Measures of body composition in blacks and whites: a comparative review[1,2]

Dale R Wagner and Vivian H Heyward

See corresponding editorial on page 1387.

ABSTRACT Biological differences exist in the body composition of blacks and whites. We reviewed literature on the differences and similarities between the 2 races relative to fat-free body mass (water, mineral, and protein), fat patterning, and body dimensions and proportions. In general, blacks have a greater bone mineral density and body protein content than do whites, resulting in a greater fat-free body density. Additionally, there are racial differences in the distribution of subcutaneous fat and the length of the limbs relative to the trunk. The possibility that these differences are a result of ethnicity rather than of race is also examined. Because most equations that predict relative body fat were derived from predominantly white samples, biological variation between the races in these body-composition indexes has practical significance. Systematic error can result in the inaccurate estimation of the relative body fat of blacks, and therefore of definitions of obesity, if these inherent differences are ignored. *Am J Clin Nutr* 2000;71:1392–402.

KEY WORDS Body fat, fat patterning, body composition, bone density, race, ethnicity, blacks, whites, review

INTRODUCTION

Traditionally, the classic 2-component models of Siri (1) and Brozek et al (2), which separate the body into fat and fat-free components, have been used to obtain reference measures of body composition. The fat-free body (FFB) can be further subdivided into water, protein, and mineral components. This chemical model relies on several assumptions: *1*) that the density of fat is 0.9007 g/cm^3, *2*) that the density of the FFB (FFBd) is 1.100 g/cm^3, and *3*) that the proportions and densities of the FFB components (water = 73.8%, 0.9937 g/cm^3; protein = 19.4%, 1.34 g/cm^3; and mineral = 6.8%, 3.038 g/cm^3) are constant for all individuals (2).

The relative percentages and densities of the FFB components were derived from cadaver analyses of a small sample of white men (2). However, the relative proportions of water, protein, and mineral, and thus, the overall FFBd, vary with age, sex, amount of body fatness, activity level, and racial or ethnic origin (3–5). Actual variations from the assumed FFBd result in systematic errors when the 2-component model equations are applied to estimate relative percentage body fat (%BF). Thus, whereas the 2-component model equations may provide accurate estimates of %BF for average white men, this body-composition model is not suitable for blacks whose FFBd varies from the assumed value of 1.100 g/cm^3.

When public health policies are being established or research is being conducted on the prevalence of obesity or obesity-related diseases, an inaccurate assessment of body fat can affect research findings and have far-reaching implications. This is especially important for the black population because, as Kumanyika (6) noted, black Americans have a high prevalence of obesity-related diseases. In addition, the most recent update of the third National Health and Nutrition Examination Survey (NHANES III) indicates that 52% of black women are overweight (7). However, the NHANES III data used a crude indicator of obesity, body mass index (BMI; in kg/m^2), as the criterion for overweight (BMI $\geq$ 27.8 for men and $\geq$ 27.3 for women). BMI correctly identified obesity in only 50.6% of a racially mixed sample of 230 women and 150 men, and there were 49.4% false-negative results (inaccurately classified as lean) when contrasted with %BF criteria obtained by hydrodensitometry (20% BF for men and 25% BF for women) (8).

A current popular theory that may partially explain the high prevalence of obesity in blacks is the apparent difference in resting energy expenditure between blacks and whites. Weyer et al (9) recently found a significantly lower sleeping metabolic rate (by 301 ± 105 kJ/d; $P < 0.01$) in blacks than in whites after adjustment for sex, age, and body composition. However, the Siri (1) formula had been used to convert body density to %BF for all subjects, including black males, who are known to have an FFBd significantly greater than that assumed by the Siri formula. One can only speculate to what extent the use of a more accurate, race-specific conversion formula to determine %BF would have on the subsequent adjustment of metabolic rate and the findings of the study. This is just one recent example of the far-reaching implications that an accurate assessment of body composition can have on research.

[1] From the Exercise and Sports Science Department, Vanguard University of Southern California, Costa Mesa, and the Center for Exercise and Applied Human Physiology, University of New Mexico, Albuquerque.

[2] Reprints not available. Address correspondence to DR Wagner, Exercise and Sports Science Department, Vanguard University of Southern California, 55 Fair Drive, Costa Mesa, CA 92626. E-mail: dwagner@vanguard.edu.

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TABLE 1
Comparisons of total body water (TBW) between blacks and whites[1]

Reference and group	Age	BMI	Method	TBW	TBW/FFM	TBW/BW	Primary findings
	y	*kg/m²*		*L*	*%*	*%*	
(10)	—	—	D_2O, vapor	—	—	—	No significant difference in TBW/FFM between races
BF (*n* = 26)	22.5 ± 3.6[2]	23.2	—	36.1 ± 2.6	73.4	—	
WF (*n* = 26)	23.6 ± 2.8	22.4	—	35.1 ± 2.7	74.0	—	
(11)	—	—	^3H_2O, blood	—	—	—	No significant difference in TBW/FFM between races
BF (*n* = 19)	44.2 ± 15.2	23.9 ± 2.5	—	33.1 ± 5.1	73.4	—	
WF (*n* = 19)	43.6 ± 15.3	23.6 ± 2.2	—	33.0 ± 4.0	74.7	—	
(12)	—	—	^3H_2O	—	—	—	No significant difference in TBW/FFM between races
BF (*n* = 72)	43.0 ± 11.9	25.5	—	32.7 ± 3.6	72.5	—	
WF (*n* = 128)	47.3 ± 12.0	23.7	—	31.3 ± 3.2	73.6	—	
(13)	—	—	D_2O, urine		—	—	No significant difference in TBW or TBW/Ht between races
BM (*n* = 46)	13.7 ± 2.9	20.2	—	32.6 ± 9.4	71.6	—	
WM (*n* = 85)	13.0 ± 2.8	20.1	—	29.7 ± 10.2	72.4	—	
BF (*n* = 45)	13.4 ± 2.9	20.8	—	28.5 ± 5.0	72.2	—	
WF (*n* = 63)	13.8 ± 2.9	20.1	—	26.7 ± 5.6	72.0	—	
(14)[3]	—	—	D_2O, urine	—	—	—	As a whole (across maturation levels), blacks had a higher TBW/BW but a TBW/FFM similar to that of whites
Blacks (*n* = 111)	—	—	—	—	—	—	
Whites (*n* = 181)	—	—	—	—	—	—	
(15)	—	—	D_2O, urine	—	—	—	No significant difference in TBW/FFM between races
BM (*n* = 15)	20.3 ± 1.7	23.1	—	46.1 ± 4.6	73.2	—	
WM (*n* = 19)	22.5 ± 3.5	23.0	—	46.0 ± 1.2	73.1	—	
(16)	—	—	^3H_2O	—	—	—	No significant difference in TBW or TBW/BW between blacks and whites; Asians had a lower TBW
BM (*n* = 88)	49.0 ± 17	26.1 ± 3.0	—	48.0 ± 7	—	60.8	
WM (*n* = 163)	50.0 ± 18	25.1 ± 3.0	—	47.0 ± 7	—	61.0	
BF (*n* = 94)	51.0 ± 16	27.1 ± 4.0	—	36.0 ± 5	—	50.7	
WF (*n* = 208)	51.0 ± 18	23.0 ± 3.0	—	33.0 ± 4	—	54.1	
(17)	—	—	D_2O, plasma	—	—	—	No significant difference in TBW/BW between races
BM (*n* = 43)	30.8 ± 8.7	26.0 ± 3.0	—	48.6 ± 4.7	—	59	
WM (*n* = 40)	37.6 ± 11.2	24.1 ± 2.4	—	45.1 ± 4.6	—	59	
BF (*n* = 45)	30.8 ± 7.0	24.4 ± 4.9	—	33.6 ± 3.7	—	52	
WF (*n* = 39)	32.5 ± 9.9	21.6 ± 2.7	—	30.5 ± 3.6	—	53	

