Body Composition and Muscle Strength as Determinants of Racial Difference in Bone Mineral Density

Youn Soo Jung, Steven A. Hawkins, and Robert A. Wiswell

The purpose of this study was to determine the contribution of body composition and muscle strength to racial differences in bone mineral density (BMD) in chronically active older adults. Participants were 49 men and 56 women grouped according to self-selected race (Black, Asian, or White). BMD, body composition, and knee strength were measured. Asian men had significantly lower body mass, strength, and BMD than White and Black men did ($p < .05$). Asian and White women had significantly lower body mass and BMD than Black women did ($p < .05$), with few strength differences between groups. When lean mass was controlled by ANCOVA, racial differences in BMD disappeared for all bone sites in both sexes. Controlling for body mass eliminated most racial differences in BMD. Controlling for strength did not alter racial differences in BMD for either sex. These results suggest that racial differences in BMD might in part result from differences in lean mass.

**Key Words:** bone mass, lean mass, body mass, fat mass

Racial differences in bone mineral density (BMD) are clearly evident. Greater BMD has been reported in Blacks than in Whites (Cote & Adams, 1993) and in Whites than in Asians (Nakamura et al., 1994). The lower BMD in Whites and Asians could account for a greater rate of hip fracture in those groups than among Blacks (Villa & Nelson, 1996). Although much of the difference in BMD between racial groups could be attributed to differences in body mass (Bhudhikanok et al., 1996), studies have suggested that bone mass might still vary between races when body mass is controlled for statistically (Nelson, Jacobsen, Barondess, & Parfitt, 1995). Racial differences in skeletal remodeling rate (Weinstein & Bell, 1988) and vitamin D receptor allele distribution (Harris, Eccleshall, Gross, Dawson-Hughes, & Feldman, 1997) have been reported that could provide part of the explanation for racial differences in bone mass. In addition, differences in skeletal muscle mass and strength, which have been directly and independently related to BMD in older participants (Bevier et al., 1989), might provide part of the explanation for racial differences in bone mass independent of body mass. Nonetheless, the roles of body composition and muscle strength in determining ethnic differences in BMD have

Jung and Wiswell are with the Department of Biokinesiology at the University of Southern California, Los Angeles, CA 90033. Hawkins is with the Department of Kinesiology and Physical Education at California State University, Los Angeles, CA 90032.
not been studied. Therefore, it was the purpose of this study to determine whether there were differences in bone mass between Black, White, and Asian men and women when differences in body mass, various measures of body composition, and muscle strength were statistically accounted for. It was hypothesized that racial differences in BMD would be diminished when controlling for lean-mass and muscle-strength differences, regardless of gender.

**Materials and Methods**

**PARTICIPANTS**

Participants in the study included 49 men (mean age 58.3 ± 7.1 years, range 43–75) and 56 women (mean age 54.3 ± 6.0 years, range 46–73). This sample was chosen partly out of convenience; most were part of an ongoing study in the lab. Also, the primary focus of the lab is the influence of exercise on physiologic function in older adults. Most participants had been involved in a study of chronically active older adults ongoing at the University of Southern California (USC) since 1986. These participants were involved in activities including walking, running, swimming, cycling, dancing, basketball, and volleyball. In addition, 12 men and 22 women, all chronically physically active, were recruited from the Korean American community of Los Angeles, CA. Participants were considered chronically active if they participated in physical activity at least 3 days per week for at least 30 min per session and had done so for at least 5 years. All participants completed medical histories, and any participant with conditions precluding full participation in the study was excluded. These included hypertension, metabolic disorders known to influence bone or muscle, and musculoskeletal injury of the legs.

All participants completed a Physical Activity Record (PAR) Questionnaire (Jackson et al., 1990) to determine activity levels and were asked to identify their racial background in a health-history questionnaire. Participants were grouped by race and gender (Asian men \( n = 19 \), mean age 59.6 ± 8.5 years, range 43–75; Asian women \( n = 29 \), mean age 54.8 ± 5.4, range 46–69; White men \( n = 15 \), mean age 56.6 ± 5.4, range 45–66; White women \( n = 18 \), mean age 52.4 ± 4.9, range 46–61; Black men \( n = 15 \), mean age 58.3 ± 6.6, range 47–70; and Black women \( n = 9 \), mean age 56.4 ± 9.1, range 47–73). The USC Institutional Review Board approved the study protocol, and participants provided written informed consent.

