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Journal

Journal of Clinical Densitometry, 10(2)

ISSN

1094-6950

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Publication Date

2007-04-01

DOI

10.1016/j.jocd.2006.12.005

Published in final edited form as:
J Clin Densitom. 2007 ; 10(2): 157–164.

Bone Mineral Density and Leg Muscle Strength in Young Caucasian, Hispanic and Asian women

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Abstract

Differences in bone density (BMD) of ethnically diverse populations are usually attributed to anthropometric characteristics, but may also be due to life style or diet. We studied healthy young sedentary women with Asian (ASN, n=40), Hispanic (HIS, n=39) or Caucasian (CAU, n=36) backgrounds. Body composition and regional BMD, were measured by dual-energy X-ray absorptiometry (DXA, Hologic or PIXI, Lunar GE for the heel and wrist). Leg strength was quantified with a leg press and dietary calcium was estimated with three-day diet records. CAU were taller than HIS and ASN (p<0.01). ASN had lower body weights, fat mass, lean body mass, and leg strength than HIS or CAU (p<0.01). Differences in BMD among groups were not eliminated by adjusting for body weight and height at the arm, trochanter, femoral neck, and total hip where BMD values remained lower in the ASN than in HIS or CAU (p<0.01). Conversely, adjusted BMD at the wrist was 7.3% higher in ASN and 8.3% higher in HIS and at the heel, 7.3% higher in ASN and 7.0% higher in HIS than in CAU p<0.05). Leg strength was a significant predictor of BMD in the hip in CAU (R = 0.53, p = 0.004), in the hip with dietary calcium in ASN (R = 0.65, p = 0.02), and in the heel with height in HIS (R = 0.57, p = 0.03). We conclude that significant factors underlying BMD in ethnically diverse young women vary as a function of ethnicity and include leg strength and dietary calcium as well as anthropometric characteristics.

Keywords

Ethnic differences; young women; wrist BMD; heel BMD; leg strength

Introduction

Differences in bone mineral density in premenopausal women of different ethnicity are commonly attributed to differences in body weight and height (1,2,3). This is most clearly demonstrated in populations with little interbreeding so that anthropometric characteristics do

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not overlap. Andersen et al. reported average differences of 10 kg in body weight and 12 cm in height in the smaller Inuit compared to Caucasian women living in Greenland. After adjustment for body size, the bone density of the Inuit women was the same as in the Caucasian women (1). Even with height and weight controlled however, there is not universal agreement that adjustment of BMD for these variables equalizes values in different ethnic groups. Actually, Finkelstein et al. found higher bone density in the lumbar spine and femoral neck in African-American, Japanese and Chinese women than in Caucasian women after adjusting for covariates of age, height and weight (2). Russell-Aulet et al. also found higher BMD in premenopausal Asian than white women when factors known to influence bone mass (height, weight, steroid use, and smoking) were controlled (3). More frequently, however, bone density is reported to be lower in Asians than Caucasians. For example, less weight-bearing activity and low dietary calcium were found to account for the low femoral neck BMC in 9 to 26 year old Asians compared to Caucasians (4). Different geographic living areas and adjustment for height, lean body mass and quadriceps muscle strength did not entirely explain ethnic variations of Asian and Caucasian BMD in a study by Ross et al. (5) and one investigation found no relationship between physical activity and BMD in young women (6).

The purpose of this study was to determine whether the differences in BMD in young women of similar age with Asian, Hispanic and Caucasian backgrounds were associated with differences in height and weight. The subjects were volunteers for an exercise study in southern California. While the candidates for the study were all sedentary by history, an objective measure of muscle strength was carried out in addition to the measurements of body composition and dietary calcium. It is well known that muscle strength or muscle mass is a determinant of bone mineral content in patients (7) young girls (8) and pre-menopausal women (9). We hypothesized that there would be differences in BMD in three ethnic groups of sedentary young women that could be explained by adjusting for the heights and weights. We also evaluated the role of leg muscle strength as a determinant of BMD in relevant skeletal sites.

