller than the average UWW %fat value for the African American women. For the white women, the equations of Sloan et al (19) and Katch and McArdle (21) produced average %fat values significantly smaller (P < 0.05) than UWW %fat values, but Wilmore and Behnke’s (20) equation, Jackson et al’s (18) seven-sites equa-
TABLE 1
Skinfold prediction equations

### Quadratic equations

1. Jackson et al’s (18) three sites
   \[ D_b = 1.0994921 - 0.0000929 \times X_1 + 0.0000023 \times X_1^2 - 0.001392 \times \text{age} \]
   \((X_1 = \text{triceps} + \text{SIA} + \text{thigh skinfolds})\)

2. Jackson et al’s (18) seven sites
   \[ D_b = 1.0970 - 0.00046971 \times X_2 + 0.00000056 \times X_2^2 - 0.00012828 \times \text{age} \]
   \((X_2 = \text{triceps} + \text{SIA} + \text{thigh} + \text{chest} + \text{axilla} + \text{subscapula} + \text{abdomen skinfolds})\)

### Linear equations

3. Sloan et al (19)
   \[ D_b = 1.0764 - 0.000081 \times \text{SIM} - 0.00088 \times \text{triceps} \]

4. Wilmore and Behnke (20)
   \[ D_b = 1.06234 - 0.00068 \times \text{subscapula} - 0.00039 \times \text{triceps} - 0.00025 \times \text{thigh} \]

5. Katch and McArdle (21)
   \[ D_b = 1.08347 + 0.0006 \times \text{triceps} - 0.00151 \times \text{subscapula} - 0.00097 \times \text{thigh} \]

### Logarithmic equations

6. Durnin and Womersley (22) three sites
   \[ D_b = 1.1566 - 0.0728 \times (\log \text{SIM} + \text{triceps} + \text{subscapula}) \]

7. Durnin and Womersley (22) four sites
   \[ D_b = 1.1599 - 0.0717 \times (\log \text{triceps} + \text{subscapula} + \text{biceps} + \text{SIM}) \]

### Notes

1. Body density \((D_b)\) was converted to percentage body fat \((%\text{fat})\) by using Lohman’s (7) equation \([%\text{fat} = (503.3/D - 459.2)]\) for white women and by using Ortiz et al’s (2) equation \([%\text{fat} = (483.2/D - 436.9)]\) for African American women. SIA, suprailliac anterior-superior to the spine; SIM, suprailliac (midaxillary).

2. The equation of Ortiz et al (2) was used to convert from density to percentage body fat for African American women and the equation of Lohman (7) was used to convert from density to percentage body fat for white women.

3. Significantly different from white females, \(P < 0.05\).

### DISCUSSION

There were no significant differences in physical characteristics between the African Americans and whites, except for subscapula skinfold thickness. This finding suggests that other body-composition factors are responsible for the differences observed in this study. This observation is consistent with results reported by others in the literature (10, 12, 24). Because the FFM of African American women is different from the FFM of white women, equations that most accurately convert body density to...
%fat should be used for each race (2, 3, 5–7). Therefore, in the present study, Lohman’s (7) equation was used for whites and Ortiz et al’s (2) equation was used for African Americans.

In the present study, average %fat computed for African American women with Jackson et al’s (18) seven-sites equation and Durnin and Womersley’s (22) four-sites equation followed a pattern consistent with results reported for white women by Sinning (14). In Sinning’s study, a comparison of different equations for estimating density and body fat in female athletes showed that nonlinear skinfold equations overestimated the average %fat value. Zillikens and Conway (10), in a study that evaluated African American and white women, found that average %fat values were within the recommended limits. The SEE values for the African American women ranged from 4.3% fat to 4.9% fat, all values being outside acceptable limits (> 3.8% fat). The highest SEE values were for the logarithmic equations.

$E$ values are statistical manipulations that assess the total error derived when one procedure is cross-validated against another. $E$ values include variation due to the lack of association between the two sets of measurements and variation due to the degree of mean difference between predicted and measured body fat (26, 27). Only when measured and predicted body fat values are identical will $E$ and $E$ values be equal. Therefore, $E$ values will generally be similar in magnitude to SEEs for effective prediction equations. The $E$ values for body fat for the white women in the present study ranged from 2.6% to 3.1%. With an average SEE of 2.7% and all of the skinfold equation values were within the recommended limits. The SEE values for the African American women ranged from 4.3% fat to 4.9% fat, all values being outside acceptable limits (> 3.8% fat). The highest SEE values were for the logarithmic equations. $E$ values for the African American women ranged from 4.3% fat to 4.9% fat, all values being outside acceptable limits (> 3.8% fat). The highest SEE values were for the logarithmic equations.

