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Original Article

Variations in Bone Density among Persons of African Heritage

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Abstract. The epidemiology of bone loss in populations of African heritage is still poorly known. We compared a convenience sample of 47 African-American (AA) residents of Rochester, Minnesota (32 women, 15 men) and 66 recent immigrants from Somalia (all women) with 684 white subjects (349 women, 335 men) previously recruited from an age-stratified random sample of community residents. Areal bone mineral density (BMD, g/cm^2) and volumetric bone mineral apparent density (BMAD, g/cm^3) were determined for lumbar spine and proximal femur using the Hologic QDR 2000 for white subjects and the QDR 4500 for the others; the instruments were cross-calibrated from data on 20 volunteers. Lumbar spine BMD was 18% higher in AA ($p < 0.001$) and 4% lower in Somali ($p = 0.147$) than white women. Femoral neck BMD was 27% higher in AA women but also 11% greater in Somali women (both $p < 0.001$) compared with whites. Lumbar spine BMD was 6% higher ($p = 0.132$) and femoral neck BMD 21% higher ($p < 0.001$) in AA than white men. No Somali men were studied. After correcting for bone size differences, both lumbar spine ($p < 0.01$) and femoral neck BMAD ($p < 0.001$) were greater for Somali than white women, but the difference between Somali and AA women persisted. Lumbar spine and femoral neck BMAD values also remained significantly greater for AA women (both $p < 0.001$) and men ($p < 0.05$; $p < 0.001$) compared with whites. Weight was associated with BMAD at both skeletal sites in all groups, but adjustment for differences in weight did not reduce the discrepancy in BMAD values between Somali and AA women or between the latter group and whites. This heterogeneity among different ethnic groups of African heritage may provide an opportunity for research to better explain race-specific differences in bone metabolism.

Keywords: African-American; Aging; Bone mineral density; Epidemiology; Ethnic group; Osteoporosis

Introduction

It has been known for at least 40 years that fracture risk is lower among African-American (AA) than white men and women in the United States [1–15]. Furthermore, even with fewer fractures observed, a lower proportion of them are attributed to osteoporosis among those of African heritage [16]. The limited data available suggest that falling is less frequent among AA women [17,18], but the discrepancy in fracture risk is generally explained on the basis of greater bone density among AA men and women compared with their white counterparts, although other mechanisms (e.g., bone geometry) could play a role [19]. This conclusion has been called into question by the recognition that comparisons of areal bone mineral density (BMD) values are confounded by skeletal size [20]. BMD values are greater among those with bigger skeletons, i.e., African-Americans [21], since adjustment for the area scanned (in g/cm^2) does not completely account for the fact that wider bones are also thicker. However, BMD is not greater in all African populations [22–24]

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even though their fracture rates are still lower than those observed in whites [22,25–29]. This suggests that the heterogeneity in bone density levels that has been described in Asian populations [30,31] might also exist in populations of African heritage. This possibility has not been adequately addressed since spine or hip BMD has not been assessed in different populations of African heritage using comparable methodology. The purpose of this investigation was to compare bone density values with and without adjustment for bone size among AA and white residents of the same community with those of recent immigrants from Somalia, who have a slighter body build compared with the AA population.

Materials and Methods

Study Subjects

We attempted to enroll as many Rochester residents $\geqslant$20 years of age of African heritage as possible. Although this segment of the community has grown rapidly in recent years, from about 790 in 1990 to over 3300 in 2000, the minority population is relatively young (90% under 50 years of age) and transient [31]. Thus, we attempted to identify AA subjects by working through a local church with strong ties to the African-American community, keeping in mind that this culture places great importance on religion. Educational materials on osteoporosis and information about the study were distributed to the congregation. In addition, we hired an African-American woman as a cultural advisor to assist with recruitment by identifying potential subjects at church and other community gatherings, providing basic information about the study and referring individuals willing to participate to the study coordinator. By virtue of these efforts, 71 potential subjects were contacted; one woman was ineligible due to pregnancy and 23 declined to participate. We were able to enroll 47 African-American residents: 32 women and 15 men. For the Somali population, we obtained a total of 86 names from a project on Somali women's perspective on prenatal care and from a list created by a community leader and interpreter from the Mayo Clinic International Department. We were able to contact 70 Somali women, of whom 66 enrolled in the study. All attempts to recruit Somali men were ineffective. A Somali physician, hired as a cultural advisor, attempted one-to-one recruiting but was unsuccessful. Group meetings at the local Red Cross attracted 18 Somali men, but they all declined to participate, even though we were willing to provide transportation and hold study sessions on Saturday mornings. All steps of the recruitment process were approved in advance by the General Clinical Research Center Advisory Committee and Mayo's Institutional Review Board, and written consent in English (and also in Somali for the immigrant population) was obtained from each subject.

