Validity of two-component models for estimating body fat of black men

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Wagner, Dale R., and Vivian H. Heyward. Validity of two-component models for estimating body fat of black men. J Appl Physiol 90: 649–656, 2001.—Commonly used two-component model conversion formulas that estimate relative body fat (%BF) from body density (Db) were cross-validated on a heterogeneous sample of black men (n = 30; age = 19–45 yr). A four-component model was used to obtain criterion measures of %BF, and linear regression and analysis of individual residual scores were conducted to assess the predictive accuracy of the formulas under investigation. The two-component formula commonly used to estimate %BF of black men (Schutte JE, Townsend EJ, Hugg J, Shoup RF, Malina RM, and Blomqvist CG. J Appl Physiol 56: 1647–1649, 1984) significantly (P < 0.01) and systematically (87% of sample) overestimated %BF (–1.28%); thus we developed the following two-component Db conversion formula: %BF = [(4.858/Db) – 4.394] × 100. Because our formula was derived from a four-component model and a larger, more heterogeneous sample than the commonly used two-component formula, we recommend using it to convert Db to %BF for black men. Additionally, there was good agreement between dual-energy X-ray absorptiometry and the four-component model, making this a suitable alternative for estimating the %BF of black men.

multicomponent body composition; African American; race; ethnicity

BLACK MEN HAVE EXHIBITED an increased risk for obesity-related chronic diseases, including cardiovascular disease, cerebrovascular disease, diabetes, and osteoarthritis (10, 15). Additionally, body composition measurements are often used to recommend desirable body weights for athletes, and black men constitute a large portion of today’s collegiate and professional athletic population. Furthermore, some jobs, such as those in the military and law enforcement, require employees to maintain certain body fat standards. Therefore, an accurate body composition assessment may be pertinent to the health, athletic performance, and employment of black males.

Traditionally, the classic two-component (2-C) models of Siri (24) and Brozek et al. (3), which separate the body mass (BM) into fat mass and fat-free mass, have been used to obtain reference measures of body composition. These models assume that the density of the fat-free body (FFBd) is 1.100 g/ml, and the proportions and densities of the components that constitute the fat-free mass (water, protein, and minerals) are constant for all individuals (3). However, these assumptions were derived from cadaver analysis of a small sample of white men (3), and it is now widely recognized that these assumptions do not hold true for black men. Numerous differences in body composition exist between black and white men, most notably a greater protein content, bone mineral content (BMC), and bone mineral density (BMD) for black men (12, 26). These differences result in a greater FFBd for black men and, therefore, a systematic underestimation of relative body fat (%BF) when the 2-C conversion equations of Siri or Brozek et al. are used.

Schutte et al. (22) calculated a greater FFBd (1.113 g/ml) for black men and developed the following 2-C model formula to convert body density (Db) to %BF for this population: %BF = [(4.374/Db) – 3.928] × 100. This conversion formula has been recommended (7) and is generally used for estimating the %BF from Db for black men. However, its validity and generalizability are suspect because 1) the conversion formula has not been cross-validated, 2) total body water (TBW), rather than a complete multicomponent model, was used as the reference method for estimating %BF, and 3) the conversion formula was based on data from a small, homogeneous sample of young, black, college-aged men (n = 15).

Therefore, the purpose of this study was to cross-validate the Schutte et al. (22) equation for black men by using a four-component (4-C) body composition model that estimates %BF from total Db corrected for relative TBW and total body bone mineral (TBBM). Additionally, the validity of the 2-C conversion formulas of Siri (24) and Brozek et al. (3), as well as the Pace and Rathbun (16) formula for estimating %BF from TBW, and the %BF estimate obtained from dual-energy X-ray absorptiometry (DXA) were evaluated on this sample of black men.

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METHODS

Subjects and preliminary procedures. Thirty black men, ages 19–45 yr, volunteered to participate in this study. Subjects were recruited from the Albuquerque area via word-of-mouth, newspaper advertisements, flyers distributed throughout the University and to health/fitness clubs, major corporations, churches, community centers, and at major public events. Each participant completed questionnaires on health history, physical activity (18), ethnic background, and socioeconomic data for descriptive purposes. Subjects had to self-report that both parents were black to be enrolled in this study. All subjects underwent a physical examination by a physician and were deemed to be in good health. The participants were informed of the purpose, procedures, risks, and benefits of the study before signing an informed consent. To control for the influence of physical activity and food and drug intake on body composition measures, subjects stayed overnight and were given a controlled dinner in the General Clinical Research Center of the University Hospital. The Human Research Review Committees of the University Hospital and the University of New Mexico approved this study.

