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Bone mass accretion rates in pre- and early pubertal South African black and white children in relation to habitual physical activity and dietary calcium intakes

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Abstract

Aim—To examine bone mass changes in 321 black and white South African children in relation to habitual physical activity (PA) levels and calcium intakes.

Methods—Children underwent two bone mass scans at ages nine and 10 years using dual x-ray absorptiometry. PA levels and calcium intakes were assessed using questionnaires. Data were analysed by regressing change in bone mineral content (BMC) and bone area (BA) from age nine to 10, against bone area (for BMC), height and body weight. The residuals were saved and called residualized BMCGAIN and BAGAIN. Residualized values provide good indication of weight, height and bone area matched accumulation rates.

Results—White children had significantly higher physical activity levels and calcium intakes than black children. Most active white males had significantly higher residualized BMCGAIN and BAGAIN at the whole body, hip and spine but not at the radius, than those who were less active. Most active white females had significantly higher residualized BAGAIN at all sites except the radius than less active girls. No such effects were seen in black children. There was no interactive effect on residualized BMCGAIN for calcium intake and PA (except at the spine in white girls).

Conclusion—Bone mass and area gain is accentuated in pre- and early pubertal children with highest levels of habitual physical activity. Limited evidence of an effect of dietary calcium intakes on BMC was found.

Keywords

Bone Mass; Physical activity; Children; South Africa; Dietary calcium intakes

Introduction

The main determinants of peak bone mass are heredity, gender and race (1). Regardless of race or gender, nutrition and physical activity participation are considered to be the most modifiable environmental factors influencing peak bone mass. This is particularly so in the prepubertal years, which appear to be the most responsive to these influences (2, 3).

A small number of studies have recently examined the effects of exercise and calcium interventions on bone mass (4-6). Iuliano-Burns et al (2003) reported main and interactive effects for calcium and physical activity interventions at the hip in pre and peri-pubertal females. Stear et al (2003) also reported enhanced bone mass with a calcium and physical activity intervention in adolescent females, although the interactive effect (if any) of the two interventions was not reported. Specker et al's (2003) intervention showed that although physical activity stimulated growth in bone width, the actual amount of bone mineral accumulated is dependant on both physical activity level and calcium intake (5). In a 12 month follow up to this trial, no consistent effect of calcium supplementation on leg bone mineral content (BMC) was noted (7).

None of these studies have reported on racial differences and all have been conducted in developed countries. There are little longitudinal observational data on the effects of habitual physical activity and calcium intakes on bone mass accretion in children, especially in racially diverse populations in developing countries such as in South Africa, where calcium intakes are generally lower than those in developed countries. Of the studies that have examined habitual physical activity and calcium intakes, data have only been reported for short time periods (one week or less) (8). Additionally, most studies have reported on the association between physical activity and BMC, and the issue of whether habitual exercise increases bone size as well has not yet been clarified. To date, only one elegantly performed study (9) has shown that a moderate level of physical activity within a school curriculum enhances BMC, bone mineral density (BMD) and bone area (BA).

With an exponentially increasing hip fracture rate in the ageing population in developed countries (10), scientists are advocating physical activity and calcium intake as important modifiers of bone mass. This research is particularly important in countries where a more sedentary lifestyle is becoming the norm and where physical education no longer forms part of the school curriculum. The situation in South Africa is of particular interest since South African blacks are reported to have among the lowest hip fracture rates in the world, but life styles are under rapid transition currently (11, 12).

The aims of our study were to examine bone mass changes over a 12 month period in a group of black and white South African pre- and early-pubertal children and to explore these changes in relation to habitual physical activity levels and calcium intakes.

Materials and Methods

Subjects

This is an observational study of a cohort of children (Bone Health Study) recruited from the *Birth to Twenty* birth cohort, a longitudinal study of child health and development (13-16). The methods of enrolment into the Bone Health Study have been described in detail elsewhere (17, 18). For this study, subjects were all healthy and aged nine years (9.51 (0.27)) at visit one and 10 years (10.54 (0.27)) at visit two. Children who were asthmatic or suffering from any disorder likely to affect bone metabolism were excluded from the study.