TABLE 3
Mean skinfold values for differences based on race

<table>
<thead>
<tr>
<th>Variable</th>
<th>African American women $(n = 39)$</th>
<th>White women $(n = 39)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>8.4 ± 3.8</td>
<td>10.0 ± 4.0</td>
</tr>
<tr>
<td>Axilla</td>
<td>12.6 ± 5.6</td>
<td>11.4 ± 4.2</td>
</tr>
<tr>
<td>Triceps</td>
<td>18.0 ± 5.3</td>
<td>19.1 ± 5.8</td>
</tr>
<tr>
<td>Biceps</td>
<td>7.2 ± 2.9</td>
<td>7.8 ± 2.9</td>
</tr>
<tr>
<td>Subscapula</td>
<td>16.7 ± 6.3$^2$</td>
<td>14.0 ± 5.3</td>
</tr>
<tr>
<td>Abdomen</td>
<td>20.7 ± 8.0</td>
<td>18.7 ± 6.0</td>
</tr>
<tr>
<td>Suprailiac (midaxillary)</td>
<td>16.9 ± 7.9</td>
<td>16.6 ± 5.3</td>
</tr>
<tr>
<td>Suprailiac (anterior-superior)</td>
<td>17.2 ± 8.1</td>
<td>16.8 ± 5.5</td>
</tr>
<tr>
<td>Thigh</td>
<td>28.0 ± 7.6</td>
<td>29.3 ± 6.2</td>
</tr>
<tr>
<td>Upper body$^3$</td>
<td>76.4 ± 28.7</td>
<td>70.9 ± 21.9</td>
</tr>
<tr>
<td>Total body$^4$</td>
<td>129.7 ± 40.8</td>
<td>127.1 ± 34.1</td>
</tr>
</tbody>
</table>

$^1 n = 35.$
$^2$ Significantly different from white women, $P < 0.05.$
$^3$ Chest + axilla + subscapula + suprailiac (m) + abdomen.
$^4$ Chest + axilla + subscapula + suprailiac (m) + abdomen + triceps + biceps + thigh.

TABLE 4
Comparison of percentage body fat (%fat) estimated by underwater weighing (UWW %fat) and by skinfold equations (skinfold %fat) in African American women

<table>
<thead>
<tr>
<th>Method</th>
<th>$\bar{x}$</th>
<th>$x_{diff}$</th>
<th>SD</th>
<th>$E$</th>
<th>$D$</th>
<th>SEE</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>UWW</td>
<td>28.3</td>
<td>—</td>
<td>6.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Quadratic equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jackson et al (18) three sites</td>
<td>28.2</td>
<td>—0.1</td>
<td>8.2</td>
<td>7.7</td>
<td>74.0</td>
<td>4.6</td>
<td>0.65</td>
</tr>
<tr>
<td>Jackson et al (18) seven sites</td>
<td>31.0$^2$</td>
<td>2.7</td>
<td>10.7</td>
<td>9.3</td>
<td>79.0</td>
<td>4.3</td>
<td>0.70</td>
</tr>
<tr>
<td>Linear equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sloan et al (19)</td>
<td>24.6$^2$</td>
<td>—3.7</td>
<td>4.2</td>
<td>7.4</td>
<td>51.0</td>
<td>4.4</td>
<td>0.68</td>
</tr>
<tr>
<td>Wilmore and Behnke (20)</td>
<td>29.2</td>
<td>0.9</td>
<td>3.7</td>
<td>6.3</td>
<td>90.0</td>
<td>4.3</td>
<td>0.69</td>
</tr>
<tr>
<td>Katch and McArdle (21)</td>
<td>26.9</td>
<td>—1.4</td>
<td>5.6</td>
<td>7.1</td>
<td>72.0</td>
<td>4.6</td>
<td>0.64</td>
</tr>
<tr>
<td>Logarithmic equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durnin and Womersley’s (22) three sites</td>
<td>29.7</td>
<td>1.4</td>
<td>4.8</td>
<td>7.0</td>
<td>85.0</td>
<td>4.9</td>
<td>0.57</td>
</tr>
<tr>
<td>Durnin and Womersley’s (22) four sites</td>
<td>30.3$^3$</td>
<td>2.0</td>
<td>4.8</td>
<td>6.9</td>
<td>92.0</td>
<td>4.8</td>
<td>0.61</td>
</tr>
</tbody>
</table>

$^1 n = 39.$ $x_{diff}$ mean difference; $E$, total error; $[E = \sqrt{(UWW - X)^2/n}$, where UWW is UWW %fat and X is skinfold %fat]; $D$, the percentage of subjects with skinfold %fat within 3.5% of UWW %fat values.