[1] FFM, fat-free mass; BF, black females; WF, white females; BM, black males; WM, white males; BW, body weight; Ht, height.
[2] $\bar{x}$ ± SD.
[3] Males and females of both races were separated into 4 maturation levels with data presented for each of 16 cells.

Additionally, body-composition measurements are often used to recommend desirable body weights for athletes, and blacks constitute a large portion of today's collegiate and professional athletes. 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 critical in determining whether one falls within the established indexes for health, performance, and employment.

We searched the MEDLINE (National Library of Medicine, Bethesda, MD) database using the key words *black*, *African American*, and *body composition*. From this list, articles with the primary purpose of contrasting blacks and whites with regard to components of the FFB, fat patterning, or body dimensions were selected. The reference lists of the selected articles were used as sources for research that predated what could be obtained from MEDLINE.

Thus, this review examines the differences between blacks and whites with regard to the components of the FFB: water, mineral, and protein. Comparisons of fat patterning and body proportions between the 2 races are made as well. The concept of researching differences in body composition from an ethnic as well as a racial perspective is also briefly discussed. Finally, the findings from this review are summarized with a practical emphasis on how these racial differences can affect the conclusions drawn from the assessment of body composition and how recommendations for future studies are made.

TOTAL BODY WATER

Total body water (TBW) makes up the largest portion of the FFB; thus, racial differences in the hydration of the FFB could lead to a systematic error in the estimation of %BF. The following studies used some form of isotope dilution to measure TBW in a racially mixed sample, and data from some of these studies are presented in **Table 1**.

Both Cote and Adams (10) and Ortiz et al (11) included TBW measurements in their multicomponent body-composition assessments of black and white females. In both studies, the 2 racial groups were matched for age, height, weight, and menstrual status. Using deuterium oxide dilution, Cote and Adams showed no

TABLE 2
Comparisons of cadaver skeletal weights between blacks and whites[1]

Reference and group	Age	Skeletal weight	Primary findings
	y	*g*	
(19)	—	—	Significantly greater skeletal weights and compact bone in blacks
BM (*n* = 54)	52.8 ± 19.6[2]	5068.9 ± 821.9	
WM (*n* = 55)	56.7 ± 18.8	4417.0 ± 645.8	
BF (*n* = 55)	50.2 ± 20.7	3659.2 ± 627.6	
WF (*n* = 39)	59.4 ± 18.3	2989.3 ± 629.6	
(20)[3]	—	—	Significantly greater limb and skeletal weights in blacks
BM (*n* = 25)	60.0	3852.7 ± 540.2	
WM (*n* = 25)	66.0	3418.7 ± 496.3	
BF (*n* = 25)	62.0	2828.2 ± 586.8	
WF (*n* = 25)	66.0	2302.5 ± 482.3	
(21)[4]	—	—	Significantly greater skeletal weights in blacks throughout the life span (fetus–100 y)
BM (*n* = 30)	63.0	3899	
WM (*n* = 30)	63.0	3446	
BF (*n* = 30)	63.0	2846	
WF (*n* = 30)	63.0	2335	

[1] BM, black males; WM, white males; BF, black females; WF, white females.
[2] $\bar{x}$ ± SD.
[3] SDs not available
[4] Age-adjusted data presented without SDs.

significant difference in average TBW and TBW/FFB values between black and white women. Likewise, Ortiz et al reported similar values and no racial difference in TBW and TBW/FFB as measured by ^3H_2O dilution. Aloia et al (12) also compared TBW using ^3H_2O in a sample of 72 black and 128 white women aged 20–70 y. The percentage hydration of lean tissue based on total body potassium (TBK) or total body nitrogen was not significantly different between the races, and the decline in TBW between 20 and 70 y of age was similar between white (−3.6%) and black (−3.8%) women.

In a study of 172 black adolescent males, Schutte (18) found that TBW, relative to height and weight, was virtually identical to that reported previously for white male adolescents. Likewise, Slaughter et al (13) found no racial difference in TBW relative to height in a sample of black and white children and adolescents aged 8–18 y. Boileau et al (14) also assessed the hydration of the FFB in blacks and whites aged 8–30 y. TBW/weight was significantly higher ($P < 0.01$) in blacks throughout maturation (prepubescence, pubescence, postpubescence, and adulthood). The difference in TBW/weight for adult males was 59.5% for whites compared with 61.1% for blacks. However, when expressed as a percentage of the FFB, the difference in TBW between whites and blacks (71.9% and 72.4%, respectively) was not significant ($P > 0.05$). This equality in TBW between races was also seen in studies of adults. Researchers that included TBW measurements in their body-composition studies of adults confirmed no significant racial differences in TBW relative to weight or to FFB (15–17).

