South African Journal of Clinical Nutrition 2019; 32(4):99–106
https://doi.org/10.1080/16070658.2018.1487614

SAJCN
ISSN 1607-0658 EISSN 2221-1268

RESEARCH

Body composition and intake of nutrients associated with bone metabolism in young adolescents in a peri-urban setting

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Objective: The aim was to describe the anthropometry, bone mineral content (BMC), bone mineral density (BMD), dietary calcium intake and 25(OH)D_3 levels in 11- and 12-year-old children in a peri-urban area.
Design: A cross-sectional, descriptive study in the quantitative domain was undertaken.
Setting: Bronkhorstspruit, Gauteng, South Africa.
Subjects: Children, conveniently selected, were assessed in two groups. The first group comprised 70 children. From the 70 children, 20 children were conveniently selected to form a sub-sample ($n = 20$).
Outcome measures: Anthropometric data (weight, height) and dietary data (three quantified multi-pass 24-hour recalls). Children in the sub-sample additionally underwent body composition assessment (dual-energy X-ray absorptiometry; DXA scan) and a finger prick for 25(OH)D_3.
Results: BMI and body composition data (body fat mass and lean fat mass) showed that the girls exceeded the boys in all measurements. The girls had a non-significantly higher BMD and BMC than the boys. The mean and median values for 25(OH)D_3 were lower than the reference range values. Dietary intake results showed that the children had a sufficient macronutrient intake, but a deficient intake of calcium, phosphate and vitamin D. The sub-sample had a mean vitamin D intake of 3.2 mcg.
Conclusion: The girls exceeded the boys in all the anthropometric and body composition measurements. The calcium and vitamin D intake of the children were of concern. There were no significant differences or relationships in the bone measurements and vitamin D status between the boys and girls.

Keywords: body composition, bone mineral content, preadolescent children, vitamin D status

Introduction

Osteoporosis is defined as a systemic skeletal disorder or disease characterised by compromised bone strength and low bone mass that results in bone fragility and an increased risk of fracture.[1–3] Osteoporosis is a very common and debilitating disease that progresses with age. All osteoporotic fractures are associated with significant morbidity, and hip and vertebral fractures are also associated with mortality. Fractures associated with osteoporosis are responsible for 0.83% of the global burden of non-communicable diseases (NCDs).[2]

Adolescence, and the period prior to adolescence, is the critical period for bone accrual and the development of peak bone mass (PBM). It has been reported that 60% of the risk for osteoporosis can be explained by the amount of bone mineral laid down in the early years of life, and 60–90% of adult bone mass is acquired during the pubertal growth spurt.[4] To ensure adequate bone mineral density (BMD) and bone mineral content (BMC), adequate dietary intake of key nutrients involved in bone metabolism such as calcium, phosphate, iron, zinc, selenium, magnesium, vitamin D and other key nutrients, as well as sufficient physical activity levels, is of the essence. Studies have investigated relationships between body weight, BMI, BMC and BMD. Many studies suggest that body weight is positively related to bone density. This protective effect could be related to the mechanostat theory. Bones react to mechanical stimuli (muscle and fat) by increasing osteogenesis.[3–5]

Although underweight and associated malnutrition have been a concern for South Africans for many years, South Africa is currently undergoing a profound health transition characterised by a double burden of disease. Amidst all this is a distinct accompanying nutrition transition. Since this is a study concerning a resource-constrained area in Gauteng, it is important to note that the burden of non-communicable diseases (NCDs) is growing in rural communities with poor people in peri-urban areas being most affected.[6] In a study that had a specific look on how nutrition transition has affected the South African black population in particular, it was found that there has been a distinct change in the diet towards being less prudent, and higher in fat and total energy.[7] An increase in NCDs in black South Africans was also found.[7] There is thus a rising concern about the health of South African black children, pre-adolescents and adolescents in these areas. Nutritional intake and dietary patterns of childhood, pre-adolescents and adolescents lay the foundation for health status in adulthood. No data are available from the SANHANES-1 regarding NCD prevalence for children under 15 years of age[8]. However, for the total sample the SANHANES-1 ($n = 15\ 332$) examined the dietary risk factors for NCDs and showed that 18.3% and 19.7% of the total national population had high fat intake and high sugar intake respectively. Specifically, high fat intake and high sugar intake for rural informal areas were 11.3% and 14.7%, and 9.8% and 11.7% for rural formal areas. In a recent study, comparing adolescent food frequency intake and socioeconomic status in urban

Reference value (IOM): 32–100 ng/ML[13].

and peri-urban schools in KwaZulu-Natal, it was found that a low socioeconomic status was associated with a high frequency of energy-dense, micronutrient-poor food intake.[9] Furthermore, it was found that adolescent eating habits in both areas were generally poor, with low dietary diversity, all of which may have implications for their future health, including their bone health.