Complete data for the two annual visits, spaced one year apart were available for 321 children. The sample was comprised of 31 white males, 141 black males, 27 white females and 122 black females. The small number of white children was primarily due to the method of enrolment. Total births over the specified time period were enrolled, and there were fewer white than black children born during this time period. All subjects and their parents provided written informed consent and ethical approval was obtained from the University of the Witwatersrand Committee for Research on Human Subjects.

Measurements

At each visit, the height (Holtaine, UK) and weight (Dismed, USA) of each child were measured with subjects wearing light clothing and no shoes. Body and site-specific BMC, bone mineral BMD and BA were measured using a Hologic QDR 4500A dual energy X-Ray absorptiometer (DXA) according to standard procedures (software version 11.2 for adults, Hologic USA). DXA scans were performed on the non-dominant midshaft radius, femoral neck of the left hip, lumbar spine (L1-L4) and whole body (WB). The analysis for the WB was done excluding the measurements of the head. The reader is referred to (17, 18) for more detailed description of the methods used in the Bone Health and Birth to Twenty Studies.

Questionnaires

Each subject completed the same questionnaires on both visits, with the caregiver present. We examined past medication, known diseases, and pubertal development (by Tanner hair development (19)). Girls were asked about their menstrual status. Dietary calcium intakes were assessed using a 24-hour dietary recall questionnaire as well as by a Food Frequency Questionnaire. Total physical activity was estimated using a structured, detailed, retrospective interview taking into consideration all physical activity and inactivity over the previous 12 months. The questionnaire has previously been used by our group (17, 18) and is based on questionnaires validated in other studies (20, 21). The questionnaire has been modified appropriately for South African children. The intensity, frequency, and duration of all physical activities (at school, after school, at home and commuting (actively and passively) to and from school) were taken into account. Intensities of activities were classified as multiples of one metabolic equivalent (MET) (the ratio of the associated metabolic rate for the specific activity to the resting metabolic rate). Physical activity was scored in two ways: (i) metabolic physical activity score (METPA) by weighting the intensity (multiples of basal metabolic rate (MET'S) and duration (hrs/wk)) (22); and (ii) mechanical physical activity score (MECHPA) by weighting the peak bone strain (ground reaction forces as multiples of body mass and duration (hrs/wk)) (23). The latter score is based on the method of Groothausen and coworkers (23), which we modified by multiplying the ground reaction force (MECH) by duration, since the original measure did not include duration or frequency. Thus a sum score MECHPA was calculated as the sum of all MECH scores multiplied by duration (hrs/wk) per activity. Since the physical activity questionnaire assessed all activity in the preceding 12 months, year 10 data was considered to be representative of activity in the 12 month assessment period.

Statistical analysis

Data were analyzed using SPSS v12.0 and a *P* level of <0.05 was considered to be statistically significant. Percentage gains in BMC and BA (BMCGAIN and BAGAIN) were calculated. An ANOVA was used to detect differences in BMCGAIN and BAGAIN between race and gender groups from age nine to 10 years and the Bonferroni multiple comparison test was used to assess group differences where appropriate. BMD is an areal density measurement (g/cm^2), and does not account effectively for diverse body sizes. To avoid size related artifacts, BMC was adjusted for body weight and BA in multiple regression analyses (24, 25). Our results indicated that height was not significantly related ($p=0.891$) to BMC, thus it was excluded as a covariate. Height was however, significantly related to BA ($p<0.001$) at all sites and was therefore included as a covariate for BA analyses. We used a novel method based on Rowlands et al's technique to assess changes in bone related variables (8). We regressed body weight and BA against BMCGAIN and saved the residuals to form a new variable called residualized BMCGAIN (BMCGAIN_{res}). The same procedure was followed for BAGAIN, whereby body weight and height were regressed against BAGAIN and the residuals were saved to form a new variable called

BAGAIN_{res}. Given a subject's weight and height, BMCGAIN_{res} and BAGAIN_{res} provide a good indication of whether the subjects are above or below their expected value for their weight and height. To assess whether the non-bone related components of weight (fat and lean mass) had different effects on BMCGAIN or BAGAIN, we ran a regression analysis including the additional covariates.