MINERALS

Because the density of the mineral component of the FFB (3.038 g/cm^3) (2) is roughly 3 times that of the other components of the FFB, any alteration in the proportion of this constituent can have a dramatic effect on the estimation of %BF. Numerous studies have examined differences in skeletal weights (**Table 2**) and bone mineral content (BMC) (**Table 3**) between blacks and whites. We considered, sequentially, cadaver analyses, in vivo studies, and theories regarding the etiology of racial differences in BMC.

Cadaver analyses

Merz et al (19) and Seale (20) examined cadavers for racial differences in BMC and skeletal weight. The whole-body skeletal weights obtained from these studies are enumerated in Table 2. Merz et al used radiographs of the femur to measure the BMC of the skeletons of 203 blacks and whites of similar stature aged 16–91 y. The mean femur weight and skeletal weight of the black men and women were greater than those of the white men and women, respectively. The circumference and amount of compact bone of the shaft of the femur were also greater in blacks than in whites. Additionally, the authors noted that blacks have proportionally longer forearms and legs than do whites.

Seale analyzed 100 dry, fat-free skeletons with a wide age range (25–100 y) evenly divided into black and white men and women. Total skeletal weight was significantly greater in blacks than in whites (3340 compared with 2870 g; $P < 0.001$ after sexes were combined). In addition to being weighed as a whole, each skeleton was divided into skull, trunk, upper extremities, and lower extremities. Analysis of covariance was done to correct for differences among total skeletal weights; proportional differences were noted. Although no racial differences existed for the skull and trunk, blacks had significantly heavier upper and lower extremities than whites. Additionally, the percentage contribution of the upper limbs to total skeletal weight was greater in blacks than in whites (19.5 ± 1.0% compared with 18.5 ± 1.2% in men, $P < 0.001$; 16.8 ± 0.7% compared with 16.2 ± 1.3% in women, $P < 0.001$).

The bone densities of 67 black and white cadavers were examined by using radiographic densitometry by Baker and Angel (27). The density, ash density, protein density, and ash and protein contents as percentages of dry, fat-free bone of the seventh thoracic vertebra, eighth rib, tibia, fibula, calcaneus, radius, and ulna

TABLE 3
Comparisons of total-body bone mineral content (BMC) and bone mineral density (BMD) between blacks and whites as measured by dual-energy X-ray absorptiometry[1]

Reference and group	Age	BMI	BMC	BMD	Primary findings
	y	*kg/m²*	*g*	*g/cm²*	
(10)	—	—	—	—	Significantly greater BMC and BMD in black females
BF (*n* = 26)	22.5 ± 3.6[2]	23.2	3021 ± 305	1.25 ± 0.05	
WF (*n* = 26)	23.6 ± 2.8	22.4	2718 ± 321	1.16 ± 0.07	
(11)[3]	—	—	—	—	Significantly greater BMC and BMD in black females
BF (*n* = 28)	44.2 ± 15.2	23.9 ± 2.5	2640 ± 490	1.18 ± 0.14	
WF (*n* = 28)	43.6 ± 15.3	23.6 ± 2.2	2320 ± 330	1.09 ± 0.09	
(22)	—	—	—	—	Significantly greater BMC in black boys across age groups
BM (*n* = 8)	4.3 ± 0.5	15.9 ± 1.4	456 ± 106	NA	
WM (*n* = 12)	4.0 ± 0.6	15.7 ± 0.9	423 ± 94	NA	
BM (*n* = 28)	7.8 ± 1.3	17.5 ± 3.0	900 ± 195	NA	
WM (*n* = 51)	7.8 ± 1.5	16.2 ± 2.1	793 ± 232	NA	
BM (*n* = 31)	12.7 ± 1.4	22.9 ± 5.8	2038 ± 633	NA	
WM (*n* = 51)	12.6 ± 1.5	20.7 ± 4.0	1655 ± 496	NA	
BM (*n* = 11)	16.9 ± 1.2	26.9 ± 4.4	3181 ± 440	NA	
WM (*n* = 31)	16.7 ± 0.9	21.9 ± 3.4	2545 ± 430	NA	
(23)	—	—	—	—	Significantly greater BMC in black girls across age groups
BF (*n* = 11)	4.4 ± 1.1	16.7 ± 3.0	469 ± 173	NA	
WF (*n* = 18)	5.0 ± 0.7	16.0 ± 2.3	461 ± 96	NA	
BF (*n* = 25)	8.1 ± 1.1	18.6 ± 4.0	944 ± 246	NA	
WF (*n* = 28)	8.3 ± 1.2	16.9 ± 3.1	775 ± 233	NA	
BF (*n* = 36)	12.2 ± 1.1	21.7 ± 4.6	1729 ± 394	NA	
WF (*n* = 55)	11.7 ± 1.0	19.3 ± 4.0	1346 ± 312	NA	
BF (*n* = 32)	15.4 ± 1.0	24.1 ± 6.8	2147 ± 394	NA	
WF (*n* = 40)	15.3 ± 0.9	20.7 ± 2.8	1979 ± 289	NA	
(24)	—	—	—	—	Significantly greater BMC, BMD, BMC/Ht, and BMD/Ht in blacks
BM (*n* = 37)	42.0 ± 6.2	28.4 ± 4.2	3110 ± 395	1.25 ± 0.10	
WM (*n* = 42)	41.6 ± 5.5	28.4 ± 5.4	2712 ± 406	1.16 ± 0.09	
(25)	—	—	—	—	Significantly greater BMD in blacks even after adjustment for covariates
BM (*n* = 109)	30.7 ± 3.2	26.3 ± 4.0	2436 ± 156	1.30 ± 0.12	
WM (*n* = 114)	31.3 ± 3.2	25.5 ± 4.1	2355 ± 160	1.18 ± 0.10	
BF (*n* = 95)	31.0 ± 3.1	28.3 ± 6.5	2096 ± 158	1.16 ± 0.09	
WF (*n* = 84)	31.8 ± 3.1	24.6 ± 6.0	2075 ± 144	1.09 ± 0.08	
(26)	—	—	—	—	Significantly greater BMC and BMC/Ht in Chaldean and black children than in whites; no significant difference between Chaldeans and blacks
BM (*n* = 210)	8.9 ± 0.6	18.1	961 ± 259	NA	
CM (*n* = 40)	8.9 ± 0.6	19.9	972 ± 280	NA	
WM (*n* = 124)	8.9 ± 0.6	17.8	855 ± 191	NA	
BF (*n* = 227)	8.9 ± 0.6	18.5	966 ± 266	NA	
CF (*n* = 31)	8.9 ± 0.6	19.3	926 ± 300	NA	
WF (*n* = 102)	8.9 ± 0.6	18.2	865 ± 257	NA	

[1] BF, black females; WF, white females; BM, black males; WM, white males; CM, Chaldean males; CF, Chaldean females; Ht, height; NA, not available.
[2] $\bar{x}$ ± SD.
[3] Measurements were made with dual-photon absorptiometry.

were measured. The individual bones from the black cadavers were significantly denser than the bones from the white cadavers. The authors attributed the greater densities to greater amounts of protein-bound calcium in the same volume of bone segment.