For comparison, we used data from a group of women and men recruited from an age-stratified random sample of Rochester residents that was selected using the medical records linkage system of the Rochester Epidemiology Project [32]. Over half of the Rochester population is identified annually in this system and the majority are seen in any 3-year period. Thus, the enumerated population (women attended in 1990 ± 1 year and men in 1991 ± 1 year) approximates the underlying population of the community, including both free-living and institutionalized individuals. Altogether, 1138 men and 938 women aged 20 years and over were approached, but 239 men and 126 women were ineligible for study, mostly as a consequence of dementia [33]. Of the 899 eligible men, 348 participated and provided full study data, as did 351 of the 812 eligible women. Given the racial composition of the community (96% white in 1990), however, all subjects except for 13 of the men and 2 of the women were white. This analysis was based on the 684 white subjects.

Bone Densitometry

In the white population sample, areal bone mineral density (g/cm^2) had been determined for the lumbar spine (L2–L4 in anteroposterior projection) and proximal femur using dual-energy X-ray absorptiometry (DXA) with the Hologic QDR 2000 instrument (Hologic, Waltham, MA). The coefficients of variation for the spine and femoral neck BMD measurements were 0.4% and 1.8%, respectively. Measurements for the Somali and AA subjects were made on the Hologic QDR 4500, which has coefficients of variation of 0.4% and 0.5% for spine and hip BMD, respectively. The two machines were cross-calibrated based on data from 20 volunteers who were measured on both devices, and both were operated in the fan-beam mode. To adjust for systematic differences that were detected in the lumbar spine measurements, a constant (0.021 g/cm^2) was added to the QDR 4500 values to make them comparable to the QDR 2000 results. Phantom bone measurements were completed regularly on both devices to ensure that calibration remained consistent. We also estimated volumetric bone mineral apparent density (BMAD, g/cm^3) from these data as previously described [34] using the following formulae: Spine BMAD = BMC/A$^{3/2}$ and femoral neck BMAD = BMC/A^2, where BMC is the bone mineral content and A is the projected bone area.

Statistical Analysis

Loess smoothers were used as a graphical tool to describe the relationships between age and BMD/BMAD of the spine and hip for the different ethnic groups. To simplify the plots, 95% confidence intervals instead of data points were displayed for the white residents. The widths of these nonparametric confidence intervals were calculated by estimating the 2.5th and 97.5th percentiles of the residuals from the smoothed fit [35]. Bone density and other characteristics of the three groups were compared using the Wilcoxon rank sum test. Spearman partial correlations were used to describe the relationship of various patient characteristics with bone density. Linear regression models were used to test whether the relationship between BMAD and the patient characteristics differed depending on ethnic origin after adjusting for age and, where indicated, body size. Multiple regression models using stepwise methods with forward selection and backward elimination were used to choose independent variables for the final models.

Results

The white subjects included 137 premenopausal women (mean age 34.9 years, range 21–54 years) and 212 postmenopausal women (mean age 67.8 years, range 34–93 years). The mean age of the 335 white men was 55.8 years (range 23–90 years). There were approximately 50 women and 50 men per decade of age from 20–29 years to age 80 years and over. A total of 66 Somali women enrolled in the study (mean age 38.1 years, range 20–70 years) as did 47 AA subjects including 32 women (mean age 38.1 years, range 22–59 years) and 15 men (mean age 39.1 years, range 23–62 years). All the Somali subjects were foreign-born, and their length of residency in the United States ranged from 0.2 to 7 years.