METPA and MECHPA scores were evaluated over the one year period preceding the second DXA scans and were assessed as categorical variables after subjects were divided into quartiles of activity within race and gender groups. To correct for the possible effects of differing physical activity on BMC and BA accumulation prior to the study period, METPA and MECHPA scores calculated at the subject's first visit (age 9) were entered into the regression analysis as covariates. BMCGAIN_{res} and BAGAIN_{res} at the whole body, radius, hip and spine were assessed within METPA and MECHPA quartiles, between race and gender groups using a multivariate ANOVA. A stepwise linear multiple regression analysis was conducted in order to assess the relationship between past year's physical activity (both METPA and MECHPA), calcium intake and BMCGAIN_{res} at all sites measured. The independent variables were entered in the following order: calcium intake, METPA, MECHPA, product of calcium intake * METPA and the product of calcium intake * MECHPA. Independent variables were centered before being entered into the regression analysis, in order to avoid the problem of multicollinearity (26). Centering involves subtracting the mean from each individual score thereby making the mean of the centered variable zero. The product terms were calculated from the centered variables. All data are presented as means (standard deviation), unless otherwise noted.

Results

Included in the study were 58 white and 263 black children, with approximately equal numbers of males and females in each group. Pubertal scores were similar between black and white children of the same sex (Table 1). None of the girls had begun menstruating and all subjects were considered to be either pre-or early-pubertal. There were no significant differences between the skeletal ages of any of any of the groups.

Table 1 shows the results for percentage gain and actual change in height, weight, and unadjusted BMC and BA from age nine to 10 years, as well as calcium intakes and pubertal stage at age 10. Black males were significantly shorter at age 10 years and had significantly lower percentage BMCGAIN at the spine, BAGAIN at the whole body, calcium intake and physical activity scores than white males ($p < 0.001$). There were no significant differences in weight at 10 years, BMCGAIN at the radius or BAGAIN at the radius and hip between any of the groups.

We assessed whether the non-bone related components of weight (fat and lean mass) had different effects on BMCGAIN or BAGAIN using a multiple regression analysis. The addition of fat mass, lean mass and calcium values to the regression had very little impact on the whole body content and area gain values. Each covariate did not contribute significantly more to the model than height alone. The same trend was evident at other sites and for other groups. We therefore did not control for these variables in the residual analysis.

Table 2 shows the results for actual year 10 and percentage gain in BMC (adjusted for weight (kg) and BA (cm²)) and BA (adjusted for weight (kg) and height (cm)) values. Black males had significantly greater adjusted hip BMC and radius BA at age 10 years ($p = 0.001$) and significantly lower percentage gains in spine BMC ($p = 0.034$) and WB BA ($p = 0.027$) than white males. Black females had significantly greater adjusted hip BMC ($p = 0.001$), WB

BA ($p=0.03$) and radius BA ($p=0.002$) and significantly lower hip BA ($p=0.017$) than white females at age 10.

We have reported previously descriptive data for this population's physical activity patterns at age nine (17, 18). At age 10, white males had significantly greater METPA and MECHPA scores than all other groups ($p<0.001$) (Table 1). Subjects were divided into quartiles of activity within race and gender groups and levels of activity were then related to $\text{BMCGAIN}_{\text{res}}$ and $\text{BAGAIN}_{\text{res}}$ at different sites. Residual values above zero indicate that the subjects' BMC and BA fall above their expected values for their weight, height and bone area and vice versa.

