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A two-year history of high bone loading physical activity attenuates ethnic differences in bone strength and geometry in pre-/early pubertal children from a low-middle income country

Rebecca M. Meiring [a,*], Ingrid Avidon [a], Shane A. Norris [b], Joanne A. McVeigh [a]

[a] Exercise Laboratory, School of Physiology, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa
[b] MRC/WITS Developmental Pathways for Health Research Unit, Department of Pediatrics, School of Clinical Medicine, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

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ABSTRACT

We examined the interplay between ethnicity and weight-bearing physical activity on the content and volumetric properties of bone in a pre- to early pubertal South African Black and White population. Sixty six children [Black boys, 10.4 (1.4) yrs, $n = 15$; Black girls, 10.1 (1.2) yrs, $n = 27$; White boys, 10.1 (1.1) yrs, $n = 7$; White girls, 9.6 (1.3) yrs, $n = 17$] reported on all their physical activities over the past two years in an interviewer administered physical activity questionnaire (PAQ). All participants underwent a whole body and site-specific DXA scan and we also assessed bone structure and estimated bone strength with pQCT. Children were classified as being either high or low bone loaders based on the cohort's median peak bone strain score estimated from the PAQ. In the low bone loading group, Black children had greater femoral neck bone mineral content (BMC) (2.9 (0.08) g) than White children (2.4 (0.11) g; $p = 0.05$). There were no ethnic differences in the high bone loaders for femoral neck BMC. At the cortical site, the Black low bone loaders had a greater radius area (97.3 (1.3) vs 88.8 (2.6) mm^2; $p = 0.05$) and a greater tibia total area (475.5 (8.7) vs. 397.3 (14.0) mm^2; $p = 0.001$) and strength (1633.7 (60.1) vs. 1271.8 (98.6) mm^3; $p = 0.04$) compared to the White low bone loaders. These measures were not different between the Black low and high bone loaders or between the Black and White high bone loaders. In conclusion, the present study shows that there may be ethnic and physical activity associations in the bone health of Black and White pre-pubertal children and further prospective studies are required to determine the possible ethnic specific response to mechanical loading.

Introduction

Participation in weight-bearing physical activity is an effective way of increasing bone mass [1]. The best time to partake in this type of physical activity is during the years preceding puberty when bone mass accretion is greatest [2]. Pre- and early pubertal children who perform weight-bearing exercise on a regular basis have geometrically bigger and stronger bones [3,4] with significantly higher areal bone mineral density (aBMD) [5], volumetric bone mineral density (BMD) [6], bone mineral content (BMC) and bone area than children who are less active [7,8]. Longitudinal studies have shown that weight bearing activities in early childhood provide sustained benefits to bone health in adolescence [9–11] and lifelong participation in physical activity is now recommended as a means of preventing osteoporotic fracture in later life [12,13].

Physical activity and bone health studies that have taken place in South African children have been limited in their interpretation due to the sole reliance on dual energy X-ray absorptiometry (DXA). One of the main disadvantages of DXA is the two dimensional nature of the scan resulting in inaccurate aBMD reporting in participants who are very large or very small [14]. A number of studies have confirmed that African American adults and children have denser and therefore stronger bones than their White counterparts [15–18] and these differences remain after adjustment for bone size. In South Africa distinct ethnic differences have also been observed for certain measures of bone health i.e. Black children and adults have bigger, stronger and denser bones than those of their White peers [19–24]. It is suggested that this advantage in bone may be lessened [25] as people living in a low-middle income country such as South Africa adopt increasingly sedentary and Westernized lifestyles [20,26,27]. What remains to be elucidated is whether in the future, the genetic advantage of stronger bones afforded to Black South African children will be attenuated with increasingly sedentary lifestyles.

Using pQCT technology, African American children have been shown to have significantly stronger bones as a result of having greater cortical volumetric BMD and cortical area compared to their White peers [18].

* Corresponding author at: Exercise Laboratory, School of Physiology, Faculty of Health Sciences, University of the Witwatersrand, 7 York Rd, Parktown, 2193 Johannesburg, South Africa. Fax: +27 86 765 5461.
E-mail address: Rebecca.Meiring@wits.ac.za (R.M. Meiring).

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More recently greater bone area and strength in Black compared to White children has been observed in South African children [25]. Although the muscle–bone relationship has been well characterized [28], Wetzsteon et al. [18] have shown that race differences in bone geometry are not attributable to differences in muscle cross sectional area (CSA). Also, it has been consistently shown by Micklesfield and colleagues that muscle CSA is greater in White compared to Black South African children [21,29,30] but the same is not true in North American children [29]. Thus the reasons for ethnic variability in bone remain poorly understood with regard to physical activity.