The aim of this study was to assess and describe the anthropometric status, body composition, 25-Hydroxyvitamin D_3 (25 $(OH)D_3$) levels and dietary intake of specific nutrients associated with bone metabolism in 11- and 12-year-old children in a peri-urban setting.

Methods

Study population and sampling

A cross-sectional, descriptive study in the quantitative domain was executed. The study protocol was approved by the Health Sciences Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria (UP) (Ref No: 178/2013). The study was also approved by the Gauteng Department of Basic Education. The pre-adolescent population (150 grade 6 learners) (11 or 12 years old) from which the sample was obtained was recruited from a primary school in Bronkhorstspruit, which is a peri-urban area. The study group consisted of two samples. The first study group comprised 70 conveniently selected children, while a second group of children was conveniently selected from that group to form a sub-sample of 20 children. The children's parents or guardians had given signed informed consent for them to participate in the study and the children signed informed assent.

Inclusion criteria included healthy 11- or 12-year-old black children (boys and girls), and English literacy. Children of parents or guardians who had not given consent were excluded.

Data collection

Anthropometry

Measurements, including weight (kg), height (cm) and skinfolds (mm) (triceps, calf and abdominal) (not reported here), were obtained for the study sample ($n = 70$ children) by trained physiologists from the Department of Physiology (UP) according to standard procedures.[10] The height was measured with a Seca 21 Height Measure scale (Seca GmbH, Germany) and the weight was taken using the Seca 813 electronic flat scale. Weight and height for the sub-sample ($n = 20$) were obtained by the principal investigator (in the clinical setting at a tertiary hospital) according to standard procedures,[10] before performing the DXA scans, using a SECA height metre (analogue). The weight was measured according to standard procedures by using a Micro PF-1 digital scale (Scalerite, South Africa).[10]

Whole-body composition assessment

Whole-body composition was assessed for the sub-sample ($n = 20$) using DXA (Hologic Discovery A densitometer) (Hologic, Madison WI, USA) at a tertiary training hospital by a radiographer. The measurements were obtained with standard positioning techniques and were analysed to produce BMD (g/cm^2), BMC (g), fat mass (g), lean mass (g), lean mass + BMC (g), total mass (g) and fat (%) for each region in the body without the head, as well as the *z*-score using the age-related reference value. A daily quality control scan was taken to ensure that precision met the required coefficient of variance. The coefficient of variance for BMD was between 0.365% and 0.502%. The coefficient for BMC was 0.571%.

Dietary assessment

Trained interviewers collected data on dietary intake by means of three quantified 24-hour recalls, using the multiple-pass method and portion size estimation aids, over three consecutive days of which one was a weekend day.[10] Those participants who were not able to complete the interview fluently in English were allocated to an interviewer who could speak the home language of the participant. The interviews were conducted at their school during a time slot allocated by the school principal during the month of March.

Blood 25(OH)D_3 assessment

$25(OH)D_3$ levels were measured for the sub-sample ($n = 20$) by collecting a drop of blood from the finger onto blood spot cards using the OneTouch® lancing device (LifeScan Inc, Milpitas, CA, USA). The spot cards were dried, sealed, labelled with the participant number and sent to ZRT laboratories (Beaverton, OR, USA) for analysis. After the blood was collected a 3 mm disk (containing 3 µl whole blood) was punched from each of the dried blood spots into glass tubes. The $25(OH)D_2$ and 25 $(OH)D_3$ concentrations were determined according to the methodology of Newman *et al.* by ZRT laboratories (Beaverton, OR, USA).[11] The level of detection using this method is 1 nmol/l. The results were captured in ng/ml. The reference values recommended by the Institute of Medicine were used.[12]

Data analyses

Data were tested for normality by using the Kolmogorov–Smirnov test. MedCalc statistical software version 12.7.7 (www.medcalc.org) was used for statistical analysis. Descriptive statistics were performed for all the measurements. The Mann–Whitney test was used for independent variables and the Pearson test for correlations. For partial correlations performed, the log transformation was used for data that were not normally distributed.

