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Lifestyle Determinants of Bone Mineral: A Comparison Between Prepubertal Asian- and Caucasian-Canadian Boys and Girls

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Abstract. The purpose of this study was to examine the difference in lifestyle and morphometric factors that affect bone mineral and the attainment of peak bone mass in 168 healthy Asian (n = 58) and Caucasian (n = 110) Canadian, prepubertal girls and boys (mean age 8.9 ± 0.7) living in close geographical proximity. DXA (Hologic 4500) scans of the proximal femur (with regions), lumbar spine, and total body (TB) were acquired. We report areal bone mineral densities (*a*BMD g/cm^2) at all sites and estimated volumetric density (*v*BMD, g/cm^3) at the femoral neck. Dietary calcium, physical activity, and maturity were estimated by questionnaire. Of these prepubertal children, all of the boys and 89% of the girls were Tanner stage 1. A 2 × 2 ANOVA demonstrated no difference between ethnicities for height, weight, body fat, or bone mineral free lean mass. Asian children consumed significantly less dietary calcium (35%) on average and were significantly less active (15%) than their Caucasian counterparts ($P < 0.001$). There were significant ethnicity main effects for femoral neck bone mineral content (BMC) and αBMD (both $P < 0.001$) and significant sex by ethnicity interactions ($P < 0.01$). The Asian boys had significantly lower femoral neck BMC (11%), *a*BMD (8%), and *v*BMD (4.4%). At the femoral neck, BMFL mass, sex, and physical activity explained 37% of the total variance in *a*BMD ($P < 0.05$). In summary, this study demonstrated differences in modifiable lifestyle factors and femoral neck bone mineral between Asian and Caucasian boys.

Key words: Bone mineral — Calcium — Physical activity — Children — Ethnicity.

There is increasing recognition that peak bone mass is an important determinant of adult bone mineral, and thus, risk of osteoporotic fracture [1–3]. Furthermore, the prepubertal years are a particularly important time for bone mineral acquisition [1, 4–6]. The major determinants of peak bone mass are genetic makeup, ethnicity, gender, weight-bearing physical activity, calcium intake, and soft-tissue composition [7, 8]. Within these determinants, ethnicity and sex are associated with differing rates of osteoporotic fracture and different amounts of bone mineral.

Studies of ethnic differences in bone mineral are often confounded by the geographical separation of the ethnic groups being compared [9] and in children, by variability in maturity and body size. Specifically, the only study of bone mineral in Asian and Caucasian children living in close proximity included subjects across a broad maturity range (9–26 years) and very few prepubertal children. To minimize age, maturity, and size-related variability, we studied bone mineral in Asian and Caucasian children aged 8 and 9 years who attend primary school classes together.

The primary aims of this cross-sectional study were (1) to report bone mineral content (BMC), bone mineral areal density (*a*BMD), and estimated bone mineral volumetric density (*v*BMD) across three skeletal sites in Asian and Caucasian boys and girls; and (2) to identify the determinants of BMC and BMD and bone volume, such as physical activity, dietary calcium intake, and soft tissue composition in this population.

Materials and Methods

Subjects

The study was presented to both the principals and the teacher-development representatives from a multiethnic school district which includes 34% of the population who report Chinese as their first language. Of the 15 schools that demonstrated initial interest, 10 schools agreed to take part in the study.

Parents' place of birth was determined by questionnaire which was available in Chinese for the non-English speaking. Children were classified as Asian if both parents were born in China, Hong Kong (72%), Japan, Taiwan, or Vietnam and as Caucasian if parents were born in North America, Australia, or Great Britain.

Parents completed a health history questionnaire for their children. There were 168 healthy boys and girls (mean age 8.9 ± 0.7 years) enrolled in the study; 58 Asians (30 boys, 28 girls) and 110 Caucasians (56 boys, 54 girls). None of the participants had medical conditions or were taking medications known to influence bone mineral.