Trotter et al (28) extensively examined racial differences in bone. In 1958, they reported that the densities of the humerus and femur were significantly greater in blacks than in whites, with the racial effect on bone density being more pronounced in the humerus ($P < 0.01$) than in the femur ($P < 0.05$). Bone densities in the humerus were as follows: black males, 0.718 ± 0.102 g/cm³; white males, 0.642 ± 0.133 g/cm³; black females, 0.640 ± 0.139 g/cm³; and white females, 0.566 ± 0.114 g/cm³. The femoral data were collected as part of an earlier study from Trotter et al's laboratory and only the means for the femur were given in this review: black males, 0.700 g/cm³; white males, 0.628 g/cm³; black females, 0.652 g/cm³; and white females, 0.589 g/cm³. Trotter et al also noted a parallel decrease in the densities of the humerus among the 4 groups with increasing age, but no age-related racial differences.

In 1960 Trotter et al (29) examined the densities of 10 bones from 80 cadavers divided evenly between black and white men and women. The skeletons came from persons of similar socioeconomic and geographic backgrounds. Bone volume was determined from displacement of millet seed. The error for this method was reported to be from 1.0% for the small bones of the vertebra to 3.5% for the femur. Bones from different regions of the body differed in density and, overall, the bones of the black skeletons were denser than those of the white skeletons.

Sequential changes and racial differences in bone weight, bone density, and percentage ash weight in 124 fetal skeletons, 144 young skeletons (birth to 23 y), and 120 adult skeletons (25–100 y) were examined by Trotter and Hixon (21). The fetal skeletons of blacks were both heavier and longer than those of whites. The relation between skeletal weight and age was best described by a sigmoidal curve. The age-adjusted mean skeletal weight of the adult blacks was significantly greater than that of the adult whites, consistent with values reported by Seale (20) in Table 2. Throughout the life span, skeletons of blacks were heavier than those of whites.

In vivo studies

New technology has enabled the assessment of bone mineral in vivo. Using neutron-activation analysis, Cohn et al (30) measured the total body calcium, phosphorus, sodium, chlorine, and potassium contents of blacks. After the data were normalized for body size and age, blacks had significantly higher mean calcium and potassium values than those reported previously for whites. Total body calcium was 21.9 ± 15.6% higher in black men ($P < 0.001$) and 16.7 ± 13.8% higher in black women ($P < 0.005$) than in their white counterparts. The greater skeletal mass in blacks observed by the in vivo analysis of Cohn et al confirmed the results of the cadaver analyses cited previously.

Probably the method most widely used over the past decade to measure bone mineral in vivo is dual-energy X-ray absorptiometry (DXA). Studies using DXA to examine differences in total-body BMC and bone mineral density (BMD) between blacks and whites are summarized in Table 3. In studies of black and white women, both Ortiz et al (11) and Cote and Adams (10) found racial differences in bone mineral. In 28 pairs of subjects matched for age, height, weight, and menstrual status, Ortiz et al reported greater BMC, BMD, appendicular skeletal muscle mass (18.0 ± 3.0 compared with 15.7 ± 2.2 kg; $P < 0.001$), and TBK (2703 ± 508 compared with 2502 ± 403 mmol; $P < 0.05$) in blacks than in whites. Using DXA, Cote and Adams showed greater BMD, BMC, and BMC relative to the FFB (61.5 ± 3.3 compared with 58.1 ± 3.8 g/kg; $P < 0.001$) in black women than in white women. Both studies suggested that errors in estimations of %BF may occur if these racial differences are not addressed in body-composition models.

In a sample of 239 racially mixed youths aged 8–18 y, Slaughter et al (13) estimated lean body mass (LBM) from TBK counting using ^{40}K. They noted significantly greater bone widths (1.34 compared with 1.25 cm^2; ie, a 7.2% difference) and BMC (0.87 compared with 0.77 g/cm; ie, a 13% difference) in black than in white males.

Lohman et al (31) used photon absorptiometry to examine bone mineral and its relation to bone density in a sample of 292 blacks and whites ranging from prepubescent to adult. The BMC and bone width of the right and left radii and ulnas were assessed. Overall, blacks had 6.1% (0.054 g/cm) more BMC and 6.0% (0.039 g/cm^2) more BMC per width than whites. After %BF was controlled for, 16% of the variance in body density was accounted for by the BMC of the forearm.

Similar racial differences in the BMC of children and adolescents were observed in DXA studies by Ellis et al (22, 23). In a study of 313 females aged 3–18 y from 3 ethnic groups, blacks had significantly greater BMCs ($P < 0.0005$) and LBMs ($P < 0.0005$) than whites, but there were no significant differences between the races in fat mass or %BF when corrections were made for height and weight (23). Likewise, in boys there was a higher mean BMC ($P < 0.0005$) in 78 blacks than in 145 whites in each of 4 age groups (3–5, 5–9, 10–14, and 15–18 y) (22). This variance in BMC between blacks and whites increased with age, with a 7.8% difference between races in the youngest group and a 25.0% difference in the oldest age group; these differences were attributed to variations in hormone concentrations during sexual maturation.

Similarly, Barondess et al (24) reported a 14.7% higher BMC and a 7.8% higher BMD in black men than in white men ranging in age from 33 to 64 y. The difference in BMC attributed to race was reduced to 9.8% after analysis of covariance with LBM and after height was controlled for. These racial differences in bone mass indexes were significant ($P < 0.001$) even though there were no significant differences in any body size or soft tissue variables between the 2 groups.