**BODY COMPOSITION**

On arrival in the laboratory, participants’ height was measured with a stadiometer, and weight determined on a calibrated Homs beam scale. Three-compartment body composition was determined by dual-energy x-ray absorptiometry (DEXA) using Hologic QDR-1500 software, version 7.1. Body composition was determined during a whole-body scan by including a calibrated tissue bar in the scanning area. Coefficient of variation for this procedure ranged from 1.5 to 2.0%.

**STRENGTH**

Isometric strength of the knee flexors and extensors was determined at 15, 30, and 45° and 30, 45, and 60° of knee flexion, respectively, on an isokinetic dynamometer
Isometric contractions were held for a period of 3 s. Isokinetic concentric and eccentric knee-extension strength were determined on the KinCom through a range of motion of 15–80° of knee flexion at a velocity of 60°/s. Participants were instructed to contract the muscle group being tested rapidly and forcefully throughout the time period/range of motion and were verbally encouraged to provide full effort on each contraction. Peak isometric and isokinetic torque were recorded and reported in N·m. Coefficient of variation for the strength measurements ranged from 1.4 to 6.7%.

**BONE MINERAL DENSITY**

BMD was measured using the Hologic QDR-1500 DEXA. Whole-body, lumbar-spine (L1–L4), and total hip measurements were performed following standard procedures as described by the Hologic users’ manual. Briefly, the participants were clothed in shorts and a T-shirt, wearing no metal. For the whole-body scan, participants lay in a supine position. For the lumbar scan, participants lay supine, flexed 90° at the hip and knees, with the lower legs supported by a pad. They remained supine for the hip scan, with the nondominant leg slightly abducted, internally rotated 20–40°, and secured to prevent movement. Coefficient of variation for the BMD measurements ranged from 0.5 to 2.0%.

*T* and *Z* scores are reported as SD for BMD from gender-matched norms for young adults and gender-matched norms for each age, respectively, as provided by the manufacturer. A *T* score of 0.0 would indicate a measured BMD equivalent to peak predicted, whereas a *Z* score of 0.0 would indicate a measured BMD equivalent to age predicted.

**STATISTICS**

Data were entered into a spreadsheet and analyzed on a personal computer using the Statistical Package for Social Sciences (SPSS), version 9.0. Two-way analysis of variance (ANOVA) was used to test for differences among racial and gender groups, with LSD post hoc comparison. Analysis of covariance was used to test for differences between racial groups with body mass, body composition, or strength as the covariate. Pearson product–moment correlation was used to determine relationships between variables. Results are reported as *M* ± *SD*, and *p* values <.05 were required for statistical significance.