Figures 1 and 2 show $\text{BMCGAIN}_{\text{res}}$ and $\text{BAGAIN}_{\text{res}}$ values at the whole body for different quartiles of METPA and MECHPA within race and gender groups. White children in quartile four (highest physical activity group for both METPA and MECHPA) showed significantly greater $\text{BMCGAIN}_{\text{res}}$ and $\text{BAGAIN}_{\text{res}}$ compared with the lowest quartiles. The same trend was observed at the weight bearing sites (hip and spine) for white males in quartile four showing significantly greater ($p<0.05$) $\text{BMCGAIN}_{\text{res}}$ and $\text{BAGAIN}_{\text{res}}$ compared with groups in the lowest quartiles (see Figures 3-6 in supplementary material online). White females in quartile four had significantly higher ($p<0.05$) $\text{BAGAIN}_{\text{res}}$ at the hip than children in lower quartiles. No differences were observed at the radius for any quartiles or groups. Additionally, white males in the highest quartile of physical activity had $\text{BMCGAIN}_{\text{res}}$ and $\text{BAGAIN}_{\text{res}}$ values well above zero. White females had $\text{BAGAIN}_{\text{res}}$ values above zero at all sites. There were no other significant differences for any of the other groups between race and/or gender.

A multiple linear regression sought to examine the effects of calcium intake and physical activity (both METPA and MECHPA) on $\text{BMCGAIN}_{\text{res}}$ at the whole body, radius, hip and spine. There were no significant effects for any of the groups at the radius. No simple effects for calcium were found at any site for any of the groups except in white females at the hip ($p=0.012$). There were significant effects of MECHPA in white boys on $\text{BMCGAIN}_{\text{res}}$ at the whole body ($p=0.03$), hip ($p=0.002$) and spine ($p=0.005$), and of METPA at the hip ($p=0.03$). A significant effect of METPA at the spine ($p=0.033$) were observed for white girls. The only significant interaction between calcium and METPA was seen at the spine in white girls ($p=0.027$).

Discussion

The present study has shown that white females and males accumulate BMC, BA, height and weight at similar rates over a 12 month period between the ages of nine and 10 years both before and after adjustment for body size. Black males however had lower height, weight, BMC (at all sites measured) and BA (whole body and spine) accumulation rates compared with the other groups. White males had the highest PA levels and white male children falling into the highest quartile of activity exhibited bone mass benefits at the whole body, total hip and lumbar spine sites. The same was true for white females at the whole body and hip. White children consumed approximately twice the amount of calcium as black children. Nevertheless, black children had higher hip BMC adjusted for body weight and bone area than white children at age nine (17) and 10 years, despite lower calcium intakes and physical activity levels.

This study describes normal habitual physical activity patterns and calcium intakes in healthy children living in South Africa. We have comparatively small numbers of white children compared with black children. This is largely a function of the racial distribution of the South African population as well as the method of enrollment used in this study. It will

be important to continue our longitudinal study in order to examine whether the observations made here persist through the pubertal growth spurt. Although a number of approaches to assessing children's PA have been described, no specific method has been identified as the best option for all studies (27). While we acknowledge that there are limitations to using activity recall questionnaires, in this large longitudinal cohort of children, recall questionnaires are the only practical way to assess PA. Additionally we are aware of the limitations of using DXA measurement in children, specifically in that the measurements we report on in this paper provide no information on structural alterations of bone and overlook the periosteal and endosteal dimensions that influence bone strength. Measurements of bone structure such as those provided by pQCT would be invaluable in this group of subjects.

The relationship between physical activity and bone mass is governed by the degree of physical activity; in order for sizeable bone mass changes to occur, physical activity must be great enough to induce these positive effects (6). Our results agree with the notion that physical activity levels need to be above a certain threshold in order for bone mass benefits to be seen. White males showed both a wider and higher range of scores for METPA and MECHPA compared with all other groups and the benefits of these higher levels of activity are reflected in the greater BMC and BA in highly active children (quartile 4). This "threshold" of activity is important to consider when designing exercise programs aimed at increasing bone mass. Whether this 'threshold' is reached by performing activities with a high enough strain on the bone for a short period of time or performing less strenuous activities for a longer period of time is unclear. The minimum effective dose of weight bearing activity remains a controversy, as studies have shown bone mass increases from jumping for as little as 3 minutes per day (28). In our study, the most popular sports among white boys were soccer, cricket, tennis and swimming. White boys in the fourth quartile of activity were playing sport for approximately one and half hours per day.