Materials and Methods

Subjects

This study was designed to compare regional BMD in 115 healthy young 20 - 35 year-old women of Asian (ASN, n=40), Hispanic (HIS, n=39) and Caucasian (CAU, n=36) backgrounds. All women were recruited from the same region of southern California where they lived. ASN included Indian/Pakistani, Southeast Asians, Chinese and Japanese, HIS included white-Hispanic, non-white Hispanic, Latinos and Mexican-American, and CAU included women of European origin. Ethnic group classification was based on the self reported history of the geographic origin of parents and grandparents, confirmed by an interview of each subject by one of the investigators. All subjects provided written informed consent for a protocol in a human research study approved by the Institutional Review Boards of California State Polytechnic University, Pomona, the University of California, Irvine and NASA Ames Research Center, Moffett Field, CA. Each subject was screened by a Health and Physical Activity Questionnaire (10) and was examined by blood tests performed at a clinical laboratory. The inclusion criteria for each subject required 1) age of 20 and 35 years 2) both birth-parents and grandparents (preferably, if known) from the same ethnic/racial group, 3) good health, and 4) not pregnant. Subjects were excluded from the study if: 1) the Body Mass Index (BMI) exceeded 30 $kg.m^{-2}$ 2) weight varied more than 4.5 kg in the 6 months prior to the study 3) abnormal menses such as amenorrhea (for a minimum of 3 months) or oligomenorrhea (defined as 4 or fewer menstrual cycles per year) 4) positive medical history for cardiovascular or pulmonary disease, diabetes, orthopedic problems, kidney disease, liver disease, thyroid dysfunction, congenital or acquired bone disease, cancer 5) chronic drug (i.e., steroid) use that might affect bone growth 6) use of a tobacco product 7) participation in physical training or regular exercise other than walking in the 6 months prior to the study and 8) a VO_{2max} result greater than 42 ml/kg/min.

Procedures

Measurements of weight and height—Weight (kg) and height (standing, cm) were measured without shoes in light indoor clothing using a clinical weight/height scale with a stadiometer calibrated by the manufacturer (Detecto, Webb City, MO). Body mass index (BMI) was calculated from weight and height (wt, kg/(ht, m)^2.

Estimate of cardiovascular fitness—Cardiovascular fitness was assessed with a Balke-Ware treadmill protocol to determine maximum oxygen uptake ($VO_{2\ max}$). During this protocol, the treadmill is maintained at a constant speed of 1.48 m/s (3.3 mph). Treadmill inclination was increased by 1% each minute until volitional exhaustion. Expired gases were measured continuously using an automatic gas analysis system (Vmax System, Sensor Medics, Yorba Linda, CA). During the exercise test the subject's cardiac activity was continuously monitored by a 12-lead electrocardiogram.

Measurement of bone density, lean body mass and fat mass—Areal bone mineral density (BMD) of forearm (radius and ulna), lumbar vertebrae 1-4, femoral neck, greater trochanter, lower extremity (femoral neck to foot) and whole body were measured with a dual energy X-ray densitometer (DXA, QDR 5000W, Hologic Corp, Waltham, MA). BMD values of the extremities were reported for the left side only. Total body mass, lean body mass, fat-mass and percent body fat were assessed using whole-body DXA scans according to the manufacturer's guidelines. These measurements were performed at University of California Irvine, General Clinical Research Center by the same operator. BMD for os calcis (heel) and distal radius and ulna (wrist) were scanned using a dual-energy X-ray absorptiometer (Lunar PIXI #50828, GE Medical Systems, Madison, WI) at California State Polytechnic University Pomona Human Performance Research Laboratory by the same investigator (MTCL).

All quality control (QC) measurements were performed daily at both sites for two 5 month periods. Mean (SD) for the lumbar spine phantom in the DXA was 1.008 (0.004) g/cm^2, CV = 0.373% and 1.012 (0.003) g/cm^2, CV 0.304%. Mean values for the phantom os calcis by the PIXI were 0.546 (0.001) CV = 0.58% and 0.547 (0.001) g/cm^2 CV = 0.59% and for the distal forearm phantom 0.433 (0.001) CV 2.29% and 0.434 (0.001) g/cm^2 CV 3.29%.

