Age-Related Changes in Musculoskeletal Mass Between Black and White Women

James A. Gasperino, Jack Wang, Richard N. Pierson Jr, and Steven B. Heymsfield

Earlier studies from our laboratory indicated that matched black and white women differ significantly in total body potassium (TBK), total body bone density (TBD), and total body bone mineral (TBBM). The aim of this investigation was to examine absolute levels and the kinetics of age-related changes in TBK, TBD, TBBM, and percent body fat in a cross-sectional cohort of 34 matched pairs (age ± 4 years, weight ± 2 kg, and height ± 4 cm) of black and white healthy non-obese women. Black and white women had a similar percentage of body weight as fat, although adipose tissue distribution (ie, waist to hip circumference ratio [WHR]) differed significantly ($P < .0007$) between the two groups (WHR, mean ± SD: black, 0.837 ± 0.062; white, 0.788 ± 0.043). TBBM and TBD were significantly ($P < .0001$) higher in young black women, and ethnic differences in total bone mineral mass persisted at all ages. TBK ($P = 0.0482$) and appendicular skeletal muscle mass ($P < .0001$) were higher in young black women; however, by ages 60 to 70 years, the two groups had similar TBK. Both groups of women lost musculoskeletal mass (ie, TBK and TBBM) and gained fat mass at similar rates. The results of this study suggest that black women have a greater appendicular muscle and skeletal mass, as well as upper-body fat distribution, than white women. These differences are independent of body weight, height, or percent fat, and the ethnic skeletal differences persist throughout the adult life span. The higher appendicular muscle mass, skeletal mass, and upper-body fat distribution suggest that black women may have greater androgenic activity than white women.

OSTEOPOROSIS continues to be a major public health problem in the United States. Nearly 20 million Americans are afflicted with osteoporosis-related fractures, and estimates of the hip-fracture rate exceed 250,000 per year.[1] Furthermore, osteoporosis is a major cause of morbidity in the United States. Half of all patients who are ambulatory before their first hip fracture lose the ability to walk afterward.[2] Fractures from accelerated bone loss also impose a considerable financial burden on the population, with annual costs estimated at seven to 10 billion dollars.[1]

Ethnicity appears to influence the risk of osteoporosis in both men and women. One study of orthopedic admissions at a United States hospital reported a hip-fracture rate three times greater for white women than for black women, and approximately five times greater for white men than for black men.[3] A retrospective study examining the relationship between ethnicity and osteoporotic fracture demonstrated a hip-fracture rate 30 times greater for white women than for black women.[4]

The mechanism(s) explaining the ethnic difference in osteoporosis-related fractures is presently unknown. Bone mineral mass is a major determinant of bone strength, and may also be a major determinant of osteoporosis-related fracture. Thus, ethnic differences in the fracture rate may be explained by differences in peak bone mineral mass, postmenopausal bone loss, or a combination of both processes. Bone mineral mass appears to be higher in black than in white women,[5,6] and this ethnic difference begins early in life.[7,8] A cross-sectional study of black and white children aged 7 to 12 years found that black girls have greater bone mineral density than their age-matched white counterparts.[8] A recent study found that black girls achieve a greater vertebral bone mineral density than white girls during late puberty.[7] Cohn et al[9] demonstrated that black women varying in age had a greater total body calcium and total body potassium (TBK) as compared with a white mixed-gender reference population.[9] Total body calcium and TBK are indirect markers of bone and skeletal muscle mass, respectively.

Taken collectively, these studies suggest that ethnic differences in total body bone mineral mass (TBBM), total body bone density (TBD), and TBK exist between black and white women throughout the adult life span. The specific aim of the present study was to test the hypothesis that black women achieve a greater peak musculoskeletal mass than white women and maintain this difference in the postmenopausal period.

SUBJECTS AND METHODS

Design

The subjects were a cross-sectional cohort of matched black and white women. Each black woman was matched to a white woman of similar age (±4 years), weight (±2 kg), height (±4 cm), and menstrual status (ie, in relation to their premenopausal or postmenopausal state) to eliminate four independent determinants of bone mass as alternative explanations for ethnic differences. Subjects of normal body mass index (18 to 25 kg/m^2) were selected to control for the greater age-related weight gain and prevalence of obesity observed in black women relative to white women.[10]

Subjects

Black and white healthy non-obese women aged 21 to 75 years were recruited from several sources, including hospital employees, newspaper advertisements, and leaflets circulated in the local community. Subjects enrolled in the study met three criteria: (1) absence of serious medical illness (ie, metabolic bone disease, diabetes, thyrotoxicosis); (2) not taking medication known to

From the Obesity Research Center, St. Luke's-Roosevelt Hospital Center, Columbia University College of Physicians and Surgeons, New York, NY.

