Race and Diet Interactions in the Acquisition, Maintenance, and Loss of Bone

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Abstract

Racial differences in bone become apparent during puberty. Studies of areal bone mineral density (aBMD) generally show the greatest aBMD in African Americans followed by American white, Hispanic, and Native Americans, with the least aBMD in Asian Americans. Racial differences in fracture risk, however, do not exactly follow racial variation in aBMD. These group differences in bone mass are largely explained by differences in bone size, although calcium intake and physical activity are also significant predictors of aBMD and bone mineral content. Racial differences in calcium metabolism, as influenced by calcium and sodium intake, explain much of the black vs. white differences in skeletal calcium accretion during puberty. The relative importance of calcium and sodium in calcium metabolism has not yet been elucidated among Asians. Predictors of aBMD have been reported for African American and American white adults and predictors of aBMD in Chinese American women have recently been studied. Much remains to be studied regarding interactions between race and diet.

Introduction

Diet and race are important predictors of areal bone mineral density (aBMD) and fracture risk. Most investigations have focused on differences between African American and American white individuals, while data are more limited when comparisons are made among other racial and ethnic groups. The interaction between diet and race is even less well understood. The purpose of this article, based on a workshop for the Nutrition and Bone Health Working Group at the American Society for Bone and Mineral Research, is to integrate newer evidence on racial differences in bone mass, acquisition, and maintenance, especially as influenced by diet.

Because only 8% of genetic variation separates the major races and human variation is continuously distributed, it could be argued that race should not be used to classify populations. However, recent genetic marker cluster analysis of 326 markers from the Family Blood Pressure Program study demonstrated distinct, nonoverlapping clustering of Hispanic, white, African American and East Asian peoples, which almost perfectly matched their self-described classification (1). Thus, genetic marker cluster analysis indicates that differences among genetic marker allele frequencies exist that sort individuals into at least these 4 major racial groups. African Americans and Hispanics are an admixture of European, Native American, and African origins. Our current understanding of genetic variation of subpopulations within these 2 admixed racial categories is inadequate to further subdivide these groups for biomedical research on a genetic basis.

Differences in bone mass among these major population groups may be affected as much or more by ethnicity as race. Ethnicity, like race, implies a shared genealogy but encompasses a broader construct that takes into account shared experiences, including cultural, linguistic, religious, historical, and sometimes geographical traits in addition to genetic traits (2). Dietary intake, physical activity, and cultural lifestyles limiting exposure to sunlight are examples of ethnic behaviors that could have major influences on calcium metabolism and, consequently, bone. This article emphasizes racial differences in bone and response to nutrient intake, recognizing the need for further work to elucidate genetic interactions with exposures that may influence bone.

Racial differences in bone density

On average, African American men and women have higher aBMD than other racial groups, including American white,
Asian, Hispanic, and Native Americans (3). Such differences are attenuated but still generally persist when aBMD data are adjusted for weight, bone size, and other covariates, such as physical activity, calcium intake, smoking, and alcohol use (4,5). aBMD is also higher in African American than American white, Asian, or Hispanic children (6,7).

Black and Asian females and Asian males reach a plateau in bone mineral density (BMD) earlier than other ethnic groups (7). Histomorphometric studies of biopsied bone indicate that premenopausal African American women have a lower rate of mineralized matrix apposition and longer formation period than American whites, 2 observations that may lead to greater deposition of bone mineral (8) and, perhaps, bone of higher quality. Most studies indicate that Hispanic Americans have similar (9,10) or slightly higher (11) bone density compared with American whites, although 1 recent study has noted lower bone density in a group of Hispanic Americans of different ethnic backgrounds (3). The majority of investigations in the Hispanic community have focused on Mexican Americans, with much less data available for Hispanic groups. We have studied a female Hispanic population from the Dominican Republic living in New York City. They also have higher aBMD, unadjusted for weight, compared with American white reference values at the femoral neck (FN) and total hip (TH). aBMD in Mexican Americans may also be higher than Mexican American reference values at the TH across some age ranges (12).

Studies in Asians have consistently shown lower aBMD than that in whites (13–15) and other racial groups (3,4). Weight or bone size accounts for the majority of these differences (4,16,17). In fact, some have suggested that when adjustments are made for differences in bone size and other covariates (4,18), BMD is actually higher in individuals of Chinese descent.

There is a paucity of bone density data among Native Americans, but bone density was reported to be comparable to North American white women (3,19,20). The available information on unadjusted aBMD could be summarized in the following hierarchy: African Americans > American white, Hispanic, and Native Americans > Asian Americans.