Dietary data were analysed with the Medical Research Council Nutrient Analysis Software programme (Food Finder 3; http://safoods.mrc.ac.za/). The Mean Adequacy Ratio (MAR) for the total sample, and for boys and girls was separately calculated for means of comparison between genders. The Nutrient Adequacy Ratio (NAR) was calculated for selected micronutrients against 100% RDA for the total sample, and for boys and girls separately. For the sub-sample ($n = 20$) mean macro- and micronutrient intakes were reported separately.

Results

Sample description

The study group as a whole consisted of 70 children, of whom only 56 children had complete anthropometric data (the correct decimal age for 14 children was not recorded and thus they were excluded from the analysis). Of the 56 children, 34 (60.7%) were girls. The sub-sample ($n = 20$) comprised 14 girls (70%). The mean age was 11.6 years (SD = 0.51) for girls and 11.5 years (SD = 0.55) for boys, but the difference was not statistically significant ($p = 0.65$).

Anthropometry

The anthropometric data were normally distributed for the sample as a whole ($n = 56$) for weight ($p = 0.79$), but not for height ($p = 0.00$) and BMI ($p = 0.02$). The girls had a higher mean BMI (18.1 kg/m^2) (median: 17.9 kg/m^2) than the boys (16.6 kg/m^2) (median: 16.8 kg/m^2), which was not statistically significant ($p = 0.06$). The mean BMI for girls and boys between

Table 1: Anthropometric assessment for boys and girls ($n = 56$)

Item	Mean	95% CI	SD	Median	95% CI	Min	Max	(25%) (75%)	Normality distribution
Girls ($n = 34$):									
Weight (kg)	37.7	34.8–0.6	8.3	37.1	33.8–40.1	22.5	64.6	(33.5) (41)	$p = 0.0076$
Height (cm)	143.6	140.9–6.3	7.6	144.5	141.2–146.5	125.0	160.1	(140.1) (148.1)	$p = 0.7111$
BMI (kg/m^2)	18.1	17.2–19.0	2.7	17.9	16.7–18.4	13.1	25.2	(16.2) (19.2)	$p = 0.1197$
Boys ($n = 22$):									
Weight (kg)	34.7	32.2–37.1	5.5	32.6	30.2–38.5	26.9	46.0	(30.2) (38.9)	$p = 0.3398$
Height (cm)	144.5	140.3–148.7	9.5	144.0	138.4–148.2	131.0	163.5	(138.4) (149.5)	$p = 0.6819$
BMI (kg/m^2)	16.6	15.7–17.4	1.9	16.8	16.0–17.5	10.7	19.2	(15.7) (18.0)	$p = 0.0013$

the 50th and 75th percentiles, and for the boys between the 10th and 25th percentiles (gender specific BMI for age).[13] Only 17 (50%) of the girls ($n = 34$) and six (27%) of the boys ($n = 22$) had a BMI above 18 kg/m^2 (Table 1).

Data were normally distributed for the sub-sample ($n = 20$) for height ($p = 0.80$) and BMI ($p = 0.06$), but not for weight ($p = 0.03$). The girls had a mean BMI (18.7 kg/m^2) (median: 17.9 kg/m^2) that was higher than for the boys (16.5 kg/m^2) (median16.1 kg/m^2), and this was statistically significant ($p = 0.05$) (Table 2).

*Body composition of the subgroup (DXA) (*n *= 20)*

Data for the sub-sample ($n = 20$) were normally distributed for fat ($p = 0.22$) and % fat ($p = 0.54$), but not for lean mass ($p = 0.02$). The girls had a higher mean fat mass (12581.3 g), % fat (32.5%), and lean mass (24343.2 g). The measurements for boys were 8123.4 g, 25.5% and 22080.1 g respectively. Of these measurements, % fat ($p = 0.02$), and fat mass ($p = 0.01$) were statistically significant between the boys and girls (Table 3).