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Address reprint requests to Steven B. Heymsfield, MD, Obesity Research Center, St. Luke's-Roosevelt Hospital, Amsterdam Avenue at West 114th Street, 10th Floor, Woman's Hospital room 1020, New York, NY 10025.

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influence bone metabolism; and (3) no unusual dietary practices (ie, prolonged high-protein diet, alcoholism, history of low calcium intake). Both groups of women were fully ambulatory and had similar daily physical-activity histories based on a simple screening questionnaire. No subject had a history of reduced ambulation or prolonged immobilization. Certain measurements were not possible on all subjects. Some subjects, for example, were uncomfortable with being placed in a confined space and thus refused to enter the whole-body ^{40}K counter. Others chose not to disrobe, which prevented measurement of the waist to hip circumference ratio (WHR). Therefore, sample sizes of less than the total sample of 34 were recorded for some studies. The investigation was approved by the institutional review board of St. Luke's-Roosevelt Hospital Center, and the participants provided informed consent before the study. Subjects in this investigation were not included in our earlier reports on the relation between ethnicity and body composition.[5]

Protocol

Upon completion of the screening evaluation, subjects underwent body composition studies that included anthropometry, bone mineral studies, and whole-body ^{40}K counting. The results of these studies were used to calculate compartmental masses and other relevant body composition indices.

Body Composition

Anthropometry. Body weight and height were measured to within 0.01 kg and 0.10 cm using an electronic scale (Weight-Tronix, Scales Electronics Development, New York, NY) and stadiometer (Holtain Limited, Crosswell, Wales, UK), respectively. Waist and hip circumferences were measured at the costal margin and at the iliac crest to the nearest 0.1 cm.[11] The WHR was assumed to represent adipose tissue distribution.

Whole-body ^{40}K counting.

TBK was evaluated with the St. Luke's 4-Pi whole-body gamma counter that measures the 1.46-MeV gamma ray decay of ^{40}K. The raw counts for each subject were adjusted for body size using a ^{42}K-derived correction equation.[12]

Bone mineral studies.

Whole-body estimates of TBBM, TBD, appendicular skeletal muscle mass, and fat were made by a whole-body dual-photon absorptiometer (DP4 Lunar Instruments, Madison, WI) and dual-energy x-ray absorptiometer (DPX, Lunar Instruments). The calibration, validation, and precision of these systems are described in detail in earlier reports from our laboratory.[13]

Statistical Analysis

We used a two-tailed paired t test to evaluate absolute ethnic differences in TBBM, TBD, TBK, appendicular skeletal muscle mass, and fat. The Bonferroni criterion was used to account for the effect of multiple comparison artifact. Only P values less than .01 (ie, .05/5) were considered statistically significant.

The method of least squares was used to develop simple linear regression equations for each compartment versus age. Ethnic differences between point estimates of the slope (ie, rate of body compartment change with age) were evaluated by Student's t test.[14] Regression equations were centered at age 40 years to improve predictability of the equation.[15] Centering the regression equation at age 40 years accounted for subjects' age beginning at the second decade of life and not zero. The percentage of change per decade was calculated using the relationship 100 × [10 years (slope)]/ predicted value at age 25 years.[16] The predicted value at age 25 years was used as a baseline for estimating relative rates.

Results of the cross-sectional data are presented as group means ± SD, and differences between group means are expressed as absolute differences ± SD. Statistical analysis was completed using the SAS statistical software program (SAS Institute, Cary, NC).

Table 1. Baseline Characteristics for Matched Black and White Women

	Black	White	*P*
Age (yr)	44 ± 13	45 ± 13	.0997
Weight (kg)	65.1 ± 7.5	64.4 ± 7.8	.0724
Height (cm)	162.6 ± 5.7	163.1 ± 4.9	.6006
No. of pregnancies	2.1 ± 2.0	2.2 ± 3.0	.5890
Physical activity (h/wk)	5.0 ± 3.5	5.7 ± 5.3	.5744

NOTE. Values are the mean ± SD for 34 matched pairs of black and white women.