Leg Strength test—Bilateral leg strength was tested on a supine leg press machine (Hammer Strength, Schiller Park, IL) using the 1RM leg press test. 1RM leg press score is the maximum weight a subject can lift with a full extension of the knees at one time. On the day of the test, subjects were familiarized with the instrument by performing 8-10 repetitions (reps) of the leg press with zero weight and then 8-10 reps with a low-load of approximately 30% of the body weight. During the test, the subject lay in a supine position on the leg press machine with the hip flexed at a 70° angle and the knee flexed at a 90° angle. The torso was stabilized with two fixed pads at the shoulders, the arms securely holding on to the side railings, and the feet placed against a moveable footplate. The warm-up activity consisted of 8 reps with a weight equal to 60% body weight, followed by 6 reps with 75% body weight, and then 4 reps with 100% body weight. From this point, additional weight of 5-20 lbs was added with 1-2 reps of full knee extension based on the subjects perceived difficulty of the previous weight lifted. Weight was added until the subject failed to complete one repetition of full knee extension, with acceptable form. The 1RM weight score was confirmed with the same weight after a 3-minute rest. The maximum weight lifted with both knees fully extended was recorded as 1RM. In all except one case subjects completed the 1RM test after 3 or 4 trials.

Assessment of Dietary Intake—A detailed food record questionnaire for three consecutive days including beverage and supplements was given to all participants during the screening visit. A three-day food record was selected to estimate dietary calcium rather than a food frequency questionnaire because of the relatively small size of the population, and the more flexible description of the nature and amount of food. We did not use a food frequency questionnaire because they are designed for larger population studies and ask the for the number of times a food, i.e. milk, was consumed each day, but not necessarily, the amounts or forms of the intake. The three-day food records were composed of food categories, portion size, number of servings and day of the week. All food consumption was accurately recorded. The dietary intake records were reviewed for completeness, errors and omissions with each participant by a registered dietician at the testing laboratory at the General Clinical Research Center. The dietary intake record was analyzed for calcium intakes using Nutritionist Pro software (First Data Bank Inc., San Bruno, CA). This program contained some ethnic foods that were used when necessary.

Power Analysis for Sample Size Determination—For multiple group comparison, the sample size was determined by power analysis based on one-way ANOVA for BMD at regional skeletal sites as the outcome variables. For femoral neck BMD [effect size (ES) = .76)], total leg BMD (ES = .71), and total arm BMD (ES = .90). The sample sizes for a directional hypothesis with a desired power of 0.80, and a significance level set at 0.05, were estimated to be between 25 and 40 per ethnic group (11). For total body, arm, leg and trunk BMD as the outcome variables, Russell-Aulet (3) used a sample size of 31 Asians and 42 Caucasians. Our sample sizes of 36 for Caucasians, 39 for Hispanics and 40 for Asians were sufficient to conduct the analyses without committing a type II error related to the primary purpose of the study.

Statistical Analysis—Statistical analyses were performed with the SAS computer Program (Version 8.0.2). For multiple comparisons among the three ethnic groups the Tukey post-hoc test was used. Before the analysis, assumptions of equality of variances and normality were made. Means, SD and independent non-directional t-tests were calculated on all normally distributed data. Adjusted group means (least square means) to estimate differences among ethnic groups were determined using one-way ANOVA and ANCOVA with weight and height as covariates. Data were also analyzed using a stepwise multivariable regression analysis. The SPSS (release 13.0 for Windows, SPSS Inc. Chicago, IL) statistical software regression models were used to examine the association between dependent and independent variables. Regional BMD areas were the dependent variables and the independent variables were: age, weight, height, body mass index, percent body fat, leg strength and dietary calcium. These analyses were performed at the University of California Irvine. Data are presented as means ± standard deviation (SD). Statistical significance was set at alpha < 0.05.