Our study confirms our previous findings of lower PA levels in black children. Similar findings have been reported in developed countries such as the US where African American children were found to have the lowest levels of activity when compared with non-Hispanic white, Hispanic and Asian children (3, 29). We have shown that when physical activity levels are high and possibly above a threshold or "active" time period, significant bone mass effects are seen. This was evident for white males, where associations between PA and residualized bone mass at the whole body, hip and spine were observed. All white males that were in the highest quartile of activity showed residualized bone mass well above zero (the expected score for the weight and bone area of the child). White females had residualized bone mass above zero at all sites for bone area. It thus appears that these were the only group who had high enough levels of habitual physical activity, such that a positive and significant effect on bone mass at the whole body, hip and spine was seen. The lack of any effect of physical activity on radial bone mass adds support to the contention that it is a weight bearing effect of PA that induces the changes in bone mass. This study supports the hypothesis that mechanical loading during the growing year's impacts on bone mass and structural indices such as bone area.

Our data do not suggest that calcium has a synergistic effect with physical activity on bone as has been previously suggested (4, 5, 8). Calcium and METPA showed an interactive effect for white girls only. The current recommendation in the United States for calcium intake in Caucasian children is 1300mg/day (30). Based on this amount, none of our groups met the current recommendation with the mean intake of white children being about 56% and that for black children about 25% of the adequate intake for calcium. The possibility that calcium intakes were not high enough in any of the groups to induce a positive association with bone mass or a synergistic effect with physical activity must be considered. This study does raise an apparent paradox. Despite the low calcium intakes and low physical

activity levels of South African black children, they still have higher bone mass at the hip than white children and similar values to their white peers at other sites.

In summary we have demonstrated differences in habitual physical activity levels and calcium intakes between black and white South African children. An interactive effect of calcium and physical activity was not shown in our study. Additionally we have shown that residualized bone mass gain, which is a good indicator of weight and bone area matched BMC gain, is highest at all weight bearing sites in the most physically active children. The same trend was observed for weight and height matched BA gain, whereby BA gain was greatest at all weight bearing sites in the most active children. It thus appears that habitual physical activity above a certain level is related to both BMC and bone size (BA). Future research should examine whether the racial differences in BMC accumulation rates observed in our study would be exacerbated if physical activity levels in black children were increased to those of white males.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Gilsanz V, Roe TF, Mora S, Costin G, Goodman WG. Changes in vertebral bone density in black girls and white girls during childhood and puberty. *N Engl J Med.* 1991; 325:1597–1600. [PubMed: 1944449]
2. Haapasalo H, Kannus P, Sievänen H, Pasanen M, Uusi-Rasi K, Heinonen A, Oja P, Vuori I. Effect of long-term unilateral activity on bone mineral density of female junior tennis players. *J Bone Miner Res.* 1998; 13:310–319. [PubMed: 9495526]
3. McKay HA, Petit MA, Khan KM, Schutz RW. Lifestyle determinants of bone mineral: A comparison between prepubertal Asian and Caucasian Canadian Boys and Girls. *Calcified Tissue International.* 2000; 66:320–324. [PubMed: 10773099]
4. Iuliano-Burns S, Saxon L, Naughton G, Gibbons K, Bass S. Regional specificity of exercise and calcium during skeletal growth in girls: A randomized controlled trial. *J Bone Miner Res.* 2003; 18:156–162. [PubMed: 12510818]
5. Specker B, Binkley T. Randomized trial of physical activity and calcium supplementation on bone mineral content in 3- to 5-Year-old children. *J Bone Miner Res.* 2003; 18:885–892. [PubMed: 12733728]
6. Stear SJ, Prentice A, Jones SC, Cole TJ. Effect of a calcium and exercise intervention on the bone mineral status of 16-18-y-old adolescent girls. *Am J Clin Nutr.* 2003; 77:985–992. [PubMed: 12663301]
7. Binkley T, Specker B. Increased periosteal circumference remains present 12 months after an exercise intervention in preschool children. *Bone.* 2004; 35:1383–1388. [PubMed: 15589220]
8. Rowlands A, Ingledew DK, Powell SM, Eston RG. Interactive effects of habitual physical activity and calcium intake on bone density in boys and girls. *Journal of Applied Physiology.* 2004; 97:1203–1208. [PubMed: 15145926]
9. Linden C, Ahlborg H, Besjakov J, Gardsell P, Karlsson M. A school curriculum-based exercise program increases bone mineral accrual and bone size in prepubertal girls: Two-year data from the Pediatric Osteoporosis Prevention (POP) study. *J Bone Miner Res.* 2006; 21:829–835. [PubMed: 16753013]