Higher levels of physical activity have been shown to be associated with higher DXA derived BMC at the hip and spine in South African children [20,31]. No studies have considered the relationship between ethnicity and physical activity on structural and geometric properties of bone in a healthy cohort of South African Black and White children. This cross-sectional study used both DXA and pQCT technology to explore the interplay between bone health and ethnicity and analyze the differences in bone content, area and strength as well as geometric properties of bone due to history of loading in pre- to early pubertal South African Black and White children. The physical activity questionnaire we used served as a proxy measure of bone loading classification. Our study had three hypotheses. First we hypothesized that children who were classified as being high bone loaders for the past two years would present with greater bone mass and strength regardless of their ethnicity. Our second hypothesis tested was that high levels of weight-bearing physical activity would negate any ethnic bone differences that may have existed in our participants. Finally we assessed whether muscle CSA could account for any differences observed in bone variables between high and low bone loading children.

Materials and methods

Participants

Participants were recruited from local schools and community centers around the greater Johannesburg area by distributing flyers containing study information during the summer months in South Africa (September 2010 to February 2011). Participants volunteered by contacting the primary investigator. All participants who volunteered for the study were from similar socioeconomic backgrounds with similar access to voluntary physical activities or after-school sports. Ninety six Black and White, boys and girls between the ages of 8 and 11 years volunteered to participate in the study. As indicated by the parent or primary caregiver, children were considered Black if both parents and grandparents were Black while children were considered White if both parents and grandparents were White. Maturational status was self-assessed using breast (girls), gonadal (boys) and pubic hair stages as the Tanner five stage classification criteria [32]. The age at onset of menarche was also requested in the Tanner questionnaire for girls. Children were included in the study if they were pre- to early pubertal or Tanner stage I to III. A general health questionnaire was administered to the parents or caregivers of each child to collect information on socioeconomic status, state of health of the child, including any medication use, as well as history of fractures and family history of osteoporosis. Children were excluded if they had been on corticosteroid medication consecutively for more than seven days in the past year, if they had any milk or lactose food allergies, if they were on a vitamin D or calcium supplement or if they had been ill or admitted to hospital in the last 3 months prior to participation in the study. Girls were excluded if they had attained menarche. All children who participated in the study had the protocol verbally explained to them and if they agreed to participate, signed an assent form. Parents/primary caregivers of the children were required to consent to their child's participation in the study. The study was approved by the Human Research Ethics Committee of the University of the Witwatersrand (protocol no.: M10635) which adheres to the principles of the Declaration of Helsinki.

Physical activity questionnaire

Children, with the assistance of their parent or caregiver, were required to fill out a physical activity questionnaire, previously validated for South African children [33]. Briefly, the PAQ was validated by assessing agreement with activity recorded using accelerometry [33]. In the present study, the questionnaire was modified to include a two-year as opposed to one year, history of the child's participation in all types of physical activity with similar access to voluntary physical activities or after-school sports. A two-year history of physical activity was obtained in order to take into account seasonal variation in sport and also to consider those children who had played a sport up to the first year but then changed to a different sport in the second year. For example, there were some children in the cohort that in the first year of PA assessment had participated in a weight-bearing sport but in the second year of assessment had participated in a non weight-bearing sport such as swimming. The rationale behind a two-year history as opposed to the conventional one-year history was to ensure that we included children who had been exposed to a season of bone loading. In addition, the sustained benefits of weight-bearing exercise are not well defined. Children and their parents listed all the physical activities that the child had participated in for the past two years. Information was gathered from four activity question domains namely, physical activity participation during school, extra-mural/after-school physical activities, leisure time activity as well as mode of transport to and from school. Children were asked to give details on the number of times per week they performed that activity as well as the amount of time they spent on each activity at any one time in order to determine the frequency and pattern of regularity of each activity. Regular participation in a specific activity was classified as the child performing an activity once a week for more than four months of the year (the usual length of a school semester in South Africa). After-school and leisure time activities were also reported on and assessed in the same way. Each regular activity was assigned an estimated bone strain score using a scoring system developed by Groothausen et al. [34], which was validated by using the ground reaction force produced by each activity to quantify the amount of bone loading of that activity. The sum of the scores for each activity made up the estimated peak bone strain score (PBSS) that was assigned to each child and allowed us to classify them as high or low bone loading. Based on the range of PBSS attained, children were divided into two groups: a high and a low bone loading group. This classification was based on the median PBSS attained for the whole sample, such that we had four groups i.e. Black high bone loading, White high bone loading, Black low bone loading and White low bone loading. Low bone loading did not necessarily mean children were physically inactive, for example, swimmers were classed as low bone loaders along with sedentary children.

Anthropometry

Participant height and weight were recorded to the nearest millimeter (mm) and 100 g using a stadiometer (Holtain, Crosswell, UK) and a digital scale (Dismed, Halfway House, South Africa) respectively. Participants were measured without shoes and while wearing light clothing. BMI percentile-for-age was calculated using software available from the World Health Organization (WHO, http://www.who.int/childgrowth/software/en). Radial and tibial lengths (to the nearest mm) were measured using sliding calipers (Holtain, Crosswell, UK) for the determination of the position of the bone scans. Radial length was defined as the distance from the tip of the olecranon process to the most distal end of the ulna styloid process. The side that was chosen for scanning was determined by asking the child which hand they wrote with and that side was scanned. Tibial length was defined as the distance from the distal end of the medial malleolus to the superior aspect of the medial tibial condyle.