$^2$ Significantly different from %fat estimated by UWW, $P < 0.05$ (Scheffé’s honestly significant difference test).
9.3%. The highest values were obtained with Jackson et al’s (18) equations, the seven-sites equation giving the highest value. The literature suggests that effective skinfold equations will generally estimate body fat within 3.5% of fat values estimated by UWW (7, 26, 28, 29). In the present study, skinfold %fat values within 3.5% of UWW %fat values occurred 85.0% and 92.0% of the time, respectively, for African American women and 90.3% and 94.9% of the time, respectively, for white women with Durnin and Womersley’s (22) three- and four-sites equations. The percentage of individual %fat estimates within 3.5% of UWW %fat values was higher in the white women for each of the skinfold prediction equations, except for one linear equation—that of Katch and McArdle’s (21). However, a fairly high percentage of both African American and white women had %fat values within 3.5% of UWW %fat values.

The correlation coefficients (range: 0.74–0.83) between UWW %fat and skinfold %fat values for the white women in this study were reasonably consistent with relations shown between values derived with prediction equations and those with a standard procedure reported in the literature (27, 30–32). In the present study, the $r$ values of 0.82 and 0.83 for Jackson et al’s (18) three- and seven-sites equations, respectively, were consistent with the $r$ value of 0.82 obtained by Jackson et al (18) with a cross-validation study of their equation. The $r$ values of 0.81 and 0.82 for Sloan et al’s (19) and Wilmore and Behnke’s (20) equations, respectively, are higher than the $R$ values obtained by the respective authors when the skinfold regression equations were developed. However, the $R$ value of 0.74 obtained when %fat estimated with Katch and McArdle’s (21) equation was compared with UWW %fat was slightly less than the $R$ value of 0.77 originally obtained when the equation was developed. On the other hand, the $r$ values between the skinfold equations and UWW %fat estimates for the African American women were relatively low, ranging from 0.57 to 0.70 (27, 30). The $r$ values for African American women were lower than those for the white women and were considerably lower than the $R$ values originally obtained by the authors who developed the different equations (18–22).

Bland and Altman (23) stated that the statistical procedure for assessing agreement between two methods is more sensitive to differences than are regressions and correlations. Two methods may be highly related yet have poor agreement. The agreement assessments in this study clearly illustrate that skinfold methods for estimating body fat were in greater agreement with UWW for white women than for African American women. This finding is

### Table 5

<table>
<thead>
<tr>
<th>Method</th>
<th>$\bar{x}$</th>
<th>$\bar{x}_d$</th>
<th>SD</th>
<th>$\bar{E}$</th>
<th>$\bar{D}$</th>
<th>SEE</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>UWW</td>
<td>25.2</td>
<td>---</td>
<td>4.6</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Quadratic equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jackson et al (18) three sites</td>
<td>26.3</td>
<td>1.1</td>
<td>7.5</td>
<td>4.9</td>
<td>90.0</td>
<td>2.6</td>
<td>0.82</td>
</tr>
<tr>
<td>Jackson et al (18) seven sites</td>
<td>27.0$^2$</td>
<td>1.8</td>
<td>9.2</td>
<td>6.2</td>
<td>82.0</td>
<td>2.6</td>
<td>0.83</td>
</tr>
<tr>
<td>Linear equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sloan et al (19)</td>
<td>21.8$^2$</td>
<td>$-3.4$</td>
<td>4.2</td>
<td>4.4</td>
<td>54.0</td>
<td>2.7</td>
<td>0.81</td>
</tr>
<tr>
<td>Wilmore and Behnke (20)</td>
<td>26.4$^2$</td>
<td>1.2</td>
<td>3.2</td>
<td>3.8</td>
<td>92.1</td>
<td>2.6</td>
<td>0.82</td>
</tr>
<tr>
<td>Katch and McArdle (21)</td>
<td>22.2$^2$</td>
<td>$-3.0$</td>
<td>4.5</td>
<td>4.6</td>
<td>62.1</td>
<td>3.1</td>
<td>0.74</td>
</tr>
<tr>
<td>Logarithmic equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durnin and Womersley’s (22) three sites</td>
<td>26.2$^2$</td>
<td>1.0</td>
<td>4.5</td>
<td>3.5</td>
<td>90.3</td>
<td>2.6</td>
<td>0.83</td>
</tr>
<tr>
<td>Durnin and Womersley’s (22) four sites</td>
<td>27.1$^2$</td>
<td>1.9</td>
<td>4.2</td>
<td>3.8</td>
<td>94.9</td>
<td>2.6</td>
<td>0.83</td>
</tr>
</tbody>
</table>