BM and height. With the men in briefs only, BM was measured twice, to the nearest 0.01 kg, on a calibrated electronic scale (Bod Pod, Life Measurement Instruments, Concord, CA), and the average of the two values was used for subsequent calculations. Height was measured twice, to the nearest 0.1 cm, by using a stadiometer (Holtain, Crymych, Dyfed Wales, UK), with the average of the two measurements recorded. This measurement was taken with participants at midinspiration, standing erect, and arms hanging freely at the sides.

Deuterium oxide dilution. TBW was determined by using the deuterium oxide (D₂O) dilution technique (20). Schoeller et al. (19) reported the accuracy of the isotope dilution method for measuring TBW to be ~1%, and the precision when using isotope ratio mass spectrometry, as was done in this study, to be between 1% and 2%.

After an overnight fast (7-h postprandial), subjects gave a 1.0-ml saliva sample to establish baseline D₂O levels. Each participant then ingested a 10-g dose of D₂O mixed in 300 ml of deionized water, as described by Khaled et al. (9). As recommended by Schoeller et al. (20), there was a 4-h D₂O equilibration period, after which a second 1.0-ml saliva sample was collected. In the interim between saliva samples, the subjects completed the other body composition assessments included in this study. Research shows that there is not a statistically significant difference in TBW when measured from saliva, serum, or urine (20).

The saliva samples were frozen (−20°C) for later analysis. The absorption of D₂O was determined by using isotope ratio mass spectrometry (21). It was assumed that the D₂O dilution space was 4% larger than TBW, due to the proton exchange between tracer and proteins and carbohydrates in the body (20); thus the value obtained from the mass spectrometry analysis was divided by 1.04 to obtain the corrected TBW value. This corrected TBW value was used in the multicomponent model (4) and to estimate %BF from TBW using the 2-C model equation of Pace and Rathbun (16).

DXA. TBBM was determined by scanning the subjects with a pencil-beam DXA (Lunar DPX, Lunar Radiation, Madison, WI). Johnson and Dawson-Hughes (8) studied the precision of DXA for measuring TBBM. The coefficients of variation for immediate retest and long-term precision, measured 9 mo later, were 0.8 and 1.2%, respectively.

The DXA was calibrated daily with the manufacturer’s “standard block” bone-simulating substance of known composition and attenuating capacity and weekly with an aluminum spirit phantom. A licensed radiologic technologist performed all scans. From a supine position, the men were scanned using the medium speed scan mode (20 min), unless body thickness exceeded 27 cm, as measured with an anthropometer from the supine position. In such cases, the slow speed scan (40 min) was used.

The DXA measurement is thought to represent bone ash, so TBBM was calculated by dividing the DXA value by 0.9582, the assumed fraction of bone mineral comprising ash (3). The nonosseous mineral-to-bone ash ratio was assumed to be 0.23048, and TBBM was subsequently calculated as the sum of the bone mineral and nonosseous components (3). Lunar software (version 3.6Z) also provided an estimate of %BF based on an extrapolation of fatness from the ratio of soft tissue attenuation of two X-ray energies in pixels not containing bone (13).

Hydrodensitometry. Total body volume and Db were calculated from measures of BM and underwater mass using hydrostatic weighing (HW) at residual lung volume (RV). RV was estimated by using a helium dilution technique (14) via closed-circuit spirometry, with a 9-liter Collins helium analyzer (Warren E. Collins, Braintree, MA), with the participant seated out of the water. A minimum of three trials was done, with the two closest readings within 100 ml being averaged and used to correct total body volume measured from HW. To minimize error, the same experienced technician conducted all lung volume measurements and performed all RV calculations.

A load cell system (Precision Biomedical, State College, PA), integrated to an analog signal acquisition system (Biopac Systems, Goleta, CA) and a personal computer, was used to measure underwater weight. The analog signal was acquired at 200 Hz and processed using commercially available software (AquKnowledge, Biopac Systems, Goleta, CA). For this assessment, the men assumed a hands and knees position on the load cell platform. A forced expiratory reserve volume maneuver was performed as the participant lowered his head below the surface of the water to be completely submerged. The underwater weight was obtained by averaging the flattest region of the waveform over ~1 s after complete expiration. Three trials within 100 g of each other were averaged and used as the underwater weight for calculation of total body volume and Db (2).