Racial differences in fracture risk
Although differences or similarities in bone density are of note, differences in fracture risk are of greater importance, because fracture risk is the clinically relevant end point. Moreover, fracture risk is determined by elements of bone quality that are not captured completely in the bone density measurement. As early as the 1960s, studies indicated reduced rates of hip (12–23) and other fractures (24) in African Americans compared with American whites. Although the greater bone density among African Americans is undoubtedly relevant, examination of other racial or ethnic groups suggest that other factors also contribute to this difference. For example, despite lower bone density, Asian (25) and Asian-American (23,26) individuals have relatively low rates of hip fracture, while vertebral fracture rates in most studies are similar to that of American white populations (27,28). Recent data from the National Osteoporosis Risk Factor Assessment study also indicate that Asian and African American women, 2 groups with markedly different BMD, share a relatively low risk of forearm osteoporotic fractures compared with American white, Hispanic, and Native American women (3).

Other factors, besides aBMD, likely also influence fracture rates. A number of hypotheses have been offered to account for the lower risk of osteoporotic fracture in Asian and African Americans. Using data from postmenopausal American white women in the Study of Osteoporotic Fractures, Faulkner et al. (29) showed that hip axis length (HAL; the distance from the inner pelvic rim to the trochanter) predicts hip fracture risk independently of height, weight, age, and FN BMD. A subsequent study indicated that HAL is shorter in Asian and African Americans than in whites (30). More recent studies have not been entirely consistent with this observation. Some studies have supported HAL as a risk factor for only certain types of hip fractures and others have found no correlation whatsoever between HAL and fracture risk (31–33). Such racial differences in HAL could account for the difference in hip fracture incidence between Asians and American white adults.

Larger bone size may also confer protection from fracture in African Americans (34). A larger cross-sectional bone diameter increases strength (i.e. resistance to bending) by placing more mass further from the axis of the long bone (35,36). Asian individuals have smaller bone size, which would increase the risk of fracture, for a given bone density. However, small bone size also leads to an artifically lower areal bone density when measured by 2-dimensional dual X-ray absorptiometry. Thus, when dual X-ray absorptiometry is used to measure BMD (18,32), small bone size could mask a higher “true” bone density, a value that can be determined only by a volumetric densitometry determination (g/cm³). Additionally, protection from fracture may be afforded by racial differences in other “bone qualities” besides bone size, such as microarchitecture, mineralization density, and collagen cross-linking, although the limited available data in African Americans thus far do not necessarily support these possibilities (8,37).

Other potential explanations for differences in fracture risk include fewer falls (38) and greater muscle strength. Slower rates of age-related bone loss (39,40) or remodeling (41) might be protective as shown in comparisons between American white and African American adults. Cross-sectional findings in Asian and Hispanic American adults suggest that differences in rates of bone loss may also exist (12–15,42), but these need to be confirmed with longitudinal studies. In contrast, African American adolescents had a higher rate of modeling than white American adolescents, consistent with high rates of skeletal acquisition during growth (43).

Diet and racial differences in rates of skeletal accretion
The higher peak bone mass observed in African American individuals may be secondary to more favorable calcium absorption and retention during growth (43), along with differences in other genetic factors that govern peak bone mass. In a pooled sample of 182 balance studies in American white and black adolescent girls, calcium intake explained 12.3% and race explained 13.7% of the variance in calcium retention (44). A model that projected the difference in calcium retention between black and white adolescent girls to peak bone mass estimated that black adult women would have 12% higher peak bone mass than white women (43). In the NHANES III sample, FN bone mineral content (BMC) was 10% higher and BMD was 13% higher in black compared with white women (10). While African Americans tend to have lower serum 25-hydroxyvitamin D levels (45) and similar (8) or higher (45) parathyroid hormone levels, sensitivity to resorptive effects of parathyroid hormone may be reduced (46). In the necessarily rather small sample sizes in metabolic balance studies, habitual calcium intake does not explain black-white differences in skeletal calcium accretion (44). This is an ethnic (exposure) rather than racial (genetic) question.

Racial and ethnic differences in bone and influence of diet and physical activity are apparent prior to puberty. In our cohort...
of 6th graders recruited from 6 geographical locations in the US comprised of 326 American white, 234 Hispanic, and 188 Asian girls, bone size explained most race and ethnic differences in BMC, although behavioral indices, i.e. dairy calcium intake and physical activity, were also significant (17). In these children, models including race/ethnicity better predicted BMC than BMD and the ability to predict bone mineral apparent density was much poorer. Also, in longitudinal studies, calcium intake has been shown to be a small but significant predictor of total body bone mass in Asian girls (47) and Canadian boys, but not girls (48). Asian adolescents have higher Speed of Sound ultrasound values than white adolescents living in Hawaii, possibly reflecting a difference in collagen content (49). The role of diet is unknown.

Another significant interaction between race and diet on bone has been observed with dietary salt in black and white adolescent girls (50). In balance studies where subjects were crossed over on high and low salt intakes, white girls excreted more sodium in urine on high-salt diets than black girls, which resulted in higher urinary calcium excretion due to shared Na/Ca transporters in the kidney. Calcium retention was lower with high-salt diets in both races, but the detrimental effect of salt was greater in white subjects (Fig. 2). Calcium retention was so much higher in black girls that, even consuming high-salt diets, calcium retention was greater in black girls than in white girls consuming a low-salt diet.