Bone measurements

Data for the sub-sample ($n = 20$) were not normally distributed (BMD [$p = 0.02$], BMC [$p = 0.01$] and *z*-score [$p = 0.00$]). The girls had a mean BMC of 1030.9 g/cm^2 ($p = 0.10$), BMD of 0.8 g/cm^2 ($p = 0.08$), and *z*-score of −1.5 ($p = 0.77$) compared with the boys who had values of 857.4 g/cm^2, 0.7 g/cm^2 and −1.5 respectively. None of these results were statistically significantly different (Table 4). Only two children in the sub-sample reported having had a bone fracture previously.

Dietary nutrient intake

Food items that were consumed on three out of the three days of the recall period were bread (77%), maize meal (53%), chicken (30%), potato/maize crisps (28%), rice (26%), polony (15%), beef (10%), tomato (10%), apple (8%) and potato (7%). Milk was the primary calcium-rich food item consumed by the participants. Tomatoes, apples, bananas, cabbage, carrots and beetroot were the most commonly consumed fruits and vegetables. For the total sample, the median NAR was 1.07 for energy (107% of RDA) and 1.7 for protein (Table 5). The NAR for selected minerals is summarised in Table 6. The median NAR for the sample ($n = 65$) for calcium intake was 0.32, for phosphorus 0.72, for iron 1.09, for zinc 0.90, 1.06 for magnesium and 0.90 for vitamin C. Nutrients that had a median NAR for the total sample of at least 0.77 or more were energy, protein, iron, zinc, selenium, chromium, manganese, thiamine, riboflavin, niacin, vitamin B6, vitamin B12, vitamin C, biotin, and pantothenate. The median NAR for the total sample for vitamin D was 0.15; for boys and girls in the total sample it was 0.16 and 0.14 respectively. Data for the MAR for the total sample were not normally distributed ($p = 0.00$). The median MAR was 1.10, and 1.15 and 0.95 for the boys and girls, respectively. The Mann–Whitney test showed no significant difference in the MAR between genders ($p = 0.05$).

The mean and median calcium intake in the sub-sample for boys and girls was 628.9 mg/day and 563.5 respectively (NAR = 0.48). The mean and median vitamin D intake in the sub-sample for boys and girls was 3.2 mg/day and 3.0 respectively (NAR = 0.21). Table 7 summarises the nutrient intakes of the sub-sample ($n = 20$) and for boys and girls respectively, which were generally higher than that of the sample ($n = 56$) as a whole.

Blood 25(OH)D_3 levels

The data distribution was not normal ($p = 0.04$), therefore log transformation was used in the correlation analysis. The boys had a higher mean 25(OH)D_3 level (24.33 mg/ml) than the girls (23.62 ng/ml), but this was not statistically significant ($p = 0.97$) (Table 8). The levels (mean and median) were lower than the reference range when considering the Institute of Medicine recommendations.[12]

Correlations

25(OH)D_3 was partially correlated with BMD with head ($p = 0.50$) and without head ($p = 0.50$), as well as with BMC with head ($p =$

Table 2: Anthropometric assessment for the sub-sample ($n = 20$)

Item	Mean	95% CI	SD	Median	95% CI	Min	Max	(25%) (75%)	Normality distribution
Girls ($n = 14$):									
Weight (kg)	42.0	37.4–46.9	8.2	39.4	35.9–45.7	33.9	62.8	(36.0) (45.6)	$P = 0.0245$
Height (cm)	149.7	145.5–153.8	7.2	150.5	144.8–153.4	138	161.5	(145.0) (153.0)	$P = 0.9327$
BMI (kg/m^2)	18.7	17.2–20.2	2.5	17.9	16.5–20.1	15.6	24.5	(16.5) (19.9)	$P = 0.2164$
Boys ($n = 6$)L									
Weight (kg)	35.0	28.3–41.7	6.4	34.3	28.1–42.8	27.7	43.3	(29.9) (40.6)	
Height (cm)	145.2	135.4–154.9	9.3	146.4	133.1–156.2	132	157.5	(137.7) (151)0	
BMI (kg/m^2)	16.5	14.8–18.2	1.6	16.1	15.1–18.9	14.9	19.5	(15.8) (16.5)	

Table 3: Body composition assessment of the sub-sample ($n = 20$)