Statistical analysis. Before the study was conducted, a power analysis was performed to determine the number of participants needed to adequately assess the validity of the equations under cross-validation. It was estimated that a sample size of 30 was adequate to distinguish a difference of 1.85% BF between equations (e.g., Schutte et al. vs. 4-C) with 80% power and level of significance (α) = 0.05. After data collection, the power analysis was performed again. The correlation between %BF₄-C and %BF₅-Schutte was higher than expected (r = 0.97), allowing for a mean difference of 0.9% BF to be detected with 80% power and α = 0.05.

Linear regression analysis, using the Statistical Package of the Social Sciences (SPSS, version 8.0 for Windows), and the cross-validation criteria developed by Lohman (11) were used to assess the predictive accuracy of the conversion formulas of Schutte et al. (22), Siri (24), Brozek et al. (3), and Pace and Rathbun (16), as well as the %BF estimated from DXA. %BF estimated from the 4-C model equation of Friedl et al. (4), which corrects Db for TBW and TBBM, was used as the criterion method. A repeated-measures ANOVA was performed to determine whether the mean %BF differences between the 4-C model and the other formulas were significant.
Linear regression analysis assumes the independent and dependent variables are normally distributed. Extreme cases will have a deleterious effect on regression solutions and should be excluded from the analysis (25). Therefore, before data analysis, the normality of the distributions was examined by inspecting the skew and kurtosis of the variables. Statistical outliers were defined as individual scores exceeding ±3.29 SD from the mean for that variable (25).

Lohman (11) established the criteria we used to evaluate the validity of the equations being challenged. 1) The means and SDs of the criterion %BF and the %BF obtained by the equation being evaluated should not differ significantly on the basis of dependent t-tests. 2) A substantial correlation (r_{x,y} ≥ 0.80) and shared variance (r^2) should exist between the criterion and predicted %BF. 3) The SE of estimate (SEE) and total error (E) of the equation should not exceed 3.5% BF. 4) There should be no systematic prediction error across levels of body fatness, as evidenced by the correlation (r_{y,res}) between the reference measure and the residual scores (e.g., %BF_{4-C} − %BF_{Schutte}). 5) The slope of the regression line should not differ significantly from 1.0, and the intercept should not be significantly different from zero.

Additionally, residual scores (e.g., %BF_{4-C} − %BF_{Schutte}) were analyzed by using a modified Bland and Altman (1) plot to determine the percentage of participants whose predicted score was correctly estimated within ±3.5% BF. The Bland and Altman method is typically used to represent the amount of data that falls between ±2 SD from the mean. However, rather than plot the data as means ± 2 SD, we represented the number of subjects who were estimated within ±3.5% BF of the 4-C model, as this value corresponds to Lohman’s (11) SEE criteria for acceptability. For this analysis, the reference score and predicted score were averaged and plotted against each participant’s residual score (e.g., %BF_{AC} − %BF_{Schutte}).

RESULTS

Descriptive characteristics. The physical characteristics of the sample (n = 30) are presented in Table 1. All variables were normally distributed with no potential outliers (z-scores < 3.29); therefore, all subjects were included in subsequent analysis. As evidenced by the data in the table, the sample was rather heterogeneous. The subjects ranged in age from 19 to 45 yr (mean age of 31.97 ± 7.71 yr), with an average height and BM of 180.32 ± 7.47 cm and 84.15 ± 14.98 kg, respectively. The %BF_{4-C} of the sample ranged from 3.52 to 36.60% (mean of 15.79 ± 6.96%).

Scores on the physical activity questionnaire (18) ranged from 1 to 7 out of a possible zero (avoid any exertion) to 7 (>3 h/wk of physical activity). However, 53% of the sample reported spending >3 h/wk in physical activity; thus this was a relatively active group. The sample was also very diverse with regard to socioeconomic status. Participants ranged from college students and the unemployed to professionals such as physicians and lawyers. Education level ranged from high school diploma or GED to advanced degree, with 33% reporting some college or trade school but no degree and 30% responding as having a bachelor’s degree. Reported family income ranged from less than $10,000 per year to $75,000 or more per year. The median income range was $25,000 to $34,000 per year.

Cross-validation results. Results of the cross-validation analyses are presented in Table 2. The relation-
3.5% BF, 87% of the subjects had negative residual scores (%BF<sub>4-C</sub> − %BF<sub>TBW</sub>) indicating a trend for overestimating the %BF of black men with this conversion formula (Fig. 2D).