RESULTS

Subjects

A total of 68 black and white women aged 21 to 75 years met the entry criteria and participated in the study (Table 1). The 34 pairs of black and white subjects did not differ significantly in age ($df = 33$, $P = .0997$), weight ($df = 33$, $P = .0724$), height ($df = 33$, $P = .6006$), physical activity ($df = 33$, $P = .5744$), or number of pregnancies ($df = 33$, $P = .5890$). Body weight did not correlate significantly with age in either ethnic group (black: $R^2 = .034$, $P = .2925$; white: $R^2 = .040$, $P = .2521$). Thirteen pairs of matched women were premenopausal, and 21 pairs were postmenopausal.

Body Composition

Bone. Black women had 14.1% higher TBBM ($df = 33$, $P < .0001$) and 10.9% greater TBD ($df = 33$, $P < .0001$) than white women (Table 2). Premenopausal black women had 16.2% ($df = 12$, $P < .0149$) higher TBBM and 10.9% ($df = 12$, $P = .0002$) greater TBD than their white counterparts (Table 3). Postmenopausal black women had 11.9% more TBBM ($df = 20$, $P = .0008$) and 10.2% greater TBD ($df = 20$, $P < .0001$) than white women (Table 4). Bone mineral mass and density decreased linearly and significantly with age in both subject groups (TBBM v age: black women, $R^2 = .17$ and $P = .0152$, white women, $R^2 = .20$ and $P = .0071$; TBD v age: black women, $R^2 = .33$ and

Table 2. Results of Body Composition Studies in Matched Black and White Women

	Black	White	*P*
TBD (g/cm²)	1.184 ± 0.104	1.067 ± 0.085	.0001*
TBBM (g)	2,660 ± 397	2,331 ± 316	.0001*
TBK (mmol)†	2,639 ± 472	2,484 ± 313	.0785
SM (kg)	17.9 ± 3.30	13.4 ± 2.33	.0001*
Fat (%)	33.4 ± 9.4	33.7 ± 7.8	.8651
WHR‡	0.837 ± 0.062	0.788 ± 0.044	.0007

NOTE. Values are the mean ± SD for 34 pairs of black and white women.

Abbreviation: SM, appendicular skeletal muscle mass.

*Significantly different with the Bonferroni correction.

†Thirty-two matched pairs.

‡Thirty matched pairs.

Table 3. Results of Body Composition Studies in Matched Pairs of Black and White Premenopausal Women

	Black	White	P
Age (yr)	30 ± 5	31 ± 5	.3308
Weight (kg)	62.8 ± 8.1	61.7 ± 8.2	.1176
Height (cm)	166.0 ± 6.4	164.5 ± 5.7	.9558
TBD (g/cm²)	1.242 ± 0.059	1.119 ± 0.064	.0002*
TBBM (g)	2,852 ± 411	2,453 ± 252	.0149*
TBK (mmol)†	2,831 ± 476	2,632 ± 342	.0482
SM (kg)	18.4 ± 3.05	13.5 ± 2.30	.0001*
Fat (%)	26.5 ± 8.5	28.9 ± 5.6	.5667
WHR†	0.832 ± 0.073	0.777 ± 0.045	.0139

NOTE. Values are the mean ± SD for 13 matched pairs of black and white women.

Abbreviation: SM, appendicular skeletal muscle mass.

*Significantly different with the Bonferroni correction.

†Eleven matched pairs.

$P = .0004$, white women, $R^2 = .42$, $P < .0001$). These cross-sectional data suggest that black and white women lose bone mineral mass and density at similar rates. Differences in the slope of TBBM or TBD per year of age were not significantly different between black and white women (P = NS; Table 5).

Muscle. Black women had 6% higher TBK ($df = 31$, $P = .0785$) and 33% greater appendicular skeletal muscle mass ($df = 33$, $P < .0001$) than white women (Table 2). Premenopausal black women had 7% higher TBK ($df = 10$, $P = .0482$) and 36% greater appendicular skeletal muscle mass ($df = 12$, $P < .0001$) than their white counterparts (Table 3). Similarly, postmenopausal black women had 1.3% higher TBK and 31% more appendicular skeletal muscle mass relative to the matched white women (Table 4). TBK decreased linearly and significantly with age in both black and white women (TBK *v* age: black, $R^2 = .21$ and $P = .0069$, white, $R^2 = .24$ and $P = .0033$; Table 5). Differences between ethnic groups in the slopes of TBK versus age were not statistically significant (P = NS). It appears that black and white women lose TBK, an index of muscle mass, at similar rates.