**Results**

Physical characteristics of the participants are given in Table 1. There were no differences in age between male or female racial groups. Women were shorter, with significantly lower body mass and lean mass and significantly greater percent body fat than men were, *F*(1, 104) = 35.10–263.06, *p* < .05. For men, percent body fat was not different between racial groups, but Asian men were shorter, *F*(2, 46) = 36.12, *p* < .05, and lighter, *F*(2, 46) = 14.35, *p* < .05, with less lean mass, *F*(2, 46) = 16.76, *p* < .05, than both Black and White men. For the women, Asians were shorter, *F*(2, 53) = 5.39, *p* < .05, than Blacks and Whites and had greater percent body fat, *F*(2, 53) = 9.32, *p* < .05, and fat mass, *F*(2, 53) = 6.11, *p* < .05, than Whites did.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Asian</th>
<th>Women</th>
<th>White</th>
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<tr>
<td></td>
<td>Men (n = 19)</td>
<td>Women (n = 29)</td>
<td>Men (n = 15)</td>
<td>Women (n = 18)</td>
<td>Men (n = 15)</td>
<td>Women (n = 9)</td>
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<tr>
<td>Age (years)</td>
<td>59.6 ± 8.5</td>
<td>54.8 ± 5.4</td>
<td>56.6 ± 5.4</td>
<td>52.4 ± 4.9</td>
<td>58.3 ± 6.6</td>
<td>56.4 ± 9.1</td>
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<td>Height (cm)</td>
<td>164.9 ± 6.1&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>158.6 ± 5.8&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>179.1 ± 4.4</td>
<td>162.4 ± 3.5</td>
<td>177.6 ± 5.6</td>
<td>164.2 ± 6.0</td>
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<td>Weight (kg)</td>
<td>64.8 ± 10.1&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>55.3 ± 7.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>76.9 ± 7.6</td>
<td>52.0 ± 4.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>80.9 ± 9.4</td>
<td>60.7 ± 9.0</td>
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<td>LBM (kg)</td>
<td>51.1 ± 7.1&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>38.6 ± 3.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>60.7 ± 5.9</td>
<td>40.1 ± 2.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>63.7 ± 6.9</td>
<td>45.2 ± 1.5</td>
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<td>Fat mass (kg)</td>
<td>11.4 ± 3.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.7 ± 4.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.2 ± 2.9</td>
<td>10.4 ± 2.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.4 ± 5.0</td>
<td>14.1 ± 6.6</td>
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<td>% Body fat</td>
<td>17.3 ± 3.7</td>
<td>26.2 ± 5.0&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>17.1 ± 3.1</td>
<td>19.8 ± 3.2</td>
<td>17.5 ± 4.5</td>
<td>22.4 ± 7.3</td>
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<td>Hip BMD (g/cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>0.944 ± 0.133&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>0.807 ± 0.115&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.039 ± 0.083&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.823 ± 0.081&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.103 ± 0.126</td>
<td>1.017 ± 0.168</td>
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<tr>
<td>Spine BMD (g/cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>0.978 ± 0.149&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.897 ± 0.154</td>
<td>1.036 ± 0.109</td>
<td>0.885 ± 0.101</td>
<td>1.129 ± 0.140</td>
<td>1.102 ± 0.235</td>
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<tr>
<td>Total BMD (g/cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.102 ± 0.095&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>1.039 ± 0.097&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.234 ± 0.087</td>
<td>1.044 ± 0.081&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.302 ± 0.096</td>
<td>1.136 ± 0.102</td>
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Note. LBM = lean body mass; BMD = bone mineral density.
<sup>a</sup>p < .05, different than White, main effect of ANOVA. <sup>b</sup>p < .05, different than Black, main effect of ANOVA.
Asian and White women had lower body mass, $F(2, 53) = 4.81, p < .05$, and lean mass, $F(2, 53) = 15.42, p < .05$, than Black women did, and Whites had lower fat mass, $F(2, 53) = 6.11, p < .05$, than Blacks did. PAR did not differ between men and women, but Asians had significantly lower PAR than did Whites and Blacks for both men ($6.5 \pm 0.6$ vs. $8.0 \pm 0.4$ and $9.3 \pm 0.4$, respectively), $F(2, 46) = 7.89, p < .05$, and women ($5.8 \pm 0.2$ vs. $8.1 \pm 0.4$ and $8.1 \pm 0.6$, respectively), $F(2, 53) = 18.09, p < .05$. The score for Asians equated to 1–3 hr/week in vigorous activity such as running, lap swimming, cycling, rowing, aerobics, basketball, tennis, racquetball, or handball. The score for Whites and Blacks equated to 3–6 hr/week in similar activities.

Isometric strength is reported at $15^\circ$ for knee-flexion strength and $60^\circ$ for knee-extension strength because these angles elicited the greatest values in most participants (Table 2). Women had significantly lower isometric and isokinetic strength than did men, $F(1, 104) = 37.7–102.9, p < .05$. For men, Asians were significantly lower than Blacks and Whites were for isokinetic concentric extension, $F(2, 46) = 6.35, p < .05$; isometric extension, $F(2, 46) = 4.18, p < .05$; and isometric flexion, $F(2, 46) = 9.99, p < .05$. White and Asian men were significantly lower than Blacks were for isokinetic eccentric extension, $F(2, 46) = 3.67, p < .05$. Women were not different in isokinetic concentric extension, isometric extension, or isometric flexion. White women were significantly lower than Blacks were for isokinetic eccentric extension, $F(2, 53) = 2.56, p < .05$.