The relationship between the %BF estimated from DXA and that obtained from the 4-C model is illustrated in Fig. 3. The mean difference in %BF between these two methods was small (−0.28%) and not significant. DXA accurately estimated 87% of the subjects within ±3.5% BF, with an equal number of subjects being over- and underestimated (Fig. 4).

DISCUSSION

The Friedl et al. (4) 4-C model equation (%BF = [(4.374/Db) − 3.928] × 100; %BF<sub>DXA</sub> = [(4.570/Db) − 4.142] × 100; %BF<sub>Schutte</sub> = [(4.950/Db) − 4.500] × 100; %BF<sub>Siri</sub> = [(BM − (TBW/0.732))/BM] × 100) was used as the criterion measure of %BF in this study. Although there are several published multicomponent models, this one was chosen because it includes TBBM in the equation rather than total body mineral that requires an extra estimation calculation. We were able to use the same DXA model and method of calculating TBBM as Friedl et al. Friedl et al. noted that the results obtained from their equation were very similar to those from other 4-C models. The potential exists for the propagation of errors from multiple measurements when using 4-C models. However, Friedl et al. (4) showed that the improved accuracy of measuring, rather than estimating, TBW and TBBM values exceeds the additive measurement errors, thus improving the accuracy of estimating fat over traditional 2-C models.

As expected, the Siri (24) and Brozek et al. (3) formulas consistently underestimated the %BF of the black men in this study. The derivation of these formulas for converting Db to %BF was based on assumptions about the proportions and densities of the FFB of

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Table 2. Cross-validation of two-component conversion formulas and reference methods

<table>
<thead>
<tr>
<th>Formula</th>
<th>r&lt;sub&gt;x'y&lt;/sub&gt;</th>
<th>SEE, %BF</th>
<th>E, %BF</th>
<th>Δ, %BF</th>
<th>t</th>
<th>r&lt;sub&gt;y',res&lt;/sub&gt;</th>
<th>Slope</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schutte&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.98†</td>
<td>1.56</td>
<td>1.98</td>
<td>-1.28</td>
<td>-4.57†</td>
<td>0.23</td>
<td>1.00</td>
<td>-1.31</td>
</tr>
<tr>
<td>Siri&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.98†</td>
<td>1.56</td>
<td>2.61</td>
<td>1.94</td>
<td>6.02†</td>
<td>-0.30</td>
<td>0.89</td>
<td>3.54†</td>
</tr>
<tr>
<td>Brozek&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.98†</td>
<td>1.56</td>
<td>2.33</td>
<td>1.75</td>
<td>6.15†</td>
<td>0.03</td>
<td>0.86</td>
<td>2.33†</td>
</tr>
<tr>
<td>Pace&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.97†</td>
<td>1.60</td>
<td>2.31</td>
<td>-1.71</td>
<td>-5.95†</td>
<td>0.21</td>
<td>1.00</td>
<td>-1.63</td>
</tr>
<tr>
<td>DXA</td>
<td>0.95†</td>
<td>2.26</td>
<td>2.39</td>
<td>-0.28</td>
<td>-0.64</td>
<td>-0.08</td>
<td>0.87†</td>
<td>1.74</td>
</tr>
</tbody>
</table>

r<sub>x'y</sub>, correlation coefficient between 4-C model and formula; SEE, standard error of estimate [SD<sub>y</sub> = (1 − r<sup>2</sup><sub>x'y</sub>)]; E, total error [SD<sub>y</sub> − y<sub>y</sub>]; Δ, %BF from 4-C minus %BF from formula; t, t value from the t-test; r<sub>y',res</sub>, correlation coefficient between reference and residual scores; DXA, dual-energy X-ray absorptiometry. <sup>a</sup>%BF = [(2.559/Db) − 0.734 (TBW/BM) + 0.983 (TBBM/BM) − 1.841] × 100; <sup>b</sup>%BF = [(4.374/Db) − 3.928] × 100; <sup>c</sup>%BF = [(4.950/Db) − 4.500] × 100; <sup>d</sup>%BF = [(BM − (TBW/0.732))/BM] × 100. See text for further explanation of formulas. *P ≤ 0.05; †P ≤ 0.01.
white men. A FFBd of 1.100 g/ml was assumed. However, it is well documented that the BMC, BMD, and protein content of black men may be greater than that of white men, resulting in a greater FFBd (12, 26). If the FFBd of black men is indeed >1.100 g/ml, then an underestimation in %BF using either of these formulas is to be expected.