Results

Anthropometrics, body composition and dietary calcium

Table 1 depicts subjects' anthropometric and physiological characteristics. CAU were 3.5% taller ($p < 0.05$) than HIS or ASN whose heights were similar. Body weights and BMI were lowest in ASN ($p < 0.05$). ASN had lower fat mass and lean body mass than HIS or CAU ($p < 0.05$). HIS had highest value for percent body fat. Leg strength measured by the 1RM leg press test revealed the lowest values in ASN, 33% lower than in CAU and 19% lower than in HIS. CAU had the highest values for leg strength ($p < 0.05$). Dietary calcium was lowest in ASN ($p < 0.05$), compared to CAU.

Bone mineral density

Table 2 shows the BMD of subjects before an adjustment was made for the covariates of weight and height. In all sites measured except for the heel, ASN had lower BMD than either CAU or HIS ($p < 0.05$). Differences in heel BMD between the CAU and HIS were not significant. CAU had the lowest wrist BMD compared to the HIS (6.6%, $p < 0.05$) and ASN (4.4%, $p > 0.05$).

Table 3 shows the BMD of subjects after the data were adjusted for the covariates. Differences in BMD among the groups were not eliminated at the wrist, total arm, heel, trochanter, femoral neck, and total hip. BMD in ASN remained lower in the forearm ($p < 0.01$), trochanter ($p < 0.05$), femoral neck ($p < 0.05$), and total hip ($p < 0.05$) than HIS. However, ASN and HIS had higher BMD than CAU in the heel (7.3% and 7.0%) and wrist (8.3% and 7.3%) respectively.

Table 4 shows multivariable regression analysis results for determining predictors of regional BMD in CAU, HIS, and ASN. From these regression analyses leg strength (multiple $R = 0.401$ to 0.647) appeared to be a common positive predictor for most BMD regions in these groups of young women. There were not independent predictors that could fit the multivariable regression model for the femoral neck, trochanter and total hip BMD in HIS. The other strong predictors of BMD were height and leg strength (multiple $R = 0.57$) for lower extremity BMD in CAU. In HIS, weight (multiple $R = 0.34$) and height (multiple $R = 0.49$) were strong predictors for wrist BMD and lower extremity BMD, respectively. In ASN BMI (multiple $R = 0.39$), weight (multiple $R = 0.49$), and leg strength with weight (multiple $R = 0.70$) were strong predictors of BMD in the wrist, heel, and lower extremity, respectively. Also, in ASN leg strength and kcal (multiple $R = 0.64$) and dietary calcium with leg strength (multiple $R = 0.65$) were strong predictors for forearm and total hip BMD, respectively.

Discussion

We have observed differences in BMD at regional skeletal sites in an ethnically diverse population of sedentary young women and found that only some of the differences were explained by group differences in body weight and height. There was a 19 percent difference in body weight between ASN and CAU whereas HIS and CAU differed by only 7 percent (Table 1). The low body weight in ASN was associated with the lowest fat mass, lean mass, leg strength and dietary calcium in any of the groups and separates ASN from the other two ethnic groups. ASN appropriately has the lowest value for the bones of the major weight-bearing joint, the hip, compared to the other two groups (Table 2). If body weight and height alone accounted for the difference in the hip of ASN compared to HIS and CAU, statistical adjustment for body weight and height should have equalized the values. This was not the case, as outlined in Table 3, where adjusted values for forearm, and total hip including femoral neck and trochanter BMD were lower in ASN than HIS. One factor that may explain the failure of height and weight alone to explain the low values in ASN may be dietary calcium. Dietary calcium along with leg strength was a significant predictor of BMD in the hip of ASN (multiple $R = 0.65$) (Table 4). This relationship between dietary calcium and hip BMD was also observed by Bhudhikanok et al. and by Wang et al. in female subjects that were younger than ours (4, 6).