Measurement

Dual X-ray absorptiometry (DXA) scans of the proximal femur,

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Table 1. Comparison of body composition and lifestyle factors between Asian and Caucasian males and females mean (SD)

	Asians			Caucasians		
	Males	Females	Total	Males	Females	Total
n	30	28	58	56	54	110
Sit height (cm)	73.3 (3.8)	74.5 (4.9)	73.9 (4.4)	73.3 (3.3)	73.9 (4.5)	73.6 (3.9)
Height (cm)	132.3 (6.6)	135.2 (7.6)	133.7 (7.2)	134.5 (6.6)	135.1 (7.6)	134.8 (7.1)
Leg length (cm)	59.1 (3.8)	60.8 (4.0)	59.9 (3.9)	61.2 (3.9)	61.2 (4.5)	61.2 (4.2)
Weight (KG)	28.6 (5.6)	30.8 (8.0)	29.7 (6.9)	31.5 (8.0)	30.0 (5.2)	30.8 (6.8)
Fat (g)	5894 (2947)	8042 (4660)	6931 (3984)	6645 (4624)	7302 (2902)	6967 (3872)
%Fat	19.9 (6.0)	24.8 (7.7)	22.3 (7.3)	19.7 (7.7)	23.8 (5.9)	21.8 (7.2)
BMFL (lean)	22516 (3127)	22470 (3622)	22494 (3345)	24563 (3842)	22430 (2853)	23516 (3543)
%BMFL	77.7 (5.7)	73.1 (7.3)	75.5 (6.8)	77.9 (7.3)	74.0 (5.6)	76.0 (6.7)
Activity score	67.4[a] (16.6)	73.3 (21.5)	70.2[x] (19.2)	87.8 (17.1)	76.0 (13.5)	82.0 (16.5)
Calcium (mg)	735[a] (367)	821 (418)	777[x] (392)	1241 (786)	1159 (841)	1201 (811)

[x] Significantly less than Caucasian Total ($P < 0.001$)
[a] Significantly less than Caucasian males (sex by ethnicity interaction $P < 0.001$)

postero-anterior lumbar spine, and total body (TB) were acquired and analyzed by the same qualified technologist, using a Hologic QDR 4500 bone densitometer (Hologic Inc., Waltham, MA). Bone mineral content (BMC, g) and areal density (*a*BMD, g/cm^2) of these sites and the femoral neck (FN) region are reported. Also, in order to more adequately represent three-dimensional size and to approximate true BMD, bone volume and volumetric density (*v*BMD) were estimated at the FN from areal density using appropriate formulae which have been used elsewhere for children [10]. Fat mass (g), bone mineral free lean mass (BMFL, g), and percentage of each were determined from the TB scan.

Stretch statures (sitting and standing) were measured to the nearest millimeter using a wall stadiometer. Weight was measured on an electronic scale to the nearest 0.1 kg. Mean values were used for analysis.

Questionnaires were administered at the time of bone densitometry measurement. Dietary calcium intake was estimated from a food frequency questionnaire that has previously been validated against food records ($r = 0.98$) as a tool for assessing calcium intake in Asian and Caucasian high school students [11].

A physical activity questionnaire which has previously demonstrated adequate test-retest reliability in children from grades 4 to 8 and has been validated against a 7-day physical activity recall interview and a Caltrac motion sensor, was used [12]. An activity score comprised of the amount of daily weight-bearing physical activity the children reported in the previous week was calculated and used to represent physical activity. The children were also asked if their previous week's activities represented their usual physical activity choices and patterns; in every case it had.

Maturity was self-assessed by ratings of breast (girls) and pubic hair (girls and boys) development using a standard approach [13] that we have used previously [14]. Self-assessment has demonstrated strong associations with direct clinical observation [15] and as it is noninvasive is preferable for use with children.

Statistical Analyses

A two by two, sex (M,F) by ethnicity (Caucasian, Asian) analysis of variance (ANOVA) was used to compare independent group means for body composition [leg, length, sitting height, height, weight, fat, and bone mineral free lean (and %)] variables. There was no statistical difference between groups for height or weight, precluding the need to control for these factors. Therefore, ANOVA was also used to determine between group differences in physical activity, dietary calcium, BMC, and *a*BMD at the proximal femur (total), FN, lumbar spine, and TB, and for bone volume and estimated *v*BMD at the FN. Results are presented as means (SD), and differences were considered significant at $P < 0.05$.

Stepwise multiple regression models were fitted to estimate the contribution of the independent variables to absolute values of bone mineral. SPSS for Windows was used for all statistical analysis.

Results

All of the boys and 89% of the girls were at Tanner stage 1. Table 1 summarizes the body composition and lifestyle characteristics of the group by ethnicity. ANOVA demonstrated a significant main effect for ethnicity for both dietary calcium intake ($P < 0.001$) and physical activity ($P < 0.001$). In both cases, the Asian group reported lower values.

As a group, the Asian children consumed, on average, 35% less dietary calcium than their Caucasian counterparts. The differences were greatest between the Asian (mean 735 mg) and Caucasian (mean 1165 mg) boys where the Asians indicated a 41% lower calcium intake. A 29% difference was noted for the girls.