10. Memon A, Pospula WM, Tantawy AY, Abdul-Ghafar S, Suresh A, Al-Rowith A. Incidence of hip fracture in Kuwait. *Int J Epidemiol*. 1998; 27:860–865. [PubMed: 9839744]
11. Schnitzler CM, Mesquita JM. Bone marrow composition and bone microarchitecture and turnover in blacks and whites. *J Bone Miner Res*. 1998; 13:1300–1307. [PubMed: 9718199]
12. Solomon L. Bone density in ageing Caucasian and African populations. *Lancet*. 1979; 2:1326–1330. [PubMed: 92673]
13. Fonn S, de Beer M, Kgamphe J. Birth to ten: Pilot Studies to test the feasibility of a birth cohort study investigating effects of urbanisation in South Africa. *S Afr Med J*. 1991; 79:449–454. [PubMed: 2020885]
14. Richter LM, Yach D, Cameron N, Greisel RD, de Wet T. Enrolment into Birth to Ten (BTT): Population and sample characteristics. *Paediatr Perinat Epidemiol*. 1995; 9:109–120. [PubMed: 7724410]
15. Richter LM, Norris SA, de Wet T. Transition from Birth to Ten to Twenty: the South African cohort reaches 12 years of age. *Journal of Paediatric and Perinatal Epidemiology*. 2004; 18:290–301.
16. Yach D, Cameron N, Padayachee G, Wagstaff L, Richter L, Fonn S. Birth to Ten: Child health in South Africa in the 1990's. Rationale and methods of a birth cohort study. *Paediatr Perinat Epidemiol*. 1991; 5:211–233. [PubMed: 2052483]
17. McVeigh JA, Norris SA, Cameron N, Pettifor JM. Associations between physical activity and bone mass in black and white South African children at age 9 yr. *J Appl Physiol*. 2004; 97:1006–1012. [PubMed: 15132999]
18. McVeigh JA, Norris SA, de Wet T. The relationship between socio-economic status and physical activity patterns in South African children. *Acta Paediatr*. 2004; 93:982–988. [PubMed: 15303817]
19. Tanner JM. Normal growth and techniques of growth assessment. *Clin Endocrinol Metab*. 1986; 15:411–451. [PubMed: 3533329]
20. Pate RR, Heath GW, Dowda M, Trost SG. Associations between physical activity and other health behaviours in a representative sample of US adolescents. *Am J Pub Health*. 1996; 86:1577–1581. [PubMed: 8916523]
21. Gorden-Larsen P, McMurray RG, Popkin BM. Adolescent physical activity and inactivity vary by ethnicity: The National Longitudinal Study of Adolescent Health. *J Pediatr*. 1999; 135:301–306. [PubMed: 10484793]
22. Ainsworth BE, Haskell WL, Leon AS, Jacobs DR, Montoye HJ, Sallis JF, Paffenbarger JR. Compendium of physical activities: Classification of energy costs of human physical activities. *Med Sci Sports Exerc*. 1993; 25:71–80. [PubMed: 8292105]
23. Groothausen J, Siemer H, Kemper H, Twisk J, Welten D. Influence of peak strain on lumbar bone mineral density: An analysis of 15-Year physical activity in young males and females. *Pediatric Exercise Science*. 1997; 9:159–173.
24. Fulkerson JA, Himes JHI, French SA, Jensen S, Petit MA, Stewart C, Story M, Ensrud K, Fillhouer S, Jacobsen K. Bone outcomes and technical measurement issues of bone health among children and adolescents: Considerations for nutrition and physical activity intervention trials. *Osteoporos Int*. 2004; 15:929–941. [PubMed: 15338113]
25. Prentice A, Parsons T, Cole T. Uncritical use of bone mineral density in absorptiometry may lead to size-related artifacts in the identification of bone mineral determinants. *Am J Clin Nutr*. 1994; 60:837–842. [PubMed: 7985621]
26. Rowlands AV, Ingledew DK, Powell SM, Eston RG. Interactive effects of habitual physical activity and calcium intake on bone density in boys and girls. *J Appl Physiol*. 2004; 97:1203–1208. [PubMed: 15145926]
27. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. *Research Quarterly Exercise and Sport*. 2000; 71:S59–73.
28. McKay HA, MacLean L, Petit M, MacKelvie-O'Brien K, Janssen P, Beck T, Khan KM. "Bounce at the Bell": a novel program of short bouts of exercise improves proximal femur bone mass in early pubertal children. *British Journal of Sports Medicine*. 2005; 39:521–526. [PubMed: 16046335]