Etiology of racial differences in BMC

From the literature cited, it appears that BMC and BMD are greater in blacks than in whites. Schutte et al (15) attempted to quantify the difference in FFBd between black and white men. They calculated the FFBd of black men to be 1.113 g/cm^3; the FFBd of white men is assumed to be 1.100 g/cm^3. The greater FFBd in blacks was attributed primarily to their greater BMC and BMD. Researchers have speculated about the reasons BMC and BMD are greater in black men than in white men. A widely held theory is that blacks have genetically greater skeletal muscle mass than whites, and this greater mass causes added stress on the bone, thereby resulting in greater BMCs and BMDs (11, 15, 30). Ellis (22) observed a strong relation between BMC and LBM ($r = 0.985$) that was independent of age and racial or ethnic classification. Furthermore, Hampton et al (32) suggested that blacks have a denser muscle mass and a greater total muscle tissue weight than whites.

In a study of 161 women in whom BMD was measured at 7 sites with the use of single- and dual-photon absorptiometry, Nelson et al (33) confirmed that BMD is greater in blacks than in whites, whereas further statistical analysis showed that body size variables correlated most strongly with the density of the bones. However, these authors speculate that greater fat mass rather than LBM may contribute more to the higher bone density seen in black women.

More recent research favors a hormonal link to racial increases in BMD. Wright et al (34) obtained measurements of both growth hormone and BMD in 16 black and 17 white men. Serum 17β-estradiol, growth hormone concentration and secretion, and BMD were all greater in blacks than in whites. The authors suggested that the higher circulating estradiol concentrations in blacks may have contributed to the greater secretion of growth hormone, which in turn led to an increase in bone mass. Heaney (35) suggested that BMC and BMD may be regulated by a "mechanostat," which is analogous to a thermostat that regulates temperature. According to the mechanostat theory, a network of osteocytes detects bone strain and modulates the activity of remodeling cells. The mechanostat set point in blacks is lower than that in whites; ie, the strain needed to trigger bone growth is less in blacks, giving them denser bones. Heaney speculated that growth hormone plays a role in establishing the bone mass set point.

TABLE 4
Comparisons of the protein portion of the fat-free body (FFB) between blacks and whites[1]

Reference and group	Age	BMI	Value	Primary findings
	y	*kg/m²*		
(11)[2]	—	—	—	Significantly greater TBK and TBK/FFB in black women
BF (*n* = 25)	44.2 ± 15.2[3]	23.9 ± 2.5	2703 ± 508 mmol	
WF (*n* = 25)	43.6 ± 15.3	23.6 ± 2.2	2502 ± 403 mmol	
(13)[2]	—	—	—	No significant difference in TBK between races; however, contrast of TBW and TBK relative to height implied greater muscle mass development in blacks
BM (*n* = 46)	13.7 ± 2.9	20.2	116.1 ± 41.1 g	
WM (*n* = 85)	13.0 ± 2.8	20.1	94.9 ± 36.8 g	
BF (*n* = 45)	13.4 ± 2.9	20.8	88.5 ± 15.2 g	
WF (*n* = 63)	13.8 ± 2.9	20.1	91.6 ± 28.3 g	
(30)[4]	—	—	—	Significantly greater TBK in both black men and women (ranging from 8.4% in women aged 40–49 y to 30% in women aged 30–39 y)
BM (*n* = 21)	—	—	—	
WM (*n* = 27)	—	—	—	
BF (*n* = 26)	—	—	—	
WF (*n* = 40)	—	—	—	
(32)[5]	—	—	—	LBM in black boys was greater when measured by ^{40}K than by anthropometry, suggesting denser muscle mass
BM (*n* = 24)	≈16	NA	59.7 ± 8.1 kg	
WM (*n* = 54)	≈16	NA	54.7 ± 7.2 kg	
BF (*n* = 25)	≈16	NA	42.2 ± 5.0 kg	
WF (*n* = 59)	≈16	NA	41.3 ± 5.8 kg	

[1] BF, black females; WF, white females; BM, black males; WM, white males; TBK, total body potassium; LBM, lean body mass; NA, not available.
[2] Measurement made by ^{40}K counting.
[3] $\bar{x}$ ± SD.
[4] Data grouped in decades ranging from age 30 to 79 y; totals not provided.
[5] SDs for age not available. LBM measured by ^{40}K counting.

PROTEIN

Schutte et al (15) noted that a 36% increase in BMC is required to raise the FFBd of 1.100 g/cm^3 assumed for white men to the 1.113 g/cm^3 that was estimated for black men. On the basis of the mineral research cited previously, it is unlikely that there is this much difference in the BMC of blacks and whites. Thus, another component of the FFB must also differ in blacks to explain the observed interrace differences. Schutte et al (15) suggested that the greater whole-body protein content observed in black men must also contribute to their greater FFBd. Data from studies that compared the protein portion of the FFB between blacks and whites are presented in **Table 4**.

Using anthropometry, ^{40}K counting, and specific gravity measurements, Hampton et al (32) examined the body composition of a racially mixed group of teenagers. These researchers noted that the LBM of black boys was higher when measured by ^{40}K counting and specific gravity than by anthropometry. They concluded that black males might have a greater and denser muscle mass.

Meneely et al (36) identified significant differences in the LBM of black and white men. ^{40}K counting was used to determine LBM in 99 blacks and 360 whites ranging in age from 7 to 79 y. At 17 y, the black men were significantly heavier than the white men, and most of this difference was attributed to a greater LBM. The LBM in black men was 5–7% greater than that of white men throughout life. There was a decline in LBM in both races after the age of 40 y, but black men in this sample still had a greater LBM than white men in the seventh decade of life.

Ortiz et al (11) reported an 8% higher TBK and greater BMCs and BMDs in black than in white women who were closely matched for age, height, weight and menstrual status. Although the TBW/FFB value was nearly equal, black women had a significantly greater TBK (mmol)/FFB (kg) (63.1 ± 8.4 compared with 56.6 ± 7.4; $P < 0.03$). The black females had greater skeletal muscle mass in the upper, lower, and combined extremities. When total skeletal muscle mass was combined with total-body bone mass to provide an estimate of musculoskeletal mass, black females had a 14.7% higher value than white females.