The patterns of change in bone density with age, as judged from these cross-sectional data, are displayed for the women in Fig. 1 and 2. As illustrated in Fig. 1A, age-adjusted BMD of the lumbar spine was 18% higher in AA than white women (1.19 vs 1.01 g/cm^2; $p<0.001$). The overall pattern of change was also different insofar as there appeared to be no decline in BMD following menopause among the AA women, although the oldest was only 59 years of age. By contrast, lumbar spine BMD was 4% lower in Somali than white women (p = 0.147), although the pattern of age-related change was similar (Fig. 1A). Lumbar spine BMD did not vary by age among the men (data not shown), but age-adjusted levels were 6% higher (p = 0.132) in AA than white men (Table 1). No Somali men were studied. Femoral neck BMD was 27% higher in AA than white women (0.95 vs 0.75 g/cm^2; $p<0.001$) and 21% higher in AA than white men (1.04 vs 0.86 g/cm^2; $p<0.001$). Even among the Somali women, age-adjusted femoral neck BMD was 11% higher than in the white women (0.83 vs 0.75 g/cm^2; $p<0.001$). Femoral neck BMD declined more or less linearly over life in both races, among women (Fig. 2A) as well as men (data not shown). Detailed data are provided in Table 1.

The AA women were taller than the white women (165.4 cm vs 161.7 cm; p = 0.003), but the men were more similar in height (172.7 cm vs 175.5 cm; p = 0.517). The Somali women were comparable in height (160.5 cm) to the white women. Bone area in the lumbar spine and in the femoral neck were similar for AA and white women but were less for Somali compared with white women and for AA compared with white men (Table 1). When differences in bone size were taken into account by calculating BMAD, the race-specific discrepancies between white and Somali women were reduced, but the AA advantage persisted (Figs 1B, 2B). Indeed, age-adjusted lumbar spine BMAD was greater among Somali than white women (0.16 vs 0.15 g/cm^3; $p<0.01$) as it was for AA women (0.18 vs 0.15 g/cm^3; $p<0.001$). Likewise lumbar spine BMAD was greater in AA than white men (0.17 vs 0.15 g/cm^3; $p<0.05$). Age-adjusted femoral neck BMAD was also greater among Somali (0.18 vs 0.16 g/cm^3; $p<0.001$) and AA (0.20 vs 0.16 g/cm^3; $p<0.001$) women compared with white women. However, both lumbar spine ($p<0.001$) and femoral neck BMAD (p = 0.007) were still greater among AA than Somali women. Age-adjusted femoral neck BMAD remained greater in AA than white men (0.18 vs 0.15 g/cm^3; $p<$ 0.001).

Since there remained differences in lumbar spine and femoral neck bone density between the Somali, AA and white women after adjusting for bone size, we explored this issue further (Table 2). There were significant differences between the groups of women in age, weight and height, with AA women being both taller and heavier than white or Somali women. The AA women had an earlier menarche but later menopause than the white women, while the Somali women had a later menarche and earlier menopause. The latter women were also more often pregnant and had borne more children. As expected, Muslim Somali women were much less likely to use tobacco or alcohol and were more physically active. The white women had a greater frequency of medication use that might influence bone metabolism, except for birth control pills which were used somewhat more by AA women. There were no significant differences in the use of anticonvulsants, anticoagulants or thyroid supplements among the groups. Other than birth control pills, few of these drugs were used by the Somali women.

In multivariate analyses, the only independent predictors of lumbar spine BMAD in the Somali women were age and weight. In addition, there was no correlation of lumbar spine BMAD with time since immigrating to the United States. Weight was also the sole predictor of lumbar spine BMAD in AA women, while age, weight, height, diuretic use, gravidity and parity all contributed to the prediction of lumbar spine BMAD in white women. Despite these differences, model R^2 values were similar for the three groups, ranging from 0.31 to 0.28. For femoral neck BMAD, the independent predictors in the Somali women were age, weight, tobacco use and age at menarche, while use of birth control pills was the predictor in AA women. Age, weight and height all predicted femoral neck BMAD in white women. The model R^2 values for femoral neck BMAD ranged from 0.20 for AA to 0.54 for white women. After adjusting for age and weight, lumbar spine and femoral neck BMAD among AA women were still 8% and 11% greater, respectively, than in white women (both $p<0.001$) and 9% and 11% greater than in Somali women (both $p<0.001$). However, the age- and weight-adjusted values in Somali women for lumbar spine and

