Comparative Skeletal Mass and Radial Bone Mineral Content in Black and White Women

S. H. Cohn, C. Abesamis, S. Yasumura, J. F. Aloia, I. Zanzi, and K. J. Ellis

The age-related changes in both skeletal mass and muscle mass were directly measured in normal black women ages 30–80 yr. The levels of total-body calcium (TBCa) were determined with the use of in vivo neutron activation. The muscle mass was measured by whole-body counting of $^{40}\text{K}$. In the same population, the bone mineral content of the radius was measured using a photon absorptiometric technique. Although there was no significant difference in stature, black women had a greater skeletal mass and bone mineral content of the radius than age-matched white female subjects. When the TBCa values were normalized for body size (i.e., corrected for height and lean body mass), the TBCa was still higher for the black women but not as high as the absolute TBCa values. Clearly, it is the larger muscle mass (as reflected by the $^{40}\text{K}$ measure) in relation to weight and height that accounts for this difference. The lower prevalence of fracture and osteoporosis observed in black women relative to white women is due in part to this greater quantity of skeleton. American black women with a higher bone density (i.e., skeletal mass) maintain mechanical integrity of the skeleton longer than individuals with a lower bone density. It is suggested that the larger muscle mass in black women is, in part, a determinant of their increased skeletal mass and is partly responsible for their apparent resistance to osteoporosis and fracture of the skeleton.

In a recent review of the relation of bone loss to aging, Garn emphasizes two points of extraordinary interest: the factors of sex and racial differences. There is a lower rate of bone loss (as measured by cortical thickness of the second metacarpal at midshaft) in black women compared to age-matched white women. The skeletal development of black children is advanced in comparison to that of white children; further, the black children exhibit greater body size up through adolescence. The Ten-State Nutritional Survey of 1969–1970 revealed both dimensional and developmental differences between black and white children. This initial increase in skeletal mass in black children continues into adulthood. Based on measurements of the metacarpal cortical area, American blacks have a greater skeletal mass than whites at all ages from 1 to 80 years.

Trotter et al., in a unique study of 80 adult skeletons, observed that the density of bones of American black subjects was greater than that of the skeleton of sex- and age-matched American white subjects. These findings have far-reaching implications for the interpretation of normal physiologic changes with age, and, more importantly, for the analysis of differences in prevalence of metabolic bone disorders, such as osteoporosis, in the two groups.

Osteoporosis is evidently rare in blacks. Nordin examined both spinal and hand films (metacarpal indices) of individuals around the world and found a
low prevalence of osteoporosis among peoples of African background. Black women are less susceptible to fracture and osteoporosis than are white women. For example, an epidemiologic study of 200 Puerto Rican women and over 2000 Michigan women indicated that black women had a lower prevalence of osteoporosis than white women. No fractures were found among the black women. The age-associated loss of compact bone from the metacarpal and the femurs of the black women was significantly less than that for white women.

In all these studies, the difference in total bone mass in black and white populations was inferred from measurements of individual bones, either radiographically or by biopsy. We have previously reported values for total skeletal mass (total-body calcium, TBCa) measured directly by means of total-body neutron activation analysis (TBNAA) in a normal white population. We now report comparable normal values for black women obtained by the same technique.

In a cross-sectional study, in order to compare TBCa in a heterogeneous population, it was necessary to normalize the data for skeletal size. In the white population, the normal skeletal weight was calculated from four parameters: height, muscle mass, age, and sex. An object of this study is to determine whether the formulation derived for predicting the TBCa in normal white women applies equally well to normal black women.

**MATERIALS AND METHODS**

Twenty-six black women, aged 30-79 yr, were subjected to total-body neutron activation analysis. All were active, in good health, and had no abnormality on physical examination. None of the subjects had a previous history or current symptoms of metabolic, renal, or cardiovascular disease. None of the postmenopausal women were receiving estrogen-replacement therapy. No patients were receiving medications known to influence calcium, phosphorus, or potassium metabolism.

TBNAA were performed with neutron exposure provided by an array of fourteen 50-Ci encapsulated 238Pu,Be neutron sources. In this technique, the subjects were uniformly exposed to a beam of partially moderated fast neutrons which induce the reactions 49Ca(n, γ) 49Ca and 31P(n, α) 28Al. The absolute levels of the induced 49Ca and 28Al (from P) were then measured in a whole-body counter. From these data, absolute levels of calcium and phosphorus were calculated. The in vivo activation technique provides an accuracy and precision of ±1.0% for TBCa and ±3.9% for total-body phosphorus (TBP) as determined with an anthropomorphic phantom.