Item	Mean	95% CI	SD	Median	95% CI	Min	Max	(25%) (75%)	Normality distribution
Girls ($n = 14$):									
% Body fat	32.5*	29.2–35.8	5.7	33.2	27.9–35.7	23.6	42.7	(28.0) (35.7)	$P = 0.8191$
Fat (g)	12581.3#	10105.9–15056.7	4287.2	11043.3	8844.0–15035.5	7739.9	20783.5	(8845.6) (14769.5)	$P = 0.2678$
Lean mass (g)	24343.2	22007.3–26679.0	4045.6	23449.8	21556.2–26736.8	18873.1	35054.2	(21577.7) (26733.1)	$P = 0.0108$*
Total mass (g)	37955.3	33490.3–42420.3	7733.1675	35448.9	31957.0–41491.7	29869.3	57086.2	(31995.8) (41363.1)	$P = 0.0388$*
Boys ($n = 6$):									
% Body fat	25.5*	19.4–31.6	5.8	23.9	20.7–34.5	20.1	36.8	(23.3) (24.9)	
Fat (g)	8123.4#	4539.1–11707.6	3415.4	7408.7	5444.9–13341.0	5431.2	14512.7	(5501.9(8477.0)	
Lean mass (g)	22080.1	18188.3–25971.9	3708.5	22402.6	17612.3–26494.3	17315.6	26961.7	(18844.1) (24554.1)	
Total mass (g)	31060.9	24291.9–37829.8	6450.2	30501.1	23972.8–38862.1	23488.9	39443.3	(25981.7) (36449.3)	
Boys and girls ($n = 20$):									
% Body fat	30.4	27.4–33.5	6.5	29.4	25.1–34.9	20.1	42.7	24.7–35.4	$P = 0.5350$
Fat (g)	11243.9	9148.0–13338.9	4476.5	10320.3	8505.3–13024.3	5431.2	20783.5	8471.4–13770.7	$P = 0.2234$
Lean mass (g)	23664.2	21795.1–25533.3	3993.7	23449.8	21406.4–25353.5	17315.6	35054.2	21062.9–26124.9	$P = 0.0246$***
Total mass (g)	35887.0	32190.8–39583.2	7897.6	33885.5	31686.8–39306	23488.9	57086.2	31471.8–40295.4	$P = 0.0556$

*Significantly different between the boys and girls at $p < 0.05$.

Table 4: Bone measurements of the children in sub-sample ($n = 20$)

Item	Mean	SD	Median	Min	Max	(25%) (75%)	Normality distribution
Girls ($n = 14$):							
BMC (g)	1030.9	215.4	952.1	762.6	1586.3	(908.9) (1176.4)	$p = 0.0172$*
BMD (g/cm^2)	0.8	0.1	0.8	0.7	0.9	0.7–0.9	$p = 0.2413$
Z–score	−1.5	0.8	−1.75	−2.4	0.9	(−1.9)–(−1.1)	$p = 0.0003$*
Boys ($n = 6$):							
BMC (g)	857.4	136.9	832.9	671.3	1013.8	(782.9) (1010.60)	
BMD (g/cm2)	0.7	0.1	0.7	0.7	0.8	(0.7) (0.8)	
Z-score	−1.5	0.7	−1.6	−2.0	−0.2.0	(−2.0) (−1.3)	
Boys and girls ($n = 20$)							
BMD (g/cm^2)	0.8	0.1	0.8	0.7	0.9	(0.7) (0.8)	$p = 0.1084$
BMC (g)	978.8	208.2	932.2	671.3	1586.3	(857.8) (1045.3)	$p = 0.0003$*
Z-score WIOH	−1.5	0.8.0	−1.75	−2.4	0.9	(−1.9)–(−1.2)	$p = 0.0053$*

BMD: bone mineral density.
BMC: bone mineral content.

0.40) and without head ($p = 0.91$). No positive correlations were found between calcium intake with BMC with head ($p = 0.16$) and without head ($p = 0.07$), as well as with BMD with head ($p = 0.38$) and without head ($p = 0.14$). The correlations adjusted for height were compared with the same correlations not adjusted for height (normal correlation) and there were no significant differences.

Discussion

In general, it appeared that the children did not suffer from any overt acute or chronic nutritional deprivation. The mean and median BMI for girls was higher than that for boys. In the study group as a whole the mean BMI for girls fell between the 50th and the 75th percentiles, and that for boys between the 10th and 25th percentiles.[13] The BMI for girls varied between 13.1 and 25.2 kg/m^2, and that for boys between 10.7 and 19.2 kg/m^2. Overnutrition among the girls in the longer run is possibly of greater concern for this group as opposed to undernutrition.