29. Gordon-Larsen P, Adair L, Popkin B. Ethnic differences in physical activity and inactivity patterns and overweight status. *Obes Res.* 2002; 10:141–149. [PubMed: 11886936]
30. French SA, Fulkerson JA, Story M. Increasing weight-bearing physical activity and calcium intake for bone mass in children and adolescents: A review of intervention trials. *Prev Med.* 2000; 31:722–731. [PubMed: 11133340]

Fig 1. Residualized whole body BMC gain (WBBMC) within quartiles of METPA (panel A) and MECHPA (panel B) for black and white male and female subjects. * $p < 0.05$, quartile 4 > quartile 1 and 2 for white males.

Fig 2.

Residualized whole body area gain within quartiles of METPA (panel A) and MECHPA (panel B) for black and white male and female subjects. * $p < 0.05$, quartile 4 > quartile 1, 2 and 3 (METPA) and quartile 4 > quartile 1 and 2 (MECHPA) for white males. ** $p < 0.05$, quartile 4 > quartile 1 for white females.

Anthropometric, calcium intakes (age 10), physical activity data and unadjusted DXA data, showing % gain in height, weight, BA (BAGAIN) and BMC (BMCGAIN) between ages 9 and 10. Data shown as Means (SD)

Table 1

	White Male (n=31)	Black Male (n=141)	White Female (n=27)	Black Female (n=122)
Weight at 10y (kg)	35.12 (4.88)	32.82 (6.44)	34.06 (7.51)	34.30 (7.93)
Weight Gain (%)	12.20(4.55)	11.90(7.58)	13.80(4.82)	14.71(6.14)
Height at 10y (cm)	142.71(6.82) ^a	137.62 (6.08)	142.51 (7.27)	139.09 (6.23)
Height Gain (%)	4.02 (1.11)	3.61(1.34)	4.55(1.35)	4.49(2.03)
BMCGAIN- Whole body (%)	10.64 (3.93)	8.32 (6.63)	10.99 (4.56)	11.67(5.63)
BMCGAIN-Radius (%)	12.27 (7.02)	10.21 (9.91)	12.15 (9.15)	12.57 (8.75)
BMCGAIN-Hip (%)	13.26 (7.27)	10.61 (6.97)	16.51 (8.74)	13.89 (10.09)
BMCGAIN-Spine (%)	12.40(4.89) ^a	9.69(4.33)	15.31(6.81)	16.16(7.72)
BAGAIN- Whole body (%)	11.31 (4.62) ^a	8.85 (4.66)	12.42 (4.68)	12.03 (4.43)
BAGAIN-Radius (%)	14.46 (6.20)	12.62 (8.15)	14.91 (6.56)	14.14 (7.97)
BAGAIN-Hip (%)	9.72 (4.66)	7.68 (4.83)	6.72 (20.79)	9.65 (6.10)
BAGAIN-Spine (%)	7.91 (3.06)	6.06 (3.28)	8.58 (3.66)	9.60 (4.69)
Calcium Intake (24hr recall)-age 10 (mg/day)	711(606) ^a	331(238)	703(479) ^b	297(175)
Calcium Intake (FFQ)-age 10 (mg/day)	822(78) ^a	453(34)	885(94) ^b	494(27)
Pubertal Stage (Hair) at age 10yr (no in stage1/2)	17/14	94/47	20/7	70/52
Skeletal Age	10.33 (0.97)	10.18 (1.02)	10.36 (1.29)	10.33 (1.24)
METPA score (yr 10)	21.15 (5.43) ^a	14.61 (0.88)	13.67 (1.73)	11.27 (0.89)
MECHPA score (yr 10)	8.45 (1.52) ^a	2.37 (0.19)	3.93 (0.72)	1.89 (0.30)