Determinants of lower extremity and lumbar spine and whole body BMD in all three groups were equalized by adjusting for height and weight, both of which are influenced primarily by one's genetic profile. This acknowledges the genetic influence of height and weight as determinants of BMD. However, differences in adjusted BMD values between two groups with similar heights but different body weights were significant for trochanter, femoral neck and hip (Table 3), the components of the major weight bearing joint. These differences between ASN and HIS that were not observed between ASN and CAU, are an indication of the influence of body weight on BMD. Our results (at the femoral neck but not the lumbar spine) differ from those of Finkelstein et al. (2) in older women, indicating the importance of age, and of Fielding et al. indicating the importance of group size and/or equipment type (12), A larger group of young women similar in ethnicity, geographic area and age as our subjects showed persisting differences in whole body and lumbar spine BMD in ethnic groups after adjustment for height and weight (12).

Low BMD values in the young ASN women may be a size-related artifact. Seeman (13) commented that reporting ethnic differences in BMD adjusted for height, weight or BMI is not adequate because these variables are poor surrogates for the actual size of the bone being measured. Conventional BMD assessments by DXA, expressed as grams per square centimeter, introduces a scale artifact that results in smaller bones having lower areal BMD than larger bones. True volumetric BMD would be expressed as grams per cubic centimeter. A technique that reduces the effect of bone size on BMD is bone mineral apparent density or BMAD, applied by Bhudhikanok et al. (4). They concluded that differences in bone mineral density are only partially accounted for by the smaller bone size in ASN when density is measured by quantitative computed tomography (QCT), a measurement of interest in the future in Asian women in this study. Davis et al. (15) suggested an explanation for higher wrist mineral density in ASN than CAU, i.e. the distribution of mineral in the smaller forearms in ASN would appear to be more dense in a smaller area than the same amount in the larger bones of CAU women.

Life style factors as well as the smaller bone size may be responsible for the differences in both heel and wrist BMD in ASN and HIS compared to CAU. Our health and physical activity questionnaire did not reveal differences in the loading history or activity of these two sites among the groups. Nevertheless, physical activities that loaded the heel were clearly important in determining the heel density in two groups (14). The objective measurement of leg muscle strength was a significant determinant of heel BMD in CAU ($R = 0.65$) and with height, in HIS ($R = 0.57$) (Table 4). The strength measurement correlated best with hip, femoral neck and trochanter BMD in CAU and ASN, an indication of physical activity and this life style factor in generating BMD. The relationship of lower extremity BMD and leg strength was most significant in ASN with weight, but not in HIS where height, a genetic determinant, was related to lower extremity BMD. Differences in wrist densities, reported by others also reveals the role of genetic influences in ethnic BMD differences (5).

A number of scientists have reported the relationship of muscle strength and bone density in studies of young women that are focused on the effects of exercise on improving bone mass (16,17,18) but we are unaware of studies with comparisons of muscle strength in young women of different ethnicities. In general, athletes have greater bone mass than their untrained counterparts in all age groups (18,19). However, the relationships between measured muscle strength and bone mass differ in athletes and sedentary individuals. Taafe and Marcus found leg press strength related to leg and whole body BMD in non-athletes only (17). These scientists suggested that while the association of muscle strength and BMD is dependent on exercise, the increased mechanical loading in athletes tends to dissociate this relationship. These studies and the relationships we have found between leg strength and BMD in some skeletal sites tends to confirm our evaluation of our subjects as sedentary and rules out athletic training in explaining the differences in bone density in the groups. A twin study that addressed the role of genetic factors in the association of muscle strength, lean mass and bone density in the femoral necks of 45 year old women concluded that genetic factors relating to size accounted for 60 to 80% of the variances in bone density (20). Clearly both the environment and genetic factors influence bone density (21).

Whether our observations of relatively low BMD in the proximal femur and in the lumbar vertebrae of young Asian women are important in the prediction of future skeletal fracture risk is unknown (22,23). The BMD values of our subjects reflected their peak bone mass, recently considered an element of major importance in the development of osteoporosis later in life. Our interest in this study of ethnicity was not to identify individuals at risk for osteoporosis, but to determine if variations in BMD in a population of young women were related to ethnicity. Siris et al. found ethnicity a factor in the increased risk of osteoporosis in women living in New York City (24). Some (25) but not all investigators link the density of bone to the fracture risk (26,27). In older women, the risk of skeletal fracture is influenced both by bone size and geometric characteristics of bone that are independent of BMD (28). Our positive results can be applied to the education of specific ethnic groups to promote bone health, i.e. the importance of dietary calcium supplementation and leg muscle strength in young Asian women.

In summary, ethnic differences in BMD in young women reflected both genetic and environmental influences. BMD in the spine and whole body in three groups of ethnically diverse women was equalized by adjusting for height and weight, as we hypothesized. However, a number of regional differences in BMD among groups showed persistent differences that can be related to ethnicity. BMD in forearm, trochanter, femoral neck and hip remained lower in the smallest group, ASN, compared with HIS or CAU. Small size, a genetic factor, was an important determinant of ASN BMD in the hip, but not in the heel or wrist where values in ASN and HIS exceeded those in CAU. An objective measure of physical activity (leg strength) and dietary calcium showed significant differences in the three ethnic groups and proved to have major influences on BMD, an indication of the important contribution of life style as well as genetics to BMD.

Acknowledgements

We thank the participants who took the time to participate in the study, and the contribution of Dr. Alane Daugherty, Dr. Scott Stevenson and our graduate research assistants for assisting in data acquisition and subject recruitment. We also thank the research administrative staff for their assistance in manuscript preparation and data entry and verification. This study was supported by a NIH BMRS-SCORE grant (No. 5 SO GM053933-06), NASA (Grant No. SAA2-401535), and University of California Irvine – General Clinical Research Center (Grant No. 5M01RR00827-29).

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Table 1

Comparison of Subjects' anthropometric and physiological characteristics, Mean (±SD)

Ethnic Group	**Caucasian**	**Hispanic**	**Asian**	**P -value**
Number of Subjects	**36**	**39**	**40**	
Age, years	23.8 (4.2)	25.9 (4.9)	24.9 (4.4)	NS
Height, cm	164 (8.9)	158.3[b] (5.4)	157.7[b] (5.8)	0.0001
Weight, kg	64.5 (14.7)	60.2 (9.4)	52.5[a] (7.2)	0.0001
BMI, kg/m^2	24.2 (3.6)	24.0 (3.4)	21.1 (2.6)	0.0001
Fat mass, kg	20.8 (7.97)	19.6 (5.93)	15.2[a] (4.08)	0.001
Lean mass, kg	43.4 (6.67)	39.4[b] (4.54)	36.3[a] (3.94)	0.01
Percent body fat, %	31.6 (5.6)	32.6 (5.5)	29.3[a] (4.1)	0.01
VO_{2max}, ml/kg/min	34.2 (8.4)	32.9 (7.5)	31.2 (8.8)	NS
1RM leg strength, lbs	214 (46.4)	191[b] (44.2)	161[a] (39.3)	0.01
Diet Calcium, mg/day	795 (372)	727 (259)	607[b] (400)	0.05

[a]Compared with Caucasians and Hispanics

[b]Compared with Caucasians

Table 2

Mean (± SD) DXA Regional and Whole Body Bone Mineral Density, g/cm^2, and Wrist and Heel measured by PIXI, Before Adjustment for Covariates of Height and Weight in Three Ethnic Groups of Young Women