The median energy NAR for the total sample ($n = 56$) was 1.07. Thus the energy intake of the total sample was adequate and well within normal acceptable limits. The girls had a distinctly higher energy intake than the boys with the girls consuming 126% of the RDA (median NAR = 1.26). This is reflected in the relatively higher median weight among the girls (37.1 kg vs. 32.6 kg for boys). The median NAR for protein intake for the total sample, girls and boys, was 1.7, 1.8 and 1.65 respectively (Table 5), showing that the protein intake per se was above the RDA.

The poor intake of dairy products was reflected in the nutrient analysis of the 24-hour recalls. The median calcium NAR for the total sample, girls and boys, was 0.32, 0.32 and 0.33 respectively (Table 6), showing that calcium intake was only one-third of the RDA. For the sub-sample ($n = 20$), the mean calcium intake was 628.9 mg (48% of the RDA). This is similar to the results found at national level (1999 NFCS)[14] where one in two, and three in four children had a calcium intake less than 50% and less than 67% of the RDA respectively. Low intake of calcium is of major concern since calcium is needed for healthy bone development. Adolescence is a critical period for building bone mass, as 90% of peak bone mass is acquired by age 18 years.[15] Calcium intake during the teenage years could profoundly impact on peak bone mass later in life and hence the risk for osteoporosis. Phosphate intake was also low, reaching only 72% of the RDA for the total sample, 76% of the RDA for girls and 68% of the RDA for boys. For the sub-sample the mean phosphorus intake was 1222.0 mg (97% of the RDA). The intake of vitamin D was exceptionally poor as the intake was only 20% of the RDA for the total sample (Table 6), and for girls and boys the intake was 19% and 22% of the RDA respectively. For the subsample ($n = 20$) the vitamin D intake was 21% of the RDA. However, the blood 25(OH)D_3 levels were just below the normal ranges, which could probably be explained by the participants' exposure to sunlight at home during the daytime, on their way walking to school, and at school where outside activities were evident.

The body composition of the sub-sample, using DXA, showed a mean of 30.4% body fat for the group with the girls having a significantly higher percentage of fat than the boys. According to McCarthy *et al*., the 50th percentile for percentage fat in 12-year-old girls is 23.5% and 17.4% for 12-year-old boys, as measured in their cohort of 1985 Caucasian children.[16] However, their measurement was done by bio-impedance, which could have underestimated percentage fat. Sopher *et al*. compared the measurement of body fat using DXA versus the four-compartment model in a group of 411 children (mean age 12 years) from mixed ethnicities and concluded that there was a significant difference between the values reported from the DXA measurement versus the four-compartment method, with the latter being lower.[17] They reported a mean body fat percentage of 28% in the girls versus 18.8% for the boys.

The mean BMC for the sub-sample ($n = 20$) was within the ranges published by Meiring *et al*. for black children, mean age nine years.[18] They reported an average whole-body BMC of 754 g, while our values ranged between 1030 g for the girls and 857 g for the boys. Zemel *et al*. reported paediatric reference curves for BMC and areal BMD according to age and gender for black and non-black children.[19] Compared with their data, the girls from the sub-sample fell exactly at the 50th percentile (1065 g) and the boys closer to the 10th percentile (842 g).

In this study the girls had higher BMD, BMC, total body fat mass (FM) and lean fat mass compared with the boys. The higher mineral density and mineral content could be explained by the protective effect of body fat related to the mechanostat theory whereby bones react to mechanical stimuli (muscle and fat) by increasing osteogenesis. The complex interaction

Table 5: Nutrient adequacy ratio for macronutrients ($n = 56$)

Item	Total sample ($n = 65$)						Girls ($n = 38$)						Boys ($n = 27$)					
	Mean	95% CI	SD	Median	95% CI	25–75 P	Mean	95% CI	SD	Median	95% CI	25–75 P	Mean	95% CI	SD	Median	95% CI	25–75 P
NAR Energy	1.131	1.046–1.216	0.342	1.073	0.989–1.184	0.890–1.316	1.245	1.136–1.354	0.332	1.258	1.050–1.322	1.004–1.397	0.97	0.855–1.086	0.292	0.904	0.844–1.074	0.805–1.088
NAR Protein	1.779	1.647–1.910	0.5309	1.73	1.600–1.813	1.437–1.918	1.846	1.655–2.036	0.579	1.8	1.653–1.865	1.432–2.023	1.684	1.507–1.862	0.4482	1.648	1.471–1.812	1.459–1.857

NAR = nutrient adequacy ratio; CI = confidence interval; SD = standard deviation.