Equations for predicting normal calcium values (Cap) were based on data from 79 normal white subjects. The measured TBCa divided by the predicted normal total-body calcium (Cap) is referred to as the calcium ratio. Deviation of the calcium ratio from 1.0, in a normal individual, reflects measurement error and statistical variation.

The method used to determine absolute measurement of total-body potassium (TBK) by whole-body counting has been previously described. As with the calcium data, the TBK was also normalized for body size. The measured TBK divided by the predicted normal K (Kp) is referred to as the potassium ratio.

The bone mineral content (BMC) of the radius was measured at the standard 8-cm site by photon absorptiometry. The absolute BMC values were also normalized for age and body size. The statistical significance of the means of the various parameters in the black and white populations was evaluated by the Student's t test.

**RESULTS**

The mean values for the TBCa and TBK in black female subjects as a function of age are tabulated in Table 1. In addition to the absolute values, the
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<thead>
<tr>
<th>N</th>
<th>Age (yr)</th>
<th>Mean Age (yr)</th>
<th>Wt. (kg)</th>
<th>Ht. (cm)</th>
<th>TBK (g)</th>
<th>TBK/Kp</th>
<th>TBCa (g)</th>
<th>TBCa/Cup</th>
<th>TBP/TBCa</th>
<th>TBCa/TBK</th>
<th>BMC (g/cm)</th>
<th>W (cm)</th>
<th>BMC/BMCp</th>
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*Coefficient of variation (per cent SD = SD/mean x 100).

Abbreviations: TBK, total body potassium, measured; Kp, total body potassium, predicted; TBCa, total body calcium, measured; Ca, total body calcium, predicted; TBP, total body phosphorus, measured; BMC, bone mineral content of radius; W, width of radius; BMC/BMCp, bone mineral content (measured/predicted).
Table 2. Comparison of Skeletal Mass, Muscle Mass, and Bone Mineral in Black and White Women

(Ratio of Black/White Women)

<table>
<thead>
<tr>
<th>N</th>
<th>Age (yr)</th>
<th>Bl</th>
<th>Wh</th>
<th>WH</th>
<th>TRK</th>
<th>TRK/Kr</th>
<th>TRCn</th>
<th>TRCn/CnP</th>
<th>TBK</th>
<th>TBK/TBCa</th>
<th>TBCa/TBK</th>
<th>TBCa/TBCa</th>
<th>BMC</th>
<th>W</th>
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<tr>
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<td>NS</td>
<td>0.01</td>
<td>0.10</td>
<td>0.01</td>
<td>0.01</td>
<td>NS</td>
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<td>0.01</td>
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*aSignificance level of the difference between the means of the absolute data for black and white women.

For abbreviations, see footnote to Table 1.
Ca ratio, the K ratio, and the P/Ca and Ca/K ratios are presented. Both the TBCa and TBK levels decreased with age, while the average variation of TBCa and TBK values within each age group was \( \pm 11\% \) (coefficient of variation, CV). The mean Ca ratios, in every age group, were greater than 1.00, and the average Ca ratio was 1.07 \( \pm 10.5\% \) (CV). Similarly, the mean K ratios were 1.031 \( \pm 8.5\% \) (CV). The average ratio of TBP/TBCa was 0.47 \( \pm 10.7\% \) (CV). The mean TBCa/TBK ratio was 9.76 \( \pm 9.9\% \) (CV).

The radius BMC values measured by absorptiometry are also presented in Table 1, along with the values for the width of the radius as a function of age. Here, the variation of BMC in each age decade averaged \( \pm 15\% \). The mean values decreased with age in a pattern similar to that of TBCa.

Mean values obtained in black and white subjects are expressed as ratios for each age decade in Table 2. While both groups have essentially the same mean height, the black women exhibited higher values for body weight, TBK, TBCa, BMC, and radius width. Indeed, when the TBCa, TBK, and BMC values were normalized for body size and age (using the previously derived relationship based on lean body mass and height), the black females still showed a higher mean Ca ratio, K ratio, and BMC ratio than the white women.

**DISCUSSION**

Although there was no significant difference in stature, black women had a greater skeletal mass and bone mineral content of the appendicular skeleton (radius) than the age-matched white subjects. The mean absolute TBCa of black females was 16.7\% higher than that of age-matched white women. Normalization for body size (i.e., corrections for height and lean body mass) showed that more than half this difference was due to the larger muscle mass, but that the bone mass was still 7\% higher for black women. Thus, for studies of metabolic bone disorders in black populations, appropriate norms or reference standards are required.