The ethnic difference in physical activity is a function of the much more pronounced level of activity in the Caucasian as compared with the Asian boys, as noted by the significant sex by ethnicity interaction ($P < 0.001$). On average, the Asian children were 15% less active than their

Table 2. Comparison of BMC, αBMD, bone volume, and *v*BMD between Asian and Caucasian males and females (mean, SD)

	Asians			Caucasians		
	Males	Females	Total	Males	Females	Total
BMC (g)						
Femoral neck	2.18[a]	2.20	2.19[x]	2.58	2.20	2.40
	(0.47)	(0.49)	(0.48)	(0.39)	(0.45)	(0.46)
Prox. fem. tot	12.12[a]	12.52	12.31	13.75	12.33	13.05
	(2.50)	(3.10)	(2.78)	(2.22)	(2.34)	(2.38)
PA spine	20.43	20.40	20.42	21.44	20.22	20.85
	(3.68)	(4.29)	(3.95)	(3.71)	(3.46)	(3.63)
Total body	842	843	843	907	833	871
	(145)	(164)	(153)	(152)	(117)	(140)
*a*BMD (g/cm^2)						
Femoral neck	0.62[a]	0.61	0.61[x]	0.67	0.60	0.64
	(0.06)	(0.08)	(0.07)	(0.06)	(0.06)	(0.07)
Prox. fem. tot	0.64	0.63	0.66	0.68	0.61	0.65
	(0.07)[a]	(0.08)	(0.07)	(0.06)	(0.06)	(0.07)
PA spine	0.56	0.56	0.56	0.56	0.56	0.56
	(0.06)	(0.08)	(0.07)	(0.06)	(0.06)	(0.06)
Total body	0.82	0.78	0.80	0.82	0.79	0.81
	(0.05)	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)
Fem. neck volume (cm^3)	6.72	6.92	6.82[x]	7.85	7.19	7.53
	(2.29)	(1.82)	(2.06)	(7.46)	(1.86)	(1.84)
Fem. neck *v*BMD (g/cm^3)	0.35	0.32	0.34	0.34	0.32	0.33
	(0.10)	(0.04)	(0.08)	(0.06)	(0.07)	(0.06)

[x] Significantly less than Caucasian Total ($P < 0.05$)
[a] Significantly less than Caucasian males (sex by ethnicity interaction $P < 0.001$)

Caucasian counterparts. Whereas 73% of the Caucasian boys participated in organized sport, only 14% of the Asian boys reported similar involvement with sports teams outside of school. The Asian children (57%) were twice as likely to be attending academic lessons (Chinese, mathematics, music, etc.) after school than the Caucasian children (28%).

There was no difference in sitting height, leg length , or soft tissue (fat mass or BMFL) between groups. Descriptive statistics for bone mineral variables are shown in Table 2. At the femoral neck there was a significant ethnicity effect for BMC and *a*BMD (both $P < 0.001$) and for estimated bone volume ($P < 0.05$), with Asian boys having consistently lower values for all of these measures (Table 2, Fig. 1). There was no difference between groups for femoral neck *v*BMD. At the proximal femur (total) there was a significant sex by ethnicity interaction for *a*BMD ($P < 0.05$) which is explained by the approximately 6.5% lower *a*BMD at this site in the Asian, as compared with the Caucasian boys. There were no between-group differences for any bone variables at either the TB or the lumbar spine.

At both the total proximal femur and femoral neck, BMFL, sex (both $P < 0.001$), and physical activity ($P < 0.05$) were significant predictors of *a*BMD and accounted for 29% and 37% of the total variance, respectively. For TB *a*BMD sex, BMFL and fat explained 25% of the variance. For BMC at the femoral neck, BMFL mass ($P < 0.001$), sex ($P < 0.001$), calcium ($P < 0.05$), and fat mass ($P < 0.05$) were significant predictors, explaining 61% of the variance.