Adiposity. Total adiposity did not differ significantly between black and white women (Tables 2, 3, and 4). However, adipose tissue distribution did differ significantly between ethnic groups. Black women had a greater WHR ($df = 29$, $P = .0007$; Table 2). Fat as a percentage of body weight increased linearly with age in both black and white women (black women, $R^2 = .25$ and $P = .0015$; white women, $R^2 = .36$ and $P = .0002$; Table 5). Differences in the slope of percent fat versus age for this cross-sectional cohort were not statistically different between ethnic groups (P = NS). Adipose tissue distribution (WHR) was not linearly related to age in either black or white women (black women, $R^2 = .009$ and $P = .6034$; white women, $R^2 = .067$, $P = .1458$; Table 5).

Table 4. Results of Body Composition Studies in Matched Postmenopausal Black and White Women

	Black	White	P
Age (yr)	52 ± 10	54 ± 9	.1923
Weight (kg)	65.9 ± 6.9	65.6 ± 7.4	.5786
Height (cm)	162.3 ± 5.1	162.7 ± 4.3	.6462
TBD (g/cm²)	1.144 ± 0.106	1.038 ± 0.084	.0001*
TBBM (g)	2,531 ± 346	2,260 ± 339	.0008*
TBK (mmol)	2,474 ± 390	2,442 ± 302	.7458
SM (kg)	17.6 ± 3.0	13.4 ± 2.4	.0003
Fat (%)	36.8 ± 7.6	36.6 ± 7.4	.9159
WHR†	0.840 ± 0.056	0.790 ± 0.044	.0191

NOTE. Values are the mean ± SD for 21 matched pairs of black and white women.

*Significantly different with the Bonferroni correction.

†Nineteen matched pairs.

DISCUSSION

The results of this study confirm that differences in appendicular muscle and skeletal mass exist throughout the adult life span of normal black and white women. Specifically, black women of all ages had greater TBBM, TBD, and appendicular skeletal muscle than white women matched for age, weight, height, and menstrual status. Both groups of women had similar self-reported physical-activity histories, total body fat, and number of pregnancies. Additionally, our results suggest that age-related changes in skeletal mass, although based on cross-sectional data, are similar between black and white women.

Adult skeletal mass reflects the difference between two competing metabolic processes: bone formation and bone resorption. Bone formation exceeds bone resorption until peak bone mass is achieved, usually by the third decade of life. Afterward, bone loss exceeds bone formation at an average rate of 1% per year.[16] The current study suggests that black women achieve a 16.2% greater peak bone mineral mass than white women, and that subsequently both black and white women lose bone mineral at similar rates (−4.2% per decade). This observation extends the findings of Luckey et al,[15] who demonstrated that black women have greater radial and vertebral bone mineral density than white women, as well as similar rates of radial and vertebral bone density loss.

Skeletal muscle mass and skeletal weight are highly correlated in humans. TBK, an index of skeletal muscle mass, follows a growth curve in humans similar to that for bone mineral. Maximum TBK values are reached by the second decade of life, and then a gradual decrease in TBK follows.[12] In the present study, black women had greater absolute values of TBK (6.2%) and appendicular skeletal muscle (33.5%) and similar relative rates of TBK loss per decade (black women, −4.8%; white women, −4.4%) than white women. The relative rates of TBK loss per decade were consistent with those reported in earlier studies. Forbes, for example, reported a 5% decrease in TBK per decade in a cohort of white women.[12] Similarly, Noppa et al[17] demonstrated a 202-mEq decrease of TBK in Swedish women aged 44 to 66 years, a 3.3% decline per decade. In the present study, both black and white women lost TBK at approximately 4% per decade.

Population-based studies indicate that black women have greater total fat mass than non-obese white women.[10] Our results suggest that after accounting for age, weight, and height, total fat mass is similar between black and white

Table 5. Regression Equations for Body Composition Parameters Versus Age in Matched Pairs of Black and White Women