Slaughter et al (13) found the mean TBK of blacks (116.1 ± 41.1 g) to be greater than that of whites (94.9 ± 36.8 g) in a sample of male juveniles, but this difference was not statistically significant. However, the authors noted that the difference in TBW between races was similar, but that TBK was 58% greater in blacks across the height scale. Because increased TBK with increasing body height is a better marker of muscle growth than is increased TBW, they speculated that there was a greater increase in the muscle mass of growing young, black males than in that of their white counterparts.

Using ^{40}K counting, Cohn et al (25) reported a 16.8% higher TBK ($P < 0.001$), and consequently a higher LBM, in black men than in white men. Likewise, the TBK of black women was 15.3% greater than that of white women ($P < 0.001$). Cohn et al noted that their results were consistent with those of Meneely et al (36). They also noted that the rate of TBK loss due to aging appeared to be similar across races.

FAT PATTERNING

"Fat patterning refers to the relative distribution of subcutaneous fat on the body as opposed to absolute amounts of fat" (37). To examine differences in fat patterning, most researchers compare skinfold thicknesses on the trunk and extremities.

According to Bjorntorp's "civilization syndrome" hypothesis (38), stress and poor coping mechanisms, such as smoking and alcohol consumption, combined with overeating and physical inactivity lead to insulin resistance and visceral obesity. The relation between fat patterns and lifestyle factors may vary by ethnicity. Regardless of the cause, research indicates that differences in fat patterning exist between blacks and whites. Relative to the fat deposition patterning of whites, blacks tend to have less subcutaneous fat in the extremities than in the trunk. Blacks also tend to carry relatively more fat on the back and lateral portions of their bodies, and whites have greater amounts of subcutaneous fat on the front of their bodies (39–43). In reviews, Malina (44, 45) stated that blacks consistently have smaller triceps skinfold thicknesses than whites, but the 2 races have essentially equal subscapular skinfold thicknesses; thus, blacks have a higher ratio of trunk to extremity skinfold thickness. This finding appears to be the case across age ranges and athletic status.

Robson et al (41) reported similar subscapular skinfold thicknesses in blacks and whites, but lower triceps skinfold thicknesses in blacks than in whites, yielding a higher ratio of subscapular to triceps skinfold thickness in black infants and children from Dominica than in white children from the United Kingdom. Likewise, in youths (n = 242) ranging in age from 6 to 16 y, Harsha et al (46) found that black boys were 22% thinner than white boys on the basis of measured skinfold thicknesses of the limbs, which were slightly greater at the subscapular site. This finding was repeated in a biracial sample of 278 children aged 7–15 y matched for body weight (39). Using a multivariate regression analysis technique, they found a disproportionate deposition of fat at the subscapular skinfold site for black boys and girls across maturation levels. The authors theorized that this departure from a more uniform fat distribution, as seen in whites, was genetically determined.

Zillikens and Conway (47) made both skinfold thickness and TBW measurements in a biracial sample of adults (n = 179). The ratios of triceps to subscapular and of thigh to subscapular thickness were lower ($P < 0.001$) in black (1.04 ± 0.28 and 1.78 ± 0.67, respectively) than in white (1.45 ± 0.33 and 2.51 ± 0.84, respectively) women, indicating that black women had relatively more subcutaneous fat on the trunk than on the extremities. Both black men and women had lower ratios of suprailiac to subscapular skinfold thickness than their white counterparts (men: 1.21 ± 0.42 compared with 1.66 ± 0.49, $P < 0.001$; women: 1.01 ± 0.32 compared with 1.59 ± 0.46, $P < 0.001$). This finding indicates a tendency for blacks to carry relatively more fat on the upper than the lower part of the trunk compared with whites.

In a study that examined the fat distribution of women residing in the southwestern United States, researchers discovered that black and Mexican American women distributed fat equally between the trunk and extremities, white women deposited a greater proportion of their fat peripherally, and Native Americans deposited more of their total fat on the trunk (48). The black women had the smallest waist-to-hip ratio, but had greater suprailiac and abdominal skinfold thicknesses than white women. Additionally, Malina et al (49) reported overall significant differences in the ratio of trunk to extremity skinfold thicknesses among adolescent girls (n = 498) from 4 ethnic groups, indicating a difference in the relative distribution of subcutaneous adipose tissue. However, post hoc comparisons showed no significant differences in the ratios between the black and white girls.

Vickery et al (42) established that skinfold thicknesses of the chest, abdomen, and thighs were greater in white men (n = 179) than in black men (n = 140). However, the mean ratio of subscapular to triceps skinfold thickness was significantly ($P < 0.05$) higher in blacks (1.57 ± 0.44) than in whites (1.47 ± 0.51). Hortobagyi et al (40) noted the same pattern: white football players had thicker skinfold thicknesses on the front of their bodies than did black football players. The ratio of the individual skinfold thicknesses to the sum of 7 skinfold thicknesses was significantly lower in blacks than in whites at the chest, abdomen, and suprailiac sites. However, once again, blacks deposited proportionally more fat at the subscapular site. These differences were confirmed in a recent study of 64 (30 blacks and 34 whites) National Collegiate Athletic Association Division I male athletes matched for age, height, weight, BMI, and training status (50). Black athletes deposited a significantly greater proportion of their subcutaneous fat in their subscapular region than did white athletes (18.6 ± 2.0% compared with 15.6 ± 2.4%; $P < 0.05$).

Using a principal-components technique, Malina et al (51) analyzed the %BF and fat patterning of athletes at the 1976 Montreal Olympics. They concluded that %BF is influenced primarily by sport and training, whereas fat patterning is more dependent on biological factors. As found in the other studies, whites had a higher ratio of extremity to trunk skinfold thickness than blacks. Similarly, Watson and Dako (43) found the triceps skinfold thickness of African athletes who participated in the first African University Games to be only 60% of that of white athletes with comparable %BF values.

Goran et al (52) expanded the knowledge of racial differences with regard to fat patterning beyond the scope of skinfold-thickness measurements. They used DXA to measure total fat mass and computed tomography to assess intraabdominal adipose tissue and subcutaneous abdominal adipose tissue in a sample of 65 black and 36 white prepubertal children. Black children had significantly less ($P < 0.05$) intraabdominal adipose tissue (boys, 22 ± 17 cm^2; girls, 28 ± 17 cm^2) than white children (boys, 27 ± 16 cm^2; girls, 54 ± 27 cm^2) and black children deposited less intraabdominal fat per unit of subcutaneous abdominal adipose tissue (0.17 ± 0.02 compared with 0.23 ± 0.02 cm^2; $P < 0.05$).