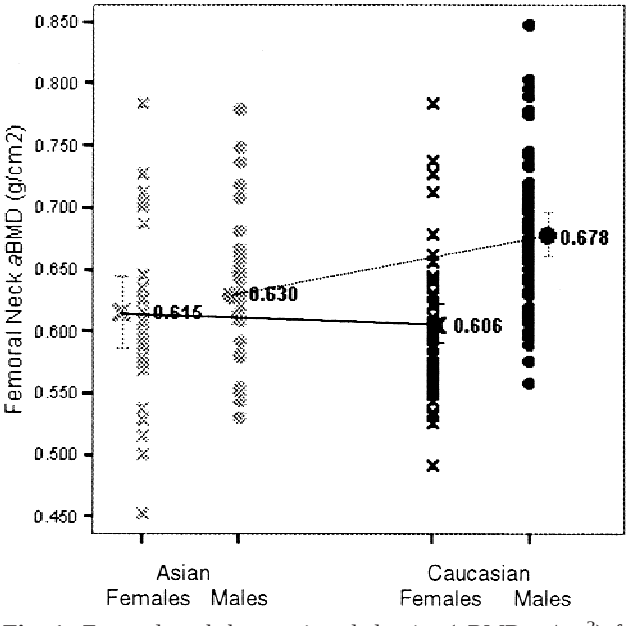

Fig. 1. Femoral neck bone mineral density (*a*BMD, g/cm^2) for Asian (▨) and Caucasian (■) boys (•) and girls (✕). Significant sex by ethnicity interaction ($P < 0.001$). Lines connect the mean values for boys (broken line) and girls (solid line). Error bar shows 95% Cl of Mean.

Discussion

Little is known about ethnic influences on bone mineral during the prepubertal years as most normative studies have been limited to Caucasian subjects [1, 16], and have had only a small number of prepubertal subjects. Ethnic differences in BMD have been attributed primarily to variations in body (bone) size [17]. In this study of prepubertal Asian

and Caucasian children living in geographical proximity, we observed racial differences in bone mineral that are not accounted for by differences in body size.

Physical activity and dietary calcium intake of Asian and Caucasian children have rarely been directly compared. We found that Asian children were less physically active than their Caucasian counterparts. In the only published study that included both Asian and Caucasian children, Bhudhikanok et al. [17] reported similar results using an activity frequency questionnaire but with far fewer (18 Asian; 34 Caucasian) and slightly older (10.5 ± 1.05 years) subjects than in the maturity group we describe. There have been no studies evaluating the effect of physical activity on bone in boys at various pubertal stages. However, recent Finnish studies in girls showed that bone mineral appears to respond maximally to mechanical loading during Tanner stage 1–3 [6] and that physical activity was a major determinant of bone mineral [18].

The mean estimated dietary calcium intakes of Asian children in this study were greater than for Asian children living in Hong Kong [19] but substantially lower than for the Caucasian children studied. Five-year-old Chinese children in Hong Kong, who consumed twice the dietary calcium intake of children in a mainland Chinese city, had a 14% greater radial BMC, as measured by single photon absorptiometry (SPA) [20]. A strength of the present study was that the same dietary calcium questionnaire that included ethnic specific foods, was administered to children of both ethnicities.

The significant ethnicity effect for femoral neck BMC in prepubertal boys in our study differs from the findings of Bhudhikanok et al. [17] who showed no ethnic differences in boys until mid-puberty. Unlike the present study, these authors also reported lower values between ethnicities for FN and total body BMC in Tanner stage 1 and 2 girls. This may reflect the small numbers of pre/early pubertal girls (5 Asian, 14 Caucasian), earlier maturation, or a greater proportion of girls in Tanner stage 2 in the Caucasian sample in that study [17]. Bhudhikanok et al. attributed ethnic differences to size which were not evident in our cohort who were of similar height and weight. We also had a larger number of prepubertal (only) subjects than has previously been reported. For TB and lumbar spine, our data support the contention that after accounting for size there are no differences in BMC between Asian and Caucasian children.

In our study, when *a*BMD was the outcome measure, thus partially correcting for size, the lower values for the Asian boys at the femoral neck persisted. We report *a*BMD data as they remain the best predictor of fracture risk in adults and to compare our findings with those studies that reported *a*BMD only [21].

Our finding of no ethnic difference in *v*BMD is consistent with studies in adults [22, 23] and in older children [17] that suggest *v*BMD is similar in Asians and Caucasians and is independent of age. Recent work by Gilsanz et al. [24] in Caucasian- and African-American children using QCT also supports this finding.

In summary, we demonstrated differences in modifiable lifestyle factors between Asian and Caucasian boys. Ethnic differences were observed for both femoral neck bone volume and *a*BMD for Asian boys and both of these variables are independent risk factors for osteoporotic fracture in adults [25, 26]. Based on these findings, and those of a recently published longitudinal study [27], we recommended that future studies evaluate a physical activity intervention in this age group.

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