Group	Intercept	Slope	SE	t	R^2	P	%Change per Decade
TBD (g/cm²)							
Black	1.204	−0.0044	0.0011	−3.982	0.33	0.0004	−3.5
White	1.092	−0.0042	0.0009	−4.897	0.42	0.0001	−3.6
TBBM (g)							
Black	2,709	−12.10	4.75	−2.564	0.17	0.0152	−4.2
White	2,392	−10.83	3.76	−2.876	0.20	0.0071	−4.2
TBK (mmol)†							
Black	2,698	−13.82	4.78	−2.890	0.21	0.0069	−4.8
White	2,576	−12.02	3.77	−3.182	0.24	0.0033	−4.4
Fat (%)							
Black	31.8	0.363	0.104	3.481	0.25	0.0015	13.7
White	31.2	0.400	0.093	4.283	0.36	0.0002	15.8
Weight (kg)							
Black	60.5*	0.100	0.097	1.070	0.03	0.2925	(NA)
White	59.0*	0.110	0.101	1.166	0.04	0.2521	(NA)
WHR							
Black‡	0.816	0.0004	0.0001	0.525	0.009	0.6034	(NA)
White	0.747	0.0008	0.0005	1.492	0.067	0.1458	(NA)

NOTE. Linear regression equations were centered at age 40 years (y = m[x − 40] + b). Coefficients for the intercept and slope represent the predicted value at age 40 years and the point estimate of the population slope (ie, TBD change with age), respectively.

Abbreviations: SE, standard error of the slope; NA, not applicable because no linear relation exists.

†Thirty-two white women.

‡Thirty black women.

women. Further, the relative increase in fat mass per decade (~17.0%) was not significantly different between ethnic groups.

An interesting finding related to adiposity was the ethnic difference in WHR. Premenopausal black women had a greater WHR as compared with their white counterparts. The greater upper-body adipose tissue distribution reported in this cross-sectional study of matched black and white women substantiates earlier reports of ethnic differences in regional adiposity.

Although the mechanism(s) leading to ethnic differences in muscle and skeletal mass is unknown, results of both a recent study conducted in our laboratory and the present study suggest that differences in androgenic activity may play an important role. For instance, Dowling and Pi-Sunyer found that obese black women had higher levels of testosterone and sex hormone–binding globulin than obese white women.[18] Sex hormone–binding globulin is now known to function as a polypeptide hormone, although its function as such is unknown.[19] Furthermore, in the present study we found that black women had greater skeletal and appendicular muscle mass, as well as upper-body adipose tissue distribution, relative to white women. Thus, the body composition of black women in this study is also consistent with an androgenic influence.

It now appears that androgens have both direct and indirect effects on bone metabolism. Colvard et al[20] observed the presence of specific androgen binding sites and androgen receptor mRNA in human osteoblast-like cells. A recent report has shown testosterone and dihydrotestosterone to stimulate directly the synthesis of both type 1 collagen (the major extracellular matrix protein in bone tissue) and an osteoblast-derived growth factor.[21] These studies suggest that androgens may regulate local control of bone metabolism.

Several clinical studies also indicate that androgens play a role in maintaining skeletal mass in women. Increased androgen levels in postmenopausal women protect against accelerated bone loss as compared with age-matched controls of comparable estrogen status.[22] Others have demonstrated that hirsute women maintain their bone mass despite undetectable estradiol levels.[23] These women have denser bones than controls. High-fiber diets depress serum androgen levels and decrease trabecular bone density in premenopausal women.[24] Further, significant correlations were found between bone density and serum adrenal androgen concentration.[25]

Androgenic hormones also have an anabolic effect on skeletal muscle tissue. Men have greater skeletal muscle mass than women, and hirsute women have greater skeletal muscle mass than controls.[23,26] Testosterone and other androgens increased TBK and created a positive nitrogen, potassium, and phosphorus balance in normal adult subjects.[27] Griggs et al[27] found that testosterone increases muscle mass by stimulating skeletal muscle protein synthesis.

An upper-body fat distribution, as indicated by the WHR, is correlated with increased androgenicity. Men, for example, have a greater WHR than women and several times greater serum testosterone concentrations than women.[26] A recent report found a significant association between women with a WHR exceeding 0.80 and lower sex hormone–binding globulin levels.[28] Moreover, in premenopausal women upper-body fat distribution (WHR) and free

serum testosterone appear to be correlated.[29] Thus, increased androgen activity occurs in association with upper-body adipose tissue distribution.

In conclusion, the present investigation demonstrates that differences in musculoskeletal mass exist throughout the adult life span of black and white women of similar adiposity. Additionally, age-related musculoskeletal changes were similar between ethnic groups, suggesting that differences in peak bone mass are responsible for differences in postmenopausal bone mass between black and white women. This hypothesis can be tested in future longitudinal studies. Our finding of greater bone mass, appendicular skeletal muscle mass, and WHR in black women combined with the available literature provides strong support for the hypothesis that androgenic activity accounts for ethnic changes in bone mass.

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