The literature indicates consistent differences in fat patterning between blacks and whites. These differences in fat deposition could produce systematic errors in the estimates of %BF from field methods that assume a consistent fat patterning between the 2 races. Thus, generalized equations need to be cross-validated in black samples. If there is poor generalizability, race-specific equations may be needed to obtain accurate estimates of %BF in the black population from field methods.

BODY PROPORTIONS

There are racial differences in body proportions. Blacks have a greater tendency toward mesomorphy and, on average, have shorter trunks and longer extremities than whites (44, 45, 53). The cadaver analyses of Merz et al (19) and Seale (20) verified that the bones of the extremities are relatively longer in blacks than in whites. Ortiz et al (11) reported significantly longer bone lengths (by ≈2 cm) in the upper ($P < 0.05$) and lower ($P < 0.01$) extremities in black females than in white females. Trotter and

Hixon (21) showed that differences in extremity lengths exist even in fetal skeletons. Hampton et al (32) noted that black youths have smaller biiliac and bitrochanteric widths relative to stature than do white youths.

These anthropometric differences between races could have a significant effect on the estimation of %BF with use of field methods. For example, with bioelectrical impedance analysis (BIA), total body resistance is largely determined by segmental resistances in the extremities (54). Because resistance is directly proportional to the length of the conductor (body segment) and because blacks have relatively longer extremities than whites, the fat-free mass of blacks may be systematically underestimated when BIA equations developed from white populations are used. Thus, race-specific equations may need to be developed for field methods that rely on body proportions and limb lengths.

ETHNICITY AND RACE

The terms *ethnicity* and *race* are often used interchangeably, and this has led to some confusion among both researchers and readers of body-composition literature. *Ethnicity* is usually reserved for classifying humans on the basis of characteristics related to culture, whereas *race* focuses on biologically based traits and characteristics (55). Most of the studies included in this review referred to their research subjects as black or white, and few made any reference to the cultural heritage of the subjects; thus, we used these racial terms throughout this review rather than making assumptions about ethnicity (eg, African American and Euro American). However, the degree to which body-composition variations are due to one's culture or genetic heredity is a complicated issue.

Bouchard (56) reviewed the complexities of genetic research with regard to body composition and concluded that there is a major gene effect for at least some body-composition variables. Other studies appear to support Bouchard's work. Ettinger et al (25) measured most of the clinical (body size, muscle, fat, physical activity, and lifestyle) and biochemical (calcium metabolism, bone turnover, sex and adrenal hormones, and growth factors) variables believed to be related to bone metabolism in 402 black and white men and women. Of 37 variables that differed between races, less than half were significantly ($P < 0.05$) associated with BMD in any of the final regression models. Even after adjustment for the clinical and biochemical covariates, a racial difference in BMD at various skeletal sites of 4.5–16.1% in men and of 1.2–7.3% in women remained. They concluded that there are racial differences in BMD that cannot be explained by clinical and biochemical variables.

Currently, one of the major topics of body-composition research is the role that leptin (the product of the recently sequenced obesity gene) plays in obesity. In addition to leptin being correlated with body fatness, research shows a racial difference in leptin concentrations that suggests a role for genetic factors in differences in body composition and obesity prevalence between black and white women (57, 58). In one study, the mean leptin concentration was significantly ($P < 0.01$) higher in 57 black girls (15.0 ± 10.1 μg/L) than in 79 white girls (8.4 ± 11.1 μg/L) aged 8–17 y (58). The authors concluded that this difference might play an important role in the accelerated growth and sexual maturation of black girls. Likewise, Nicklas et al (57) reported a strong correlation between leptin and %BF for both black ($r = 0.71$, $P < 0.0001$) and white ($r = 0.61$, $P < 0.001$) obese postmenopausal women, but a significant racial difference in leptin concentration (36.0 ± 4.8 compared with 45.8 ± 3.5 μg/L; $P < 0.05$), respectively. Additionally, leptin correlated with resting energy expenditure in black women ($r = 0.58$, $P < 0.001$) but not in white women ($r = 0.08$).

According to the anthropologist PJ Brown (59), genetic predisposition for a particular genotype, such as obesity, is more evident in cultures in whom ethnic endogamy is the rule, eg, obesity-prone Pima Indians. However, genetic racial variations in body composition are confounded by the amalgamation of races. Admixed individuals are forced into a single racial classification, and often those with only a small fraction of African heritage are classified as black. Thus, the "black" group in the cited literature may be heavily admixed with the genes of its contrast group, the "whites." In a position statement on the biological aspects of race, the American Association of Physical Anthropologists claim that "pure races, in the sense of genetically homogeneous populations, do not exist in the human species" and *race* has largely been rejected by anthropology (60).

Indeed, there is a trend in body-composition research to focus on ethnic rather than on racial differences. Nelson and Barondess (30) found that the Middle Eastern subgroup of Chaldeans, who are usually racially classified as white, are more similar in body composition to blacks or African Americans. They reported no significant differences in BMC (964 ± 263 compared with 952 ± 288 g) or BMC (g)/ht (cm) (7.03 ± 1.65 compared with 6.95 ± 1.79) between African American ($n = 437$) and Chaldean ($n = 71$) children, but both groups had greater values ($P < 0.05$) than those of white American children ($n = 226$; BMC = 859 ± 223 g; BMC:height = 6.37 ± 1.42 g/cm).

Furthermore, research supports the notion that there are ethnic differences in body composition within a single race. In a study of body-composition variables in blacks from Nigeria ($n = 314$), Jamaica ($n = 242$), and the United States ($n = 335$), Luke et al (61) found that the trend for both sexes was as follows: United States > Jamaica > Nigeria for the variables of height, weight, waist and hip circumferences, BMI, and %BF. Even more striking was these authors' recent finding that there were large differences in mean plasma leptin concentrations across black populations (62). The leptin concentrations in men from Nigeria (2.8 ± 2.8 mg/L) were not significantly different from those in men from Jamaica (3.9 ± 3.7 mg/L), but both were significantly ($P < 0.01$) lower than those in black males from the United States (6.8 ± 5.7 mg/L). Leptin concentrations varied for black women across all 3 cultures (Nigeria, 10.3 ± 8.3 mg/L; Jamaica, 18.6 ± 13.9 mg/L; and the United States, 27.7 ± 19.5 mg/L; $P < 0.01$).