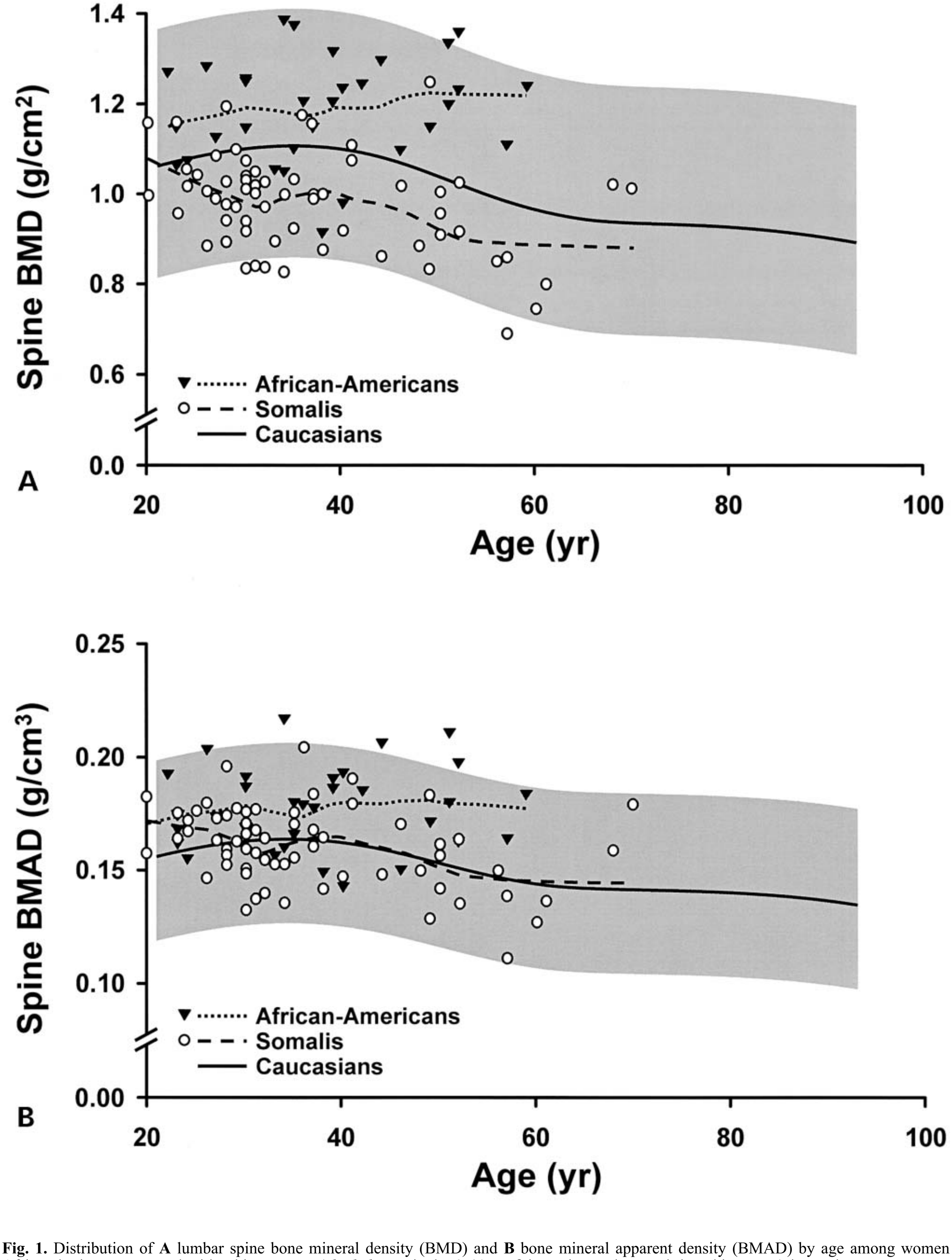

Fig. 1. Distribution of **A** lumbar spine bone mineral density (BMD) and **B** bone mineral apparent density (BMAD) by age among women of African heritage compared with white women (*shaded area* is the 95% confidence interval around the white mean) in Rochester, MN.