Table 6: Nutrient adequacy ratio for minerals and vitamins ($n = 56$)

Nutrient	Total sample ($n = 65$)						Girls ($n = 38$)						Boys ($n = 27$)					
	Mean	95% CI	SD	Median	95% CI	25–75 P	Mean	95% CI	SD	Median	95% CI	25–75 P	Mean	95% CI	SD	Median	95% CI	25–75 P
Calcium	0.343	0.304–0.382	0.158	0.32	0.270–0.385	0.217–0.410	0.346	0.287–0.405	0.1801	0.32	0.246–0.395	0.207–0.410	0.339	0.291–0.388	0.1235	0.333	0.255–0.387	0.224–0.403
Iron	1.119	1.027–1.211	0.3721	1.087	0.972–1.166	0.853–1.344	1.16	1.021–1.300	0.4241	1.094	1.000–1.305	0.867–1.357	1.061	0.950–1.172	0.2806	1.017	0.890–1.252	0.843–1.290
Zinc	0.977	0.894–1.060	0.3343	0.903	0.852–1.020	0.764–1.130	1.025	0.899–1.150	0.3831	0.967	0.855–1.105	0.703–1.163	0.91	0.814–1.005	0.2412	0.867	0.825–0.998	0.811–1.065
Selenium*	0.964	0.853–1.075	0.4485	0.888	0.760–1.105	0.625–1.293	0.957	0.798–1.117	0.4845	0.805	0.647–1.233	0.538–1.390	0.974	0.815–1.133	0.4011	0.947	0.840–1.144	0.729–1.234
Magnesium*	1.082	1.001–1.164	0.3293	1.064	0.968–1.154	0.820–1.303	1.155	1.047–1.262	0.3269	1.119	0.971–1.291	0.830–1.377	0.98	0.857–1.103	0.3102	1.007	0.830–1.125	0.739–1.172
Phosphate	0.739	0.687–0.791	0.2108	0.722	0.632–0.772	0.595–0.834	0.768	0.693–0.843	0.2273	0.763	0.616–0.828	0.580–0.881	0.698	0.626–0.770	0.1814	0.677	0.625–0.728	0.613–0.788
Vitamin C	1.433	0.785–2.082	2.6167	0.903	0.731–1.117	0.477–1.643	1.71	0.617–2.803	3.3249	0.919	0.832–1.342	0.681–1.630	1.044	0.678–1.409	0.9234	0.726	0.332–1.086	0.281–1.661
Vitamin D	0.204	0.167–0.241	0.1492	0.148	0.129–0.182	0.114–0.238	0.192	0.145–0.239	0.1436	0.144	0.122–0.187	0.109–0.210	0.221	0.158–0.283	0.158	0.155	0.128–0.236	0.117–0.322

*Data normally distributed for total sample.

Table 7: Nutrient intake from 24-hour recalls in sub-sample ($n = 20$)

Nutrient	RDA Boys/Girls (9–13 years)	Girls ($n = 14$)		Boys ($n = 6$)		Boys and girls ($n = 20$)	
		Mean	Median	Mean	Median	Mean	Median
Protein (g)		74.9	72.9	51.1	67.2	73.9	71.2
Ca (mg)	1300	679.0	613.0	543.0	479.0	628.9	563.5
Fe (mg)	8	12.3	10.4	15.2	10.0	10.5	10.3
Zn(mg)	8	10.0	9.1	9.3	8.0	9.8	8.8
Se (mcg)	40	47.4	43.3	35.6	36.2	44.0	41.2
Na (mg)	1500	1960.0	1859.9	2553.6	2315.3	2621.8	3189
Mg (mg)	240	331.9	322.5	320.3	301.2	328.4	317.8
P (mg)	1251	1236.1	1216.2	1189.3	1109.3	1222.0	1184.0
Vitamin C (mg)	45	189.8	149.7	198.3	58.3	159.7	122.3
Vitamin D (mcg)	15	2.6	2.0	4.7	5.4	3.2	3.0

between fat and bone, related to the hormones and adipokines involved, and the fact that adipocytes and osteoblasts both come from the same progenitor (mesenchymal stem cell), also plays a significant role.[20,21]

Clark found a strong positive relationship between total body FM and bone mass and area (total body without head) even after they adjusted for height and/or lean mass in pre-pubertal children, aged nine years. There was also a positive association between the total body FM and bone mass in girls in Tanner stage 1 girls, but not for girls in Tanner stage 2 or 3.[22]

A meta-analysis published in 2013 reported on studies from 1989 to 2013, including males and females aged 18–92 years.[23] They found that lean mass had a greater effect on femoral neck BMD in males than in females. In premenopausal women, the effect of lean body mass (LBM) was greater than the effect of FM on BMD. In postmenopausal women, however, the effects of LBM and FM on BMD were comparable.[23] It seems as if the protective effect of FM diminishes with age. This could possibly be another explanation for the results in this study. The girls had a significantly higher FM than the boys, but also a higher LBM, which could explain the higher BMD and BMC. This study did not determine the relationship between the anthropometric measurements and LBM, FM, BMC and BMD.

Zhao *et al*. investigated the relationship between FM, LBM, BMD and BMC. They found that FM was genetically, environmentally and phenotypically inversely related with bone mass when the mechanical loading of body weight on bone mass was controlled for. Therefore, they suggested that body FM does not have protective effects on bone mass, and that genetic and environmental factors could have beneficial effects on obesity and osteoporosis.[24]

In 2008, El Hage *et al*. investigated the importance of LBM and FM on BMD in a group of adolescent girls and boys.[25] They measured BMD with DXA and found that in boys LBM was positively related to whole-body BMD while FM was negatively related. In the girls, both FM and LBM were associated with BMD. This could also relate to the findings in this study reported here as the boys had a lower lean and fat mass than the girls. Using multiple regression analysis, they found that FM was a better positive determinant of BMD in girls than LBM, and was a negative determinant in boys. George *et al*. showed that LBM and FM influence BMD across races.[26] They investigated body fat and LBM and BMD in black and Asian Indian participants aged 18–65 years in South Africa. They showed that BMD is significantly higher in all sites measured in black Africans as compared with Asian Indians. Furthermore, they showed that LBM was significantly associated with BMD in both ethnic groups.[26]

In summary, the literature indicates that total body weight is related to a higher BMD. However, the fat percentage is negatively related to BMD,[23–26] therefore LBM has a positive effect on BMD, whereas FM does not have a similar effect. Thus, one needs to consider body composition as opposed to considering only BMI in relation to bone density. It is clear that fat plays an important role in bone density, but excessive FM negatively influences the bones. Many factors contribute to the differences in results of studies, including age, gender, FM, LBM, sample size, study design and statistical analysis, as well as the many confounding factors that should be considered during puberty.

Table 8: $25(OH)D_3$ levels for the sub-sample ($n = 20$)

Item	Mean (SD)	Median	(Min) (Max)	(25%) (75%)
Girls ($n = 14$)				
$25(OH)D_3$ (ng/mL)	23.6(5.6)	23.0	(17.0) (39.0)	(22.5) (24.5)
Boys ($n = 6$)				
$25(OH)D_3$ (ng/mL)	24.3(5.7)	23.0	(18.0) (33.0)	(21.0) (29.0)
Girls and boys ($n = 20$)				
$25(OH)D_3$ (ng/mL)	23.8 (5.5)	23.0	(17.0) (39.0)	(20.0) (39.0)

Conclusion

The body composition of the sub-sample indicated a mean of 30.4% body fat for the group, with the girls having a significantly higher fat percentage than the boys. The girls also had a significantly higher BMI and FM than the boys, and also higher LBM. The higher fat mass could explain the higher, though not statistically significant, BMD and BMC in the girls in this study. The girls (sub-sample $n = 20$) fell exactly at the 50th percentile and the boys closer to the 10th percentile according to the paediatric reference curves for BMC and areal BMD. However, one needs to consider body composition as opposed to only considering BMI in relation to bone density. There were no significant differences or relationships in the bone measurements and vitamin D status between the boys and girls. The $25(OH)D_3$ levels were just below normal ranges. No correlations were found between calcium intake, BMC and BMD.

The dietary intake of the children from this peri-urban area resembled a Westernised dietary pattern (high in energy and macronutrients), which increases the risk of overweight and obesity in later life. Even though the macronutrient intake of the children was sufficient (and even on the high side), