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# Ethnic differences in bone geometry and strength are apparent in childhood

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ABSTRACT

*Purpose:* Ethnic differences in bone strength and structure likely contribute to the disparity in fracture rates, however few studies have assessed bone structure in multiethnic cohorts of children. The purpose of this study was to investigate ethnic differences in bone strength in childhood and to characterize the structural bases for these differences.

*Methods:* Peripheral quantitative computed tomography (pQCT 3000, Orthometrix) was used to assess bone parameters at the radius and tibia in Caucasian (CA, $n=21$), African American (AA, $n=23$), and Hispanic (HI, $n=29$) children ($10.9 \pm 0.1$ yrs). At the distal site (8%), we measured compressive bone strength (BSI), trabecular and total bone density, and total bone area. Polar strength-strain index, total and cortical bone area, and cortical density were assessed at the midshaft (50%). Muscle cross-sectional area (CSA) and fat CSA were measured at the tibia (66%) and the radius (50%). Physical activity and calcium intake were assessed by questionnaire. Analysis of covariance was used to compare bone outcomes among ethnic groups adjusting for age, sex, limb length and muscle CSA.

*Results:* Age, BMI, and body composition were similar among the 3 groups, however AA children were taller and had longer bone length. At all sites, AA and HI children had higher bone strength (SSIp and BSI +10–37%) than CA children due mainly to greater bone tissue density (2–18%>CA) at the distal sites of the radius and tibia. The greater bone strength at the midshaft was due to both a higher bone density (2–5%) and greater bone area than CA (7–18%).

*Conclusion:* AA and HI children have significantly higher bone strength than CA children, due to greater bone volumetric density and greater cortical area. AA and HI children also have higher bone strength relative to load. These observations suggest that ethnic differences in bone strength manifest in childhood.



## Introduction

The prevalence of osteoporosis and related fractures is estimated to rise with the aging population [1]. To alleviate the population burden of osteoporosis, it is helpful to identify populations at greatest risk for fracture and characterize variations in normal bone development in early life.

Several large epidemiological studies have found certain ethnic groups to be at greater risk for fracture than others. In particular, Caucasians tend to fracture more than Hispanics, who in turn, fracture more than African Americans [2–4]. Ethnic differences in bone size, mass, and architecture, have been documented in adult populations [5]. African American adults have greater areal bone mineral density (aBMD) than Caucasian adults [6–11]. These observations may help explain why African American adults fracture less than Caucasian adults.

Identifying *when* ethnic differences in bone strength and differences in bone structure manifest is important for establishing optimal prevention strategies. Some studies of ethnic differences in aBMD report no differences among ethnic groups [12,13], while several others reported that African American children exhibit greater aBMD and/or bone mineral content (BMC) [12–20]. These data suggest that ethnic differences in bone strength may have their roots in childhood. However, these studies have only used dual energy X-ray absorptiometry (DXA) and have focused largely on differences between African American and Caucasian children. DXA-derived outcomes fail to reveal information about bone structure and *volumetric* density, and thus are unable to characterize the structural bases for differences in bone mass or strength. DXA outcomes are also confounded by bone size, which is a particularly important limitation when measuring bone during growth [21]. Therefore, studies using measurement techniques such as peripheral quantitative computed tomography (pQCT), which

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measure bone structure and volumetric bone mineral density (vBMD), are needed.

The purpose of this study therefore was to explore ethnic differences in bone strength among Caucasian, African American, and Hispanic children and to characterize bone volumetric density and structure using pQCT in a multiethnic cohort of children.

## Methods

### *Subjects*

Children were recruited from 7 public schools in Minneapolis, MN. A total of 125 children from grades 4–6 (9–12 years of age) participated in baseline measurements. For this cross-sectional analysis, we included Caucasian (CA, $n=21$), African American (AA, $n=23$), and Hispanic (HI, $n=29$) children. None of the participants had any physical disabilities. Parental and grandparent geographical origins and self-identified ethnicity were assessed by questionnaire completed by parents. Participants were classified into ethnic group based on National Institute of Health definitions. But, children who were Native American, Asian, Somali or Multiracial were excluded ($n=52$) due to the small sample size of each group. To simplify throughout this text, we will refer to non-Hispanic black children as African American and non-Hispanic white children as Caucasian. All participants were healthy and none had medical conditions or took medications known to affect bone metabolism. Since the Minneapolis Public Schools Research Department would not allow administration of a physical maturity questionnaire, physical maturity was not assessed in this study. Consent forms were signed by both the children and a parent or guardian. The University of Minnesota Institutional Review Board and the Minneapolis Public Schools Research Department approved this study.

### *Socioeconomic status*

Due to regulations of the Minneapolis School board, we were not able to collect socioeconomic status (SES) on each individual child. However, we estimated SES based on school-wide data showing the percentage of children receiving reduced or free lunch. From these estimates, slightly more Hispanic children (~88%) received free or reduced lunch compared to Caucasian (~62%) or African American (69%) children. Using "school" as a covariate did not change the outcomes however.