The conversion formula of Schutte et al. (22) was an attempt at correcting for the greater FFBd of black men and the subsequent underestimation of %BF when Db was applied to 2-C conversion formulas appropriate for white men (3, 24). However, the results from this study indicate that the %BF of black men is consistently overestimated using that formula. Thus the actual FFBd of black men is likely to be somewhere between the 1.100 g/ml assumed for white men and the 1.113 g/ml Schutte et al. (22) estimated for black men.

In the present sample, the average relative TBW, total body mineral, and total body protein of the FFB were 71.73, 6.81, and 21.46%, respectively. Whereas the water and mineral components were obtained by isotope dilution and DXA, respectively, the protein portion was simply estimated as the remainder of the

![Fig. 2. Analysis of the individual residual %BF scores for the 2-C conversion formulas. A: Schutte et al. (22). B: Siri (24). C: Brozek et al. (3). D: Pace and Rathbun (16). Residual %BF = %BF from 4-C model - %BF from 2-C conversion formula. Average %BF = (%BF from 4-C model + %BF from 2-C conversion formula)/2.](image1)

![Fig. 3. Relationship between %BF derived from the 4-C model and %BF estimated from dual-energy X-ray absorptiometry (DXA). Solid line, line of identity; dotted line, regression line.](image2)

![Fig. 4. Analysis of the individual residual and average %BF scores for DXA.](image3)
FFB [protein = 100% − (water% + mineral%)]. Using the respective densities for water, mineral, and protein, the overall FFBd was estimated to be 1.10570 g/ml in the present sample. Assuming the density of fat is 0.9007 g/ml and the average FFBd is 1.10570 g/ml, the following conversion formula was derived for black men: %BF = [(4.858/Db) − 4.394] × 100. This formula produced a mean difference of only −0.03% BF compared with %BF4-C. Furthermore, 97% of the subjects were accurately estimated within ±3.5% BF, and there was no systematic error or prediction bias (r_y,res = −0.23) for this race-specific conversion formula (Fig. 5). However, accuracy of this new 2-C model may be inflated because it was derived from the 4-C model values to which it was compared; thus we strongly emphasize that this new conversion formula should be cross-validated on an independent sample.

Inserting the mean Db of this sample (1.06744 g/ml) into the new conversion formula yields an average value of 15.71% BF. The same Db entered in the Siri (24) and Schutte et al. (22) conversion formulas yields %BF values of 13.73 and 16.97%, respectively. These between-formula differences in %BF are reduced at lower Db values but increased at higher Db values. Thus, for obese subjects, all the Db conversion formulas will yield similar results, but, for very lean subjects, the differences in %BF between equations are proportionately much larger. This relationship is illustrated in Fig. 6.

There are several plausible explanations for the differences in conversion formulas and FFBd observed in the present study compared with that reported by Schutte et al. (22). First, the black men of the present study varied widely in age (19–45 yr) and BF (3.52–36.60% BF4-C), as well as physical activity level and socioeconomic status. In contrast, Schutte et al. (22) used a relatively homogeneous sample of college students. That sample was both younger (20.3 ± 1.70 yr) and leaner (12.1 ± 5.81% BF_{TBW}) than the subjects in the present study. No reference was made to the physical activity status of the other study’s subjects, but a young, lean sample may also have been very athletic, with increased BMC and BMD values. This could partially account for the greater FFBd reported by Schutte et al. (22).

Also, Schutte et al. (22) used the hydrometry formula of Pace and Rathbun (16) to convert TBW to %BF for a reference measure. A multicomponent model, such as the one used in the present study, is less likely to be affected by large variations in hydration. Data from the present study indicate that the TBW method might slightly overestimate %BF in black men. If this were the case in the Schutte et al. study, the difference they obtained between %BF estimated from densitometry and hydrometry would have been less, thereby reducing their estimation of FFBd.

It is logical that the actual FFBd of black men is closer to the 1.10570 g/ml obtained from the present data rather than the 1.113 g/ml reported by Schutte et al. (22). Schutte and co-workers noted that a FFBd of 1.113 g/ml would require a BMC that is 36% greater than that assumed for white men and acknowledged that this is unlikely, given that past cadaver analysis showed only a 10–20% increase in BMC for black men. Indeed, in a study of 24 black and 24 white men matched for age, height, and weight, Gerace et al. (6) reported that the BMC measured by dual photon absorptiometry of black men was only 8.7% greater than that of white men. Furthermore, the sample size of the black men in the present study was double that of the sample used by Schutte et al. Due to the larger sample size, greater heterogeneity of our sample, older average age, and higher average %BF, the present study may be more representative of the black male population; thus the results may have a greater generalizability.