It is clear that variations in human body composition are the result of a complex multifactorial entanglement of lifestyle, environmental, and genetic differences. Brown (59) reviewed obesity from an anthropologic perspective and concluded that obesity is probably the result of both genetics and culture. In areas of food scarcity, genetic traits have probably been selected to improve the chance of survival, whereas fatness has also been socially selected as a cultural symbol of social prestige. It behooves body-composition researchers to make note of the ethnic and cultural backgrounds of their research subjects. This cultural data combined with the rapid advances in genetic research could uncover many of the mysteries behind why some population subgroups have an increased incidence of obesity-related diseases.

SUMMARY AND RECOMMENDATIONS

Our review unequivocally shows that the FFB of blacks and whites differs significantly. It has been shown from cadaver and in vivo analyses that blacks have a greater BMC and BMD than do whites. These racial differences could substantially affect measures of body density and %BF. According to Lohman (63), a 2% change in the BMC of the body at a given body density could, theoretically, result in an 8% error in the estimation of %BF. Thus, the BMC and BMD of blacks must be considered when %BF is estimated.

Additionally, it is apparent from the limited research that the protein portion of the FFB is greater in blacks than in whites. This difference in protein, along with the greater BMCs and BMDs observed in blacks than in whites, violates the assumptions of the traditional 2-component body-composition models of Siri (1) and Brozek et al (2). Thus, these models are probably invalid for estimating the %BF of black men.

Because of differences in the proportions and densities of the FFB components, we recommend using a multicomponent model that accounts for variations from the assumed values (obtained from white samples) for FFB constituents to estimate the %BF of blacks. Although not entirely free of assumptions, DXA is a good alternative to the multicomponent model for estimating the %BF of blacks. DXA measures BMC and BMD directly, so its estimate of %BF is not affected by the greater bone mineral values typical of blacks. For more information about the theory and assumptions of DXA and other methods of body-composition assessment, refer to our recent review (64).

Because the FFBd of blacks is greater than that assumed for whites (1.100 g/cm^3), the use of body-density conversion formulas that were derived from white, male cadavers [eg, those of Siri (1) and Brozek et al (2)] will systematically underestimate %BF in black men. Schutte et al (15) estimated the FFBd of black men to be 1.113 g/cm^3 and reported an underestimation of 3% BF in black men when the Brozek et al (2) formula was used to estimate %BF in their sample. Using a multicomponent model and a larger, more heterogeneous sample than used by Schutte et al (15), Wagner (65) estimated the FFBd of black men to be 1.1057 g/cm^3 and subsequently developed the following conversion formula: %BF = [(4.858/body density) − 4.394] × 100. We advocate the use of this formula for converting body density to %BF in black men, but also recommend that it be cross-validated in a future study. Ortiz et al (11) recommend a similar race-specific formula for estimating the %BF of black women.

Rather than a systematic underestimation of %BF as seen with the traditionally used body-density conversion formulas, one could argue that for a given BMI, blacks might have less adiposity because of their greater tendency toward mesomorphy. Therefore, surveys such as NHANES, which use BMI as the index, might overestimate the prevalence of obesity in blacks. There is research to support this theory. Kleerekoper et al (66), using DXA to estimate %BF, found that black women (40.5 ± 7.2% BF) were not more obese than white women (39.0 ± 8.0% BF) despite having a significantly higher BMI (31.7 ± 6.0 compared with 29.2 ± 5.9; $P = 0.002$). However, in a study of 202 black and 504 white men and women, Gallagher et al (67) reported that race did not significantly influence the relation between BMI and %BF determined by a multicomponent model after age and sex were controlled for. We believe that more research is needed regarding the influence of race on BMI because this could have implications for the false assessment of the prevalence of obesity.

In addition to variations in FFBd and somatotype, differences between races in fat patterning could result in errors when %BF or body density are estimated from skinfold thicknesses, near-infrared interactance, or anthropometry. Most prediction equations have been developed using white populations. Thus, racial differences in fat patterning could produce systematic errors in the prediction equations of field methods. Specifically, our review showed that blacks deposit relatively less subcutaneous fat on the extremities and front of the body but more on the trunk and back than do whites.

Furthermore, Vickery et al (42) reported that the mean measured body density was significantly higher ($P < 0.05$) in blacks (1.075 ± 0.015 g/cm^3) than in whites (1.065 ± 0.012 g/cm^3), but the mean sum of 7 skinfold thicknesses was not significantly different (79.3 ± 43.2 compared with 88.0 ± 36.1 mm, respectively). The authors concluded that the relation of skinfold-thickness measures to body density is significantly different in black and white men. For a given sum of skinfold thicknesses and age, body density was, on average, 0.0070 g/cm^3 higher in blacks than in whites. Likewise, Schutte et al (15) showed that in a closely matched group, anthropometrically determined body density was similar to observed body density in whites, but was significantly underestimated in blacks. Thus, at similar sum of skinfold thickness values, blacks have a greater body density than whites. Additionally, blacks in general have longer extremities relative to height than do whites. These racial variations could result in errors when %BF is estimated from skinfold thicknesses or BIA, which rely on assumptions of consistent fat patterns and body proportions.

However, whether generalized prediction equations yield inaccurate results for blacks is still unclear. Research has shown that the generalized skinfold-thickness equations of Jackson and Pollock (68) and Jackson et al (69) are appropriate for estimating the %BF of black men and women, respectively (70, 71). Likewise, a modification (72) of the fatness-specific BIA equation of Segal et al (73) was shown to be accurate for both black women (74) and men (75). However, other researchers reported errors when using generalized formulas to estimate the body composition of black samples and recommend the development of race-specific equations (42, 76). Currently, we recommend the use of the generalized equations referenced, but additional cross-validation on black samples seems warranted.

Finally, only a few of the comparative studies that we reviewed made any mention of the socioeconomic status or environmental background of the subjects studied. These are certainly important variables that may confound the findings of racial differences in body-composition research. For example, there are inverse relations between social class and both protein deficiency and obesity in affluent, modernized societies, whereas there is a positive correlation between class and obesity in developing countries (59). We urge body-composition researchers to collect and report socioeconomic, ethnic, and environmental background data in future studies. This information, combined with the emerging advances in genetic research, could lead to a better understanding of the differences in body composition between racial or ethnic groups and the prevalence of obesity-related diseases.

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