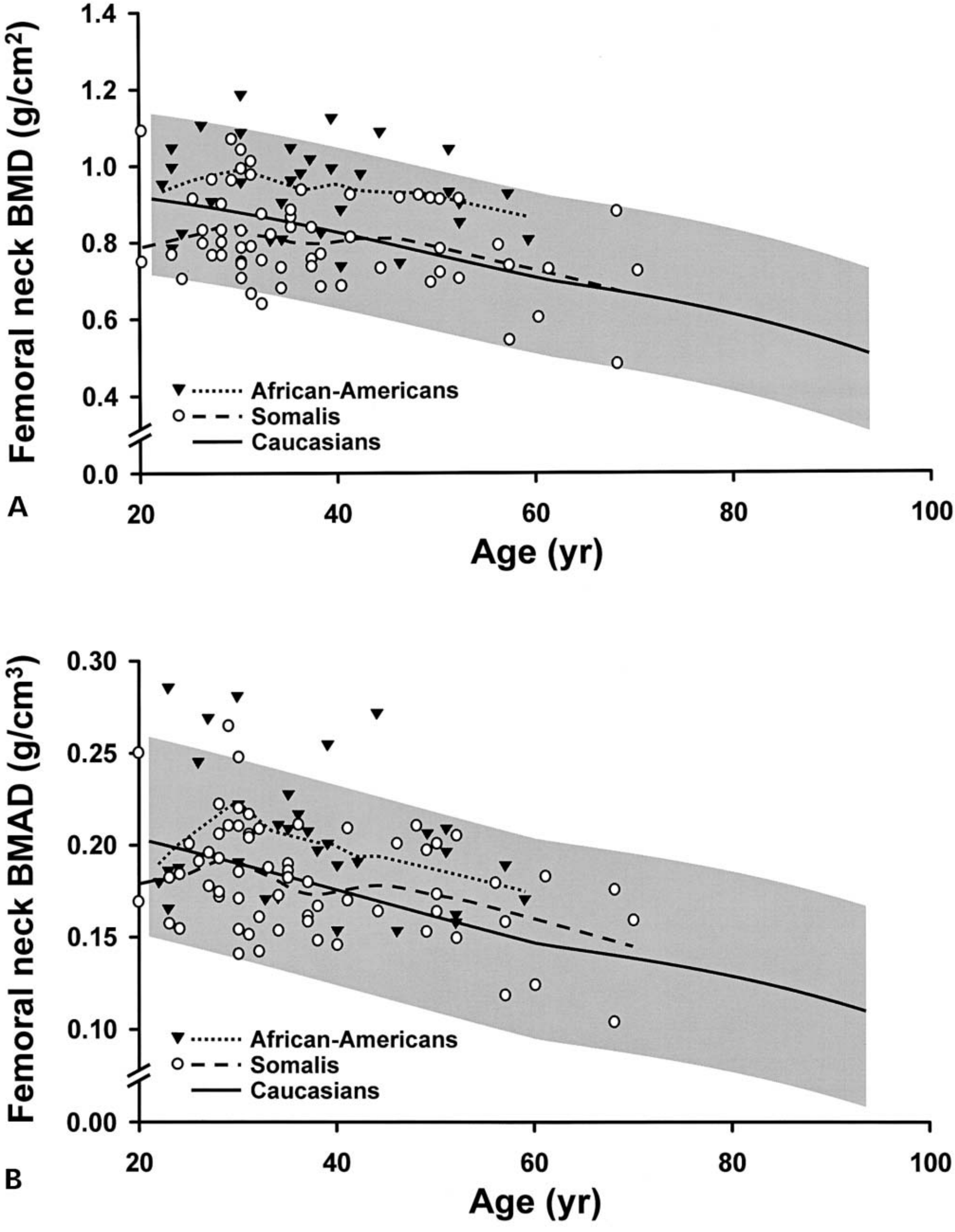

Fig. 2. Distribution of **A** femoral neck bone mineral density (BMD) and **B** bone mineral apparent density (BMAD) by age among women of African heritage compared with white women (*shaded area* is the 95% confidence interval around the white mean) in Rochester, MN.