TBW, estimated from D_{2}O dilution and mass spectrometry, was converted to %BF using the Pace and Rathbun (16) formula. The values for absolute TBW and TBW relative to the FFB from this study were...
similar to those found in other studies (4, 5, 22, 23, 27). The average TBW for the black men in the present study (50.35 ± 6.77 l) was greater than that reported by Schutte et al. (46.1 ± 4.63 l), but average BM was also greater for the subjects in the present study (84.15 ± 14.98 kg vs. 72.0 ± 8.99 kg).

Overall, this method and formula produced %BF results very similar to what was obtained with the 4-C model. However, although the difference was not large, there was a consistent overestimation of %BF using the Pace and Rathbun formula. This overestimation was the result of a difference between the assumed and actual proportions of water in the FFB. Because the hydrometry method is based solely on the assumption of a constant value for the hydration fraction of the FFB, any deviation from this value will result in an over- or underestimation of %BF. The Pace and Rathbun formula assumes the hydration fraction of the FFB to be 73.2%, but, on average, the actual percentage of water in the FFB from this study was only 71.73%. Additionally, the hydration fraction of 87% of the subjects in this study was below 73.2% accounting for the consistent overestimation of %BF by the Pace and Rathbun formula.

The mean hydration fraction of the FFB of the subjects in the present study was very similar to the 71.94% proposed by Siri (24). However, Siri also estimated a biological variability of 2% in the water content of the FFB and noted that values from 67 to 74% are common. The hydration fractions of the FFB in the present study ranged from 69.7 to 75.6% with a mean of 71.73 ± 1.32%. Other studies that have used a multicomponent model to obtain reference FFB for men have reported mean hydration fractions of 73.32 ± 2.19 (5) and 72.6 ± 1.3% (4), with ranges of 69.4–78.4% and 71.1–74.2%, respectively. As long as the variance in the hydration fraction of the FFB remains small and the TBW-to-fat-free mass ratio is close to the assumed value of 73.2%, the hydrometry method with the Pace and Rathbun formula will accurately estimate a sample within the ±3.5% BF standard. However, with large interindividual variations in the proportion of water in the FFB, there is the potential for substantial individual errors in the estimation of %BF.

Mean %BF was estimated better by DXA than any of the other conversion formulas or reference methods. On average, DXA overestimated %BF by only 0.28%. A similar level of accuracy was also observed in other studies that compared 2-C reference methods to a 4-C model (4, 5, 17). These research teams reported similarly small mean differences in the %BF estimated from DXA and 4-C models ranging from –0.4 to 1.3%.

Furthermore, DXA was the only reference measure that did not consistently over- or underestimate %BF in this sample of black men (Fig. 4). The Siri (24) and Brozek et al. (3) formulas consistently underestimated %BF, whereas the formulas of Schutte et al. (22) and Pace and Rathbun (16) consistently overestimated %BF. Thus the present study is in agreement with the findings of Friedl et al. (4), Fuller et al. (5), and Prior et al. (17), who concluded that DXA is a better predictor of %BF than HW or TBW.

It is not surprising that DXA produced the best estimation of %BF compared with the other reference methods in this sample of black men. Based on a review of the literature (26), a primary difference in body composition between black and white men is the greater BMC and BMD found in black men. Whereas the densitometry and hydrometry methods rely on assumptions about BMC and BMD, DXA directly measures these variables. Thus DXA will account for any race-specific variation in BMC and BMD that results in a FFBd different from the assumed value.

In conclusion, we have shown that the hydrometry conversion formulas developed from the cadaver analyses of white men consistently underestimate the %BF of black men but that the race-specific conversion formula of Schutte et al. (22) consistently overestimates the %BF of black men. By using a multicomponent body composition model on a heterogeneous group of black men, we calculated the FFBd of black men as 1.10570 g/ml. Subsequently, we developed a 2-C model formula to convert Db to %BF for black men (%BF = [(4.858/Db) – 4.394] × 100). We recommend using this formula for estimating the %BF of black men aged 19–45 yr from hydrometry; however, we suggest that it be cross-validated on other independent samples of black men. Additionally, although the SEE for DXA is greater than the 2-C HW formulas, DXA appears to be a suitable alternative to HW for the estimation of %BF of black men.

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