### *Anthropometry*

A portable stadiometer (Seca, Model 214, Hanover, MD, USA) was used to measure height to the nearest 0.1 cm. A digital scale (Tanita, Model BWB-800S, Arlington Heights, IL, USA) was used to measure body weight to the nearest 0.1 kg. Tibia length and forearm (ulna) length were measured to the nearest millimeter with a segmometer (Rosscraft, Model Segmometer 4, Canada). Tibia length was measured from the tibial plateau to the medial malleolus and forearm length was measured from the ulnar styloid process to the olecranon process. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared.

### *Questionnaires*

The Physical Activity Questionnaire for Older Children (PAQ-C) was used to determine general physical activity level [22]. The average of the PAQ-C items was used to calculate general physical activity scores (PA score) that ranged from 1 (low active) to 5 (high active). An estimate of the time (load time, hours/week) spent in activities with loads greater than walking was also obtained from the PAQ-C. A validated food frequency questionnaire (FFQ) was administered to assess daily dietary intake of calcium (mg/day) based on the calcium content (mg) of common food items [23]. These questionnaires have been used in previously published studies of bone health in this age group [24–27]. Trained research assistants were available to assist the children if they had questions on completing the questionnaires.

### *Bone variables and muscle cross-sectional area*

Slices ($2.3\pm0.2$ mm) of the left tibia and non-dominant radius were obtained at the 8 and 50% sites for bone outcomes and 66% site for muscle CSA and fat CSA, proximal to the articular surface of the distal end of the tibia and radius, using peripheral quantitative computed tomography (pQCT, Norland/Stratec XCT 3000 bone scanner, Stratec Medizintechnic GmbH, Pforzheim, Germany). A voxel size of 0.4 mm was used and the scan speed was set at 25 mm/s. The anatomic reference line (for determination of the distal end of the bone) was identified by acquisition of a 30 mm planar scout view of the joint line. The distal sites of the tibia and radius were assessed for trabecular volumetric density (TrabBMD, mg/mm$^3$), total volumetric density (TotBMD, mg/mm$^3$), and total bone cross-sectional area (TotArea, mm$^2$) using Contour mode 3 (200 mg/cm$^3$), Peel mode 5 (automatic), and Cort mode 3 (169 mg/cm$^3$). An estimate of the compressive bone strength (Bone Strength Index, BSI) was calculated as TotArea * TotBMD$^2$ [28,29] for the distal sites of the tibia and radius. The proximal sites were assessed for total bone area (TotArea, mm$^2$), total cortical area (CortArea, mm$^2$), cortical volumetric density (CortBMD, mg/mm$^3$), and polar strength-strain index (an estimate of bone strength for cortical bone, SSIp, mm$^3$) using Contour mode 1 (710 mg/cm$^3$), Peel mode 2 (540 mg/cm$^3$), and Cort mode 1 (480 mg/cm$^3$). Muscle cross-sectional area (muscle CSA, cm$^2$) and fat cross-sectional area (fat CSA, cm$^2$) were also determined at the 66% site of the tibia and 50% site of the radius. Strength strain index (SSI) was measured at the midshaft of the tibia and denotes density-weighted polar section modulus and reflects torsional and bending rigidity of the long bone shaft. Ferretti et al., found that in 103 Wistar rats, SSI, assessed by pQCT, was found to closely correlate ($r=0.94$, $p<0.001$) with the actual, mechanically tested bending breaking force of all bones [30]. Bone strength index (BSI), which is reported for the distal end of the tibia, denotes the product of a square of the total density and the total cross-sectional area and reflects the strength of the structure against compression.

One of three trained operators performed the measurements and one operator analyzed all scans. Precision with repositioning was determined in our laboratory in adults (women $n=11$, men $n=4$, age $28.5\pm6.5$ years) as a coefficient of variation (CV, %) and varied from 0.28 (TotBMD) to 1.20 (TrabArea) at the distal tibia and from 0.31 (CortBMD) to 0.41 (TotArea) at the shaft. An anthropomorphic phantom was scanned daily for quality assurance.

### *Statistical analysis*

Data were checked for outliers and for normality using histograms and tests of skewness and kurtosis for normality. One child's data were excluded for values being consistently high. Several of the bone variables were modestly skewed, so we ran both log transformed and untransformed models. Results were similar so we therefore report the untransformed data for clarity. We used analysis of covariance (ANCOVA) to compare descriptive characteristics between ethnic groups, adjusting for sex. For comparison of ethnic differences in bone outcomes ANCOVA was used adjusting for age, sex, limb length and muscle CSA. There were no ethnic group × sex interactions, so both boys and girls were analyzed in the same model. Least square difference (LSD) was used to adjust for multiple comparisons and statistical differences are shown between each pair (AA vs. CA, HI vs. CA, and AA vs. HI) in Table 2. Data were analyzed using SPSS (v 14.0)