Diet and racial differences in rates of bone loss

Whether diet contributes to racial differences in rates of bone loss is not clear. Calcium intake within a number of racial groups is associated with higher bone density or slower rates of bone loss (5,51,52). The beneficial effect of soy, likely due to phytoestrogens, has been investigated, particularly in Asian postmenopausal women, and may have a small effect on moderating bone loss (53). Soy consumption was impressively related to reduced fracture risk in a cohort of >75,000 Asian women living in Shanghai (54). Research to determine whether this dietary effect on fracture risk is specific to race (Asian) or ethnicity (habitual soy consumption, for example) is needed. Protein intake may also influence bone loss (55), although the effect may be dependent on adequate calcium intake (56). Because of a paucity of data, it is not yet clear whether these or other nutritional and lifestyle factors explain differential rates of bone loss among races.

Chinese American women: a growing, at-risk population

Few data are available regarding the effect of environmental factors influencing bone density among Chinese American women, a growing at-risk population for osteoporosis. The U.S. Census Bureau estimates that by the year 2050, one-tenth of the U.S. population will be of Asian descent, many of them Chinese American (57). In a cross-sectional study, we examined predictors of BMD in 359 ambulatory Chinese-American women aged 20–90 y, using stepwise multiple regression analysis (58). Variables in the model included age, weight, height, menarcheal age, years since menopause, immigration age, years in the US, percentage of life in the US, number of pregnancies, oral contraceptive use, family history of osteoporosis, daily calcium intake, exercise, time outdoors, alcohol consumption, and tobacco use.

Among premenopausal women, weight was the strongest predictor of BMD, accounting for 10.5% of the variance at the lumbar spine (LS), 12.9% at the TH, and 17.2% at the FN. Time outdoors was also a positive predictor of BMD (1.4% at LS, 2.8% at TH, 1.6% at FN), whereas family history of osteoporosis (1.4% at TH) and age (3.7% at FN) were negative predictors. Among postmenopausal women, greater BMD at the LS and TH was associated with greater weight and earlier immigration age. Weight accounted for 16.4% of the variance at the LS and 19.8% at the TH; immigration age accounted for 3.1% of the variance at the LS and 4.1% at the TH. The FN, years since menopause and weight were predictors of BMD, accounting for 14.4 and 8.7% of the variance, respectively. As in other racial groups, weight is the dominant predictor of BMD in Chinese American women. Limited nutritional information was collected. Calcium intake, determined using a validated FFQ (15) that included calcium-specific foods typical of this population, was low $[612 \pm 17 \text{ mg (mean \pm SD)}$] daily, although not an independent determinant of BMD in this study. Among premenopausal women, time outdoors was a significant predictor of BMD. This variable may reflect vitamin D status, physical activity, or general health. Among postmenopausal women,

![FIGURE 1](https://academic.oup.com/jn/article-abstract/138/6/1256S/4670300)

**FIGURE 1** Calcium retention as a function of calcium intake is higher in black (upper solid line and black diamonds, mean and 95% CI) than white (dashed lower line and white circles) adolescent girls ($P < 0.0001$). Adapted from Braun et al. (44).

![FIGURE 2](https://academic.oup.com/jn/article-abstract/138/6/1256S/4670300)

**FIGURE 2** Calcium retention decreased with high dietary salt in both black (upper line) and white (lower line) adolescent girls ($P < 0.01$), but calcium retention in black girls was higher than for white girls at both sodium levels ($P < 0.01$). Values are means $\pm$ SEM, $n = 36$. Adapted from Wigertz et al. (50).
older age of immigration to the US, independent of weight or age, had a negative effect on BMD. We hypothesize that later age of immigration may impact BMD because (1) older individuals are less likely to take on a Western lifestyle when they immigrate or (2) individuals who immigrate past a certain age may not significantly alter BMD with lifestyle changes. More data on acculturation from this population would be necessary to differentiate between these possibilities. BMD in Chinese American women is influenced by a number of biological and lifestyle factors, including immigration. The results of this study provide new insights into risk factors for low bone density as they relate to environmental determinants in the growing population of Chinese American women.

Conclusions
Racial differences in BMD exist and are influenced by weight, bone size, and lifestyle factors, including diet. Differences in African Americans persist even with adjustment for these factors. Black adolescents have higher calcium retention than white adolescents across a wide range of calcium intakes, which contributes to their higher peak bone mass. Both black and white adolescents retain less calcium on high-salt diets, but the effect is more detrimental to bone in white adolescents. The response in Asian is unknown. Racial differences in fracture rates are not completely explained by differences in aBMD and the role of diet is unclear. The relationship between BMD and fracture risk may be altered by racial differences in bone size, HAL (hip fracture), other bone qualities, or nonskeletal factors.

Literature Cited

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