Table 1. Comparison of bone area, bone mineral content (BMC), bone mineral density (BMD) and bone mineral apparent density (BMAD) for Rochester, MN residents of Somali origin compared with white and African-American (AA) residents of the community

	Lumbar spine				Femoral neck			
Ethnic group	Area (cm^2)	BMC (g)	BMD (g/cm^2)	BMAD (g/cm^3)	Area (cm^2)	BMC (g)	BMD (g/cm^2)	BMAD (g/cm^3)
Women								
AA	45.3 ± 4.6	53.0 ± 8.1***	1.19 ± 0.12***	0.18 ± 0.02***	4.8 ± 0.5	4.4 ± 0.6***	0.95 ± 0.11***	0.20 ± 0.04***
Somali	37.6 ± 3.3***	36.0 ± 6.6***	0.97 ± 0.13	0.16 ± 0.02**	4.6 ± 0.3***	3.7 ± 0.6	0.83 ± 0.12***	0.18 ± 0.03***
White	45.2 ± 4.5	45.7 ± 9.8	1.01 ± 0.16	0.15 ± 0.02	4.9 ± 0.5	3.7 ± 0.8	0.75 ± 0.15	0.16 ± 0.04
Men								
AA	50.2 ± 2.9**	58.5 ± 9.0	1.19 ± 0.17	0.17 ± 0.02*	5.6 ± 0.3	5.7 ± 1.2*	1.04 ± 0.16***	0.18 ± 0.02***
Somali	NA	NA	NA	NA	NA	NA	NA	NA
White	54.5 ± 5.5	61.6 ± 13.6	1.12 ± 0.18	0.15 ± 0.02	5.9 ± 0.5	5.0 ± 0.9	0.86 ± 0.15	0.15 ± 0.03

Values are mean ± SD.
NA, no data available.
p values (*$p < 0.05$, **$p < 0.01$ and ***$p < 0.001$) for age-adjusted difference from a comparable white group.

Table 2. Distribution of various characteristics among recent immigrants from Somalia and African-American (AA) compared with white women from the population of Rochester, MN

	Distribution		
	AA	Somali	White
Age, years (mean ± SD)	38.1 ± 10.5***	38.1 ± 12.7***	54.9 ± 19.8
Height, cm (mean ± SD)	165.4 ± 5.2**	160.5 ± 5.1	161.7 ± 6.9
Weight, kg (mean ± SD)	82.3 ± 20.2***	73.8 ± 16.3**	68.2 ± 14.7
Age at menarche, years (mean ± SD)	12.3 ± 1.3*	13.9 ± 1.9***	13.0 ± 1.6
Gravidity (mean ± SD)	2.3 ± 1.5	5.0 ± 3.8***	2.5 ± 2.3
Parity (mean ± SD)	1.9 ± 1.3	4.2 ± 3.1***	2.1 ± 1.9
Age at menopause, years (mean ± SD)	49.6 ± 3.2	45.9 ± 4.4	45.7 ± 6.7
Tobacco use, % use	28.1%	7.6%***	44.4%
Alcohol use, % yes	81.3%	0.0%***	85.4%
Physically active, % yes	87.5%	98.5%***	83.5%
Hormone replacement, % yes	12.5%	3.0%***	25.2%
Birth control pills, % yes	62.5%	9.1%***	49.6%
Thiazide diuretic use, % yes	9.4%	0%***	20.9%
Corticosteroid use, % yes	6.3%	1.5%**	14.0%

*$p<0.05$, ** $p<0.01$, ***$p<0.001$ in comparison with white women.

femoral neck BMAD were almost identical to those in white women.

Discussion

Although osteoporosis is often thought of as a disease affecting postmenopausal white women, 7% of overall expenditures for the care of osteoporotic fractures in the United States have been attributed to those fractures that occur among nonwhite women and men [36]. At a total cost approaching $1 billion annually, this represents an important public health problem for these other groups that cannot be ignored [37]. Unfortunately, however, the epidemiology of osteoporosis in minority populations remains relatively unknown. Data from the Third National Health and Nutrition Examination Survey (NHANES) clearly demonstrate, as found here, that femoral neck BMD is significantly greater among AA than white men and women [38], although the general pattern of bone loss over life appears to be similar [39]. In the more robust samples studied in NHANES, mean femoral neck BMD was 16% greater in AA than white women and 15% greater in AA than white men, compared with the differences of 27% and 21%, respectively, found here. We have extended these results by showing that lumbar spine BMD is also greater among AA men and women. This has been observed previously by other investigators [40–47], who found excesses compared with white subjects of 6–12% in AA women and 8–10% in AA men. In the present study, lumbar spine BMD was 18% and 6% higher, respectively, in AA than white women and men.