Bone-density results are presented in Table 1. Women had significantly lower BMD at all sites than men did, $F(1, 104) = 14.57–52.63, p < .05$. For men, Asians had significantly lower BMD of the total hip, $F(2, 46) = 7.97, p < .05$, and whole body, $F(2, 46) = 20.66, p < .05$, than either Blacks and Whites did and significantly lower BMD of the spine, $F(2, 46) = 5.26, p < .05$, than Blacks did. White men had significantly lower total hip BMD, $F(2, 46) = 7.97, p < .05$, than did Black men. For women, Whites and Asians had significantly lower BMD of the total hip, $F(2, 53) = 11.87, p < .05$, and whole body, $F(2, 53) = 3.94, p < .05$, than Blacks did. Despite apparent differences in spine BMD for women, statistical significance was not noted, $F(2, 53) = 2.27, n.s$.

Figure 1 presents the $T$ and $Z$ scores for ethnic and gender groups for hip and spine BMD. Asian men and women and White women demonstrated $T$ scores approximately 1 SD below the mean for both hip and spine BMD. White men and Black women were approximately one-half SD below the mean for the spine only. For $Z$ scores, Asian men and women and White women tended to be lower than the mean for both hip and spine BMD, whereas White men and Black men and women tended to be higher than the mean for both hip and spine BMD.

Individually controlling for fat mass or muscle strength did not affect racial-group differences in bone mass at any site for either men or women. Conversely, controlling for lean mass abolished racial differences in bone mass at all sites for both men and women, whereas controlling for body mass abolished racial-group bone-mass differences of the total hip and spine for men and of the whole body for women. Finally, racial-group differences in muscle strength were uniformly abolished when either body mass or lean mass was controlled for.

Pearson's correlation demonstrated significant relationships between body mass and bone mass for men at all bone sites ($r = .47–.76, p < .05$) and for women at the hip only ($r = .43, p < .05$). Relationships between lean mass and bone mass
Table 2  Strength Characteristics of the Participant Groups (M ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Asian</th>
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<td>Women (n = 18)</td>
<td>Men (n = 15)</td>
<td>Women (n = 9)</td>
</tr>
<tr>
<td>Isometric extension (N·m)</td>
<td>140.4 ± 29.7⁹</td>
<td>104.2 ± 25.8</td>
<td>159.1 ± 22.7</td>
<td>102.1 ± 16.9</td>
<td>171.7 ± 41.2</td>
<td>114.2 ± 19.9</td>
</tr>
<tr>
<td>Isometric flexion (N·m)</td>
<td>64.3 ± 17.2⁹</td>
<td>43.1 ± 12.8</td>
<td>87.2 ± 17.2</td>
<td>46.3 ± 10.7</td>
<td>88.4 ± 19.6</td>
<td>53.3 ± 16.4</td>
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<tr>
<td>Isokinetic extension</td>
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<td>concentric (N·m)</td>
<td>108.7 ± 34.0⁹</td>
<td>76.3 ± 25.0</td>
<td>140.9 ± 29.7</td>
<td>80.1 ± 22.2</td>
<td>146.9 ± 37.9</td>
<td>82.6 ± 25.8</td>
</tr>
<tr>
<td>eccentric (N·m)</td>
<td>171.4 ± 46.9⁹</td>
<td>130.9 ± 37.3</td>
<td>177.1 ± 49.9⁹</td>
<td>122.4 ± 32.0⁹</td>
<td>213.3 ± 45.2</td>
<td>153.3 ± 21.0</td>
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⁹p < .05, different than White, main effect of ANOVA. ⁹p < .05, different than Black, main effect of ANOVA.
were similar for men ($r = .45-.74, p < .05$), whereas for women relationships with lean mass were significant at all bone sites ($r = .30-.58, p < .05$; Figure 2). In addition, body mass and lean mass were similarly related to all measures of muscle strength in men ($r = .35-.59, p < .05$), whereas only lean mass was related to muscle strength in women ($r = .29-.46, p < .05$). Neither fat mass nor percent body fat was related to bone mass for men or women. Isometric and isokinetic knee-extension strength correlated significantly with all bone sites in women ($r = .31-.43, p < .05$), and isometric knee-flexion strength was correlated to spine BMD ($r = .35, p < .05$) and hip BMD ($r = .37, p < .05$). For the men, all measures of knee-muscle strength were significantly related to all bone sites ($r = .32-.57, p < .05$; Figure 3).