The higher body weights in the black women are reflected, in part, by their higher absolute levels of TBK (15.3\%). When the K values were normalized for body size (weight and height), the difference between the black and white women diminished to 3.1\%. These data are in accord with a previously reported study which measured body K in a normal population of 915 black and white subjects. A consistently higher K concentration (8\%-10\%) was found in black male and female subjects compared to age-matched white subjects.\(^{19}\) The age- and sex-specific changes in the shape of the plot of the K data as a function of age in the above study were identical to that of three large studies which measured K by means of whole-body counting.\(^{20-22}\)

Since the ratio of TBCa/TBK remains rather constant over the life span,\(^{23}\) it would be expected that the rate of loss of TBCa would be related to loss of muscle. As the mean rate of loss of TBK in black and white populations appears to be similar, it would be expected that the mean rate of loss of TBCa would be the same in both groups. Indeed, Trotter et al., in a study of adult skeletons from cadavers, found that within sex-race groups the rate of decrease of bone mass with age was the same in each group and was uniform.\(^6\) No significant difference was found in the mean rate of loss of TBCa with age between the black and white populations. However, Garn, in comparing large samples
of black and white adults in the United States, observed that black women had a lower rate of adult bone loss than white women.\textsuperscript{1} Black men, on the other hand, lost bone at the same rate as white men, based on medullary cavity expansion.\textsuperscript{1}

The mean ratio of TBCa/TBK appears to be the same in black and white woman. Thus it appears that the ratio of TBCa/TBK holds relatively constant in the black population; although they have larger TBCa, they also have a proportionately larger lean body mass.

One clue as to the nature of possible chemical change in the bone with age is the TBP/TBCa ratio. The variation in this ratio is largely due to the variation in the TBP values in each age group. The average black/white ratio of TBP/TBCa in women was 0.97. The data suggest that there is no significant difference in the chemical composition in terms of TBP/TBCa concentrations between the black and white groups.

The mean absolute BMC values for black women averaged 19.6\% higher than the mean of the white subjects. When these BMC values were normalized for skeletal size, the BMC ratio (measured BMC divided by the predicted BMC) was reduced to 8.9\%. These absolute and relative values of BMC parallel closely the TBCa and Ca ratios of the two groups. The correlation coefficient between the TBCa and BMC for the black female population was $r = 0.82$, the same as that determined for the white population. The mean radius width of black females was approximately 12\% higher than that of the corresponding white population. This finding is consistent with that of Trotter and Gleser,\textsuperscript{24} indicating that black subjects have larger limb bones relative to their stature than do whites.

The increased skeletal mass of black women observed here confirms the in vitro finding of Trotter et al. that the bones of black women are denser than those of age-matched white women.\textsuperscript{6} The present findings also confirm the radiographic studies of Garn based on the larger cortical area of the second metacarpal at midshaft in black women.\textsuperscript{1,2}

To what extent the lower prevalence of fracture and osteoporosis observed in black women relative to white women is due to some inherent quantity or quality of the skeleton is not known. Obviously, other factors such as nutritional levels, hormonal levels, vitamin D levels, and physical activity greatly influence the skeleton. This increased resistance to osteoporosis, even under adverse nutritional circumstances, could also be due to genetic difference. For example, a disproportionately high incidence of osteoporosis, associated with vertebral structural defect, has been reported among the white population of Anglo-Saxon origin\textsuperscript{10,12} as compared to the black population.

Since the section modulus and compression strength are directly related to bone density, a reasonable hypothesis is that a high bone mass is also directly related to a low prevalence of fracture. It would also be reasonable to conclude that a natural protection against the sequelae of bone loss is a large initial skeletal mass. Those individuals who have achieved a large bone mass by early adulthood would be slower to evince the clinical concomitants of bone loss in later life. Thus American blacks with a higher bone density, i.e., large skeletal mass, may maintain mechanical integrity of the skeleton longer than individuals
with a lower bone density. It is possible that this more favorable skeletal status of black women is responsible for their apparent greater resistance to osteoporosis and fracture of the skeleton.

Doyle et al. also found a significant correlation between bone mass and muscle mass, particularly when body weight, age, and height were taken into account. They proposed that the weight of the muscle reflects the force exerted on bone to which it is attached, and hence that muscle weight is an important determinant of bone mass. Furthermore, the present study has shown that the variation in bone mass with age in black and white women is reduced when muscle weight and height is taken into account. Thus differences in the bone mass between white and black populations may reflect the differences in their muscle mass. The higher prevalence of osteoporosis in women compared to men and in white populations compared to black populations of West African origin may depend, in part, on the quantitative differences in muscle mass.

REFERENCES

20. Anderson EC, Langham WH: Average