$^1 n = 39$. $\bar{x}_d$, mean difference; $\bar{E}$, total error; [$\bar{E} = \sqrt{(UWW - X)^2/n}$, where UWW is UWW %fat and $X$ is skinfold %fat]; $D$, the percentage of subjects with skinfold %fat within 3.5% of UWW %fat values.

$^2$ Significantly different from %fat estimated by UWW, $P < 0.05$ (Scheffé test).

**Figure 1.** Agreement assessment between percentage body fat (%fat) estimated by underwater weighing and Jackson et al’s (18) three-sites skinfold prediction equations in African American (A; n = 39) and white (B; n = 39) women. Means are plotted against the difference between the two procedures. The center line represents the mean difference between the two methods and the other two lines represent 2 SDs from the mean (95% CIs).
Similar to results obtained by Vickery et al (13), who found that similar skinfold values produced different ($P < 0.05$) body fat estimates in African American and white males. Similar to other findings in the literature, this finding suggests that the relation between subcutaneous fat and total body fat in African American women is different from the relation in white women (33).

The analyses used in this study partially followed the recommendations of Lohman (26), who stated that cross-validation should include not only SEE, $E$, and SD values but also the slopes of the regression lines. In this study, agreement assessments were used rather than the slopes of regression lines. These analyses allow for error assessments and for an illustration of the differences in $\%$fat estimated by UWW criterion and skinfold prediction equations. The overall analyses showed that curvilinear equations are effective estimators of $\%$fat in white women. Furthermore, these data showed that the skinfold equations used in this study (developed with white subjects) were less accurate predictors of $\%$fat in African American women than in white women. These findings are similar to the results of Sparling et al (34), who found that bioelectrical impedance was more effective for estimating body fat in white women than in African American women. Curvilinear equations were no better at estimating body fat in African American women than were linear equations.

Fewer skinfold $\%$fat estimates were significantly different from UWW $\%$fat values for the African American than for the white women. This finding may be related to the fact that the SD of the $\%$fat measurements was larger for the African Americans and thus required a larger difference to be significant. However, on the basis of $E$ values, SEE values, agreement assessment, and $r$ values, the results of the present study failed to support the hypothesis that existing skinfold equations for estimating $\%$fat are appropriate to use (without adjustment) for African American women.

The results from this study indicate that the greater errors and lower $r$ values seen for African American women than for white women make the equations less accurate and less appropriate in African American women. The findings appear to be consistent with findings in the literature that report a different relation between skinfold thicknesses and subcutaneous fat deposits in African American and white women (10, 33), which partly explains why skinfold equations designed for white women are less effective in estimating body fat in African American women (2, 3, 12). Although further validation of these results are warranted, these data suggest that popula-

![Figure 2](https://academic.oup.com/ajcn/article-abstract/67/6/1155/4666052/fig2)

**FIGURE 2.** Agreement assessment between percentage body fat ($\%$fat) estimated by underwater weighing and Sloan et al’s (19) skinfold prediction equation in African American (A; $n = 39$) and white (B; $n = 39$) women. Means are plotted against the difference between the two procedures. The center line represents the mean difference between the two methods and the other two lines represent 2 SDs from the mean (95% CIs).

![Figure 3](https://academic.oup.com/ajcn/article-abstract/67/6/1155/4666052/fig3)

**FIGURE 3.** Agreement assessment between percentage body fat ($\%$fat) estimated by underwater weighing and Durnin and Womersley’s (22) three sites skinfold prediction equation in African American (A; $n = 35$) and white (B; $n = 39$) women. Means are plotted against the difference between the two procedures. The center line represents the mean difference between the two methods and the other two lines represent 2 SDs from the mean (95% CIs).
tion-specific skinfold equations are probably more accurate for estimating body fat in African American women than are skinfold equations developed in another population.

REFERENCES