Ethnic Group	**Caucasian**	**Hispanic**	**Asian**	
Number of Subjects	**36**	**39**	**40**	**p-value <:**
Wrist	0.446 (0.043)	0.475[c] (0.058)	0.465 (0.053)	0.01
Forearm	0.718 (0.048)	0.718 (0.061)	0.673[b] (0.042)	0.001
L1	0.893 (0.095)	0.910 (0.108)	0.863[a] (0.104)	0.05
L2	0.993 (0.087)	1.018 (0.123)	0.954[a] (0.117)	0.01
L3	1.035 (0.083)	1.045 (0.120)	0.991[a] (0.103)	0.05
L4	1.044 (0.086)	1.051 (0.114)	0.993[b] (0.103)	0.01
Total lumbar	0.997 (0.077)	1.011 (0.112)	0.956 [a] (0.101)	0.01
Trochanter	0.706 (0.096)	0.709 (0.097)	0.644[b] (0.094)	0.01
Femoral neck	0.870 (0.102)	0.870 (0.115)	0.786[b] (0.120)	0.01
Lower extremity	0.958 (0.110)	0.958 (0.113)	0.874[b] (0.110)	0.01
Total leg	1.123 (0.099)	1.108 (0.084)	1.064[b] (0.072)	0.05
Heel	0.522 (0.085)	0.542 (0.088)	0.519 (0.076)	NS
Whole body	1.098 (0.075)	1.115 (0.088)	1.068[a] (0.065)	0.01

[a]Compared with Hispanic

[b]Compared with Hispanic and Caucasian

[c]Compared with Caucasian

Table 3

Mean (± SD) DXA Regional and Whole Body Bone Mineral Density, g/cm^2, and Wrist and Heel measured by PIXI, After Adjustment for Covariates of Height and Weight in Three Ethnic Groups of Young Women.

Ethnic Group	Caucasian	Hispanic	Asian	P value, <:
No. of subjects	36	39	40	
Wrist	0.435 (0.010)	0.469[b] (0.009)	0.474[b] (0.009)	0.01
Forearm	0.709 (0.009)	0.718 (0.008)	0.685[a] (0.009)	0.01
L1	0.871 (0.019)	0.901 (0.017)	0.886 (0.018)	NS
L2	0.969 (0.021)	1.009 (0.018)	0.981 (0.019)	NS
L3	1.011 (0.019)	1.037 (0.017)	1.015 (.0176)	NS
L4	1.027 (0.019)	1.044 (0.017)	1.012 (0.018)	NS
Total lumbar	0.975 (0.018)	1.003 (0.016)	0.980 (0.017)	NS
Trochanter	0.686 (0.018)	0.706 (0.015)	0.653[a] (0.017)	0.05
Femoral neck	0.851 (0.021)	0.865 (0.018)	0.801[a] (0.019)	0.05
Total hip	0.929 (0.020)	0.951 (0.017)	0.898[a] (0.019)	0.05
Lower extremity	1.097 (0.015)	1.105 (0.013)	1.092 (0.014)	NS
Heel	0.502 (0.015)	0.540[b] (0.013)	0.542[b] (0.014)	0.05
Whole body	1.083 (0.014)	1.110 (0.012)	1.091 (0.013)	NS

[a] Compared with Hispanic

[b] Compared with Caucasian

Table 4

Multivariate regression analysis for determining the predictors of Bone Mineral Density (BMD) at 7 skeletal sites where ethnic differences remained after the adjustment for the covariates of age, height, weight and body mass index.

Ethnicity group	Significant Predictors*	Skeletal site BMD	R	p value
Caucasians	Leg strength	Forearm	0.59	0.001
N = 28	"	Heel	0.65	0.001
	"	Total hip	0.53	0.004
	"	Femoral neck	0.42	0.025
	"	Trochanter	0.42	0.025
	Leg strength & height	Lower extremity	0.57	0.002
Hispanic	Leg strength	Forearm	0.40	0.017
N = 35	Leg strength & height	Heel	0.57	0.027
	Height	Lower extremity	0.49	0.003
Asian	Body mass index	Wrist	0.39	0.023
N = 33	Leg strength & Kcal	Forearm	0.64	0.032
	Weight	Heel	0.49	0.004
	Leg strength & calcium	Total hip	0.65	0.023
	Leg strength	Femoral neck	0.53	0.002
	"	Trochanter	0.53	0.002
	Leg strength & weight	Lower extremity	0.70	0.009

*Predictors are: weight, height, body mass index, % body fat, leg strength, dietary calcium, total kcal, and % kcal from fat, carbohydrate, and protein.