^a white males > black male, p<0.001

^b white females>black females, p<0.001

Table 2

Gain in bone mass measurements between years 9 and 10

Bone mineral content (BMC) at age 10 adjusted for bone area (cm²) and body weight (kg).Bone Area (BA) adjusted for body weight (kg) and height (cm). Percentage gain in BMC (adjusted for body weight and bone area cm²) and percentage gain in BA (adjusted for body weight (kg) and BMC (g)) from age 9 to 10. Data shown as means (SE)

	White Male (n=31)	Black Male (n=141)	White Female (n=27)	Black Female (n=122)
WBBMC yr 10 (g)	1007.92 (9.51)	1015.43 (4.45)	987.27 (10.13)	987.38 (4.78)
Radius BMC yr 10 (g)	3.65 (0.05)	3.58 (0.02)	3.55 (0.06)	3.43 (0.03)
Hip BMC yr 10 (g)	14.79 (0.29)	16.01 (0.14) ^a	13.18 (0.32)	14.54 (0.14) ^c
Spine BMC yr 10 (g)	24.48 (0.47)	24.03 (0.22)	24.45 (0.50)	25.44 (0.24)
WBBA yr 10 (cm ²)	1234.00 (11.18)	1252.13 (5.16)	1201.57 (11.76)	1238.34 (5.49) ^c
Radius BA yr 10 (cm ²)	8.96 (0.15)	9.63 (0.07) ^a	8.44 (0.16)	9.07 (0.07) ^c
Hip BA yr 10 (cm ²)	21.30 (0.30)	21.15 (0.14)	22.25 (0.32) ^d	21.18 (0.15)
Spine BA yr 10 (cm ²)	44.15 (0.52)	44.08 (0.24)	41.56 (0.55)	43.04 (0.26)
BMCGAIN-Whole body (%)	10.16 (1.07)	8.19 (0.52)	10.70 (1.21)	11.34 (0.54)
BMCGAIN-Radius (%)	11.69 (1.56)	11.29 (0.75)	10.56 (1.76)	11.83 (0.79)
BMCGAIN-Hip (%)	10.03 (1.79)	8.09 (0.85)	14.83 (1.99)	11.03 (0.90)
BMCGAIN-Spine (%)	12.80 (1.18) ^b	9.18 (0.56)	15.12 (1.29)	15.51 (0.61)
BAGAIN-Whole body (%)	11.30 (0.84) ^b	8.92 (0.39)	12.61 (0.91)	11.92 (0.41)
BAGAIN-Radius (%)	13.83 (1.47)	12.87 (0.68)	14.49 (1.58)	14.11 (0.72)
BAGAIN-Hip (%)	9.31 (1.47)	7.82 (0.70)	6.37 (1.60)	9.68 (0.73)
BAGAIN-Spine (%)	7.60 (0.72)	6.16 (0.34)	8.26 (0.79)	9.65 (0.36)

^aBlack males > white males, p<0.05

^bWhite males > black males, p<0.05

^cBlack females> white females, p<0.05

^dWhite females > black females, p<0.05