Discussion

The major finding of this study was that controlling for differences in lean mass, but not muscle strength, abolished racial differences in BMD in this group of chronically
active older men and women. This finding suggests that part of the variance in bone mass between racial groups might result from differences in lean body mass. This finding is certainly not surprising, because lean mass has been directly and independently related to BMD in older participants by several authors (Bevier et al., 1989; Doyle, Brown, & LaChance, 1970; Edelstein & Barrett-Connor, 1993). Nonetheless, it adds important insight into understanding racial differences in bone mass.

In contrast, it was surprising that controlling for muscle strength did not alter racial differences in BMD. Given the close association between muscle mass and
muscle strength (Maughan, 1984), we had hypothesized that controlling for both lean mass and muscle strength would similarly influence BMD differences. It is possible that the chronic activity undertaken by these participants influenced these findings. The nature of the activities undertaken by these participants might be expected to exert a greater influence on muscle function rather than on muscle mass. When expressed as a percentage, strength differences between racial groups tended to be greater than lean-mass differences for both genders, but when either body weight or lean mass was controlled for, racial differences in muscle strength disappeared. Therefore, it remains unclear why muscle strength did not appear to contribute to racial differences in BMD in these participants.

These data also demonstrate that controlling for body mass accounted for racial differences in BMD at the hip and spine for men and for the whole body for women. This result is different from that in the report of Nelson et al. (1995), who demonstrated racial differences in BMD when body mass was controlled for. The contrast in findings could be caused by activity-level differences; participants in Nelson et al.'s study were sedentary as opposed to the chronically active participants in the current study. Chronic physical activity is known to influence both body mass and BMD and might have altered the relationship between these two variables.

These data suggest that fat mass and percent body fat do not contribute to racial variance in BMD, because there were no relationships between body fat and bone and controlling for body fat did not influence the racial differences in BMD. Fat mass has been suggested to contribute to differences in BMD in older women (Marone et al., 1997), which might be related to the influence of greater fat mass on total body mass, but there is no clear evidence to date that fat mass is a significant independent contributor to BMD, and these results do not support a role for body fat in explaining racial differences in bone mass.

The results of this study also suggest that there are gender differences in relationships between body composition and BMD. Whereas men demonstrated significant relationships between body mass, lean mass, and BMD, women demonstrated significant relationships between only lean mass and BMD. It is possible that smaller variance in body mass in the women participants could provide part of the explanation, but lean mass was also less variable in the women than in the men. Thus, this result remains unexplained.

Despite the chronic activity of participants in this study, Asian men and women and White women had lower than age-predicted average hip and spine BMD as determined by Z scores. This result is likely more reflective of the influence of race and chronic activity on body mass, however, rather than the effect of chronic activity on bone mass. Given the cross-sectional nature of the study design, it would be imprudent to interpret the Z scores as reflective of the influence of exercise on bone. In addition, it should be pointed out that the small sample size and the chronic activity undertaken by these participants limit the extent to which these findings can be generalized to the older adult population at large.

In conclusion, this study suggests that racial differences in BMD might in part result from differences in lean mass and, at some bone sites, body mass. Furthermore, these data suggest that fat mass and muscle strength did not contribute to racial differences in BMD in these participants. Finally, the data suggest that gender differences might exist in relationships between body mass, body composition, and BMD.
Acknowledgments

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References