As we also found, correcting for bone size with BMAD did not reduce the proportionate advantage in lumbar spine bone density of AA compared with white women [44], and similar results have been reported for comparisons of lumbar spine BMAD between white women and African-Caribbean [48] or South African women [49]. In the latter three studies, femoral neck

BMAD was also greater in those of African heritage. Others have recommended that differences in body size be corrected by adjusting BMC for bone area, height and body weight [50]. However, this corrects not only for bone size but also for an important risk factor, weight, that may differ substantially among the groups, as shown in the present study. Thus, the difference in lumbar spine but not femoral neck bone density between South African women and whites was eliminated by this approach [49], but it is unclear whether this result is due to correction of a bone size artifact or to adjustment for a difference in risk factors. Nonetheless, when our own data are reanalyzed in this fashion, adjusted lumbar spine bone density was still 7% ($p = 0.016$) and femoral neck bone density 14% ($p = 0.085$) higher in AA compared with white women, but white women now had age-, bone area-, height- and weight-adjusted values 5% ($p = 0.023$) and 27% ($p < 0.001$) higher, respectively, than Somali women.

This is the first report of bone density levels among immigrants from Somalia, who have femoral neck BMD values intermediate between AA and white women but lower levels of lumbar spine BMD. The only similar data concern women from the nearby country of Oman, who were also found to have lower lumbar spine BMD than healthy European women [23]. The relevance of the East African Somali population stems from the fact that they have a different body habitus than the AA population, which mostly derives from West Africa [19]. Thus, Somali women had significantly smaller bone areas in both the lumbar spine and femoral neck than did either the white or AA women. As a consequence, areal BMD values would have been underestimated in them [20]. When bone size was adjusted for, BMAD values at the lumbar spine and femoral neck were actually somewhat greater for Somali than for white women. Likewise, recent studies have shown that adjustment for bone or body size reduces apparent differences in bone density between white and Asian women [31,44,51–55]. However, this correction did not equilibrate bone density values among those of African heritage, as BMAD values were still significantly greater among AA than Somali women.

The latter observation reinforces the notion that individuals of particular races should not be viewed as members of a uniform class [56] but rather that efforts should be made to explore differences among the component ethnic groups [31]. Unfortunately, no obvious explanation for differences in bone density between Somali and AA women was found with the limited data available here. Although previous investigators have emphasized the importance of greater body mass index or weight among African-Americans [44,57,58], which was also observed here, adjustment for differences in weight did not eliminate the residual discrepancies in bone density that remained after variations in skeletal size were accounted for with BMAD. Similar results have been found when AA and white men and women were matched on body size [45,59]. One interesting speculation has it that native Africans and African-Americans both have the genetic potential for superior bone density compared with whites but that the potential is not realized in Africa because of nutritional deficiencies [60].

This study had a number of limitations. First, the sample size was quite small, although many previous studies on populations of African origin have been similarly restricted. Both the AA and Somali populations in Olmsted County are limited and proved somewhat difficult to recruit despite exhaustive efforts. Indeed, we were unsuccessful in recruiting Somali men. In part, this may be due to less concern about osteoporosis relative to other important health conditions (e.g., hypertension or prostate cancer) in the AA community [37,61], while the Somali women were generally unaware of osteoporosis altogether. In addition, the minority study population was highly selected because it was necessary to use a convenience sample of minority subjects. In particular, the Somali population in Olmsted County, like other migrant groups [31], is a mobile one. As a consequence, there was no adequate population-based sampling frame for nonwhite residents of the community. By contrast, we were able to randomly sample the mostly white population, although only 41% of eligible subjects actually volunteered for the study. We showed previously that ill health was an important reason for nonparticipation among elderly individuals [62], so even the white subjects represent a selected study population to some extent. Finally, different densitometers were used to measure BMD in the white and nonwhite subjects. However, the two Hologic devices were both operated in the array mode and they were cross-calibrated on subjects as well as phantoms. Moreover, the AA and Somali women were studied on the same instrument. Despite these limitations, the observation that heterogeneity in bone density exists among populations of African heritage, like that previously observed among Asian populations [30,31], reveals an opportunity for research to better understand the race-specific differences in bone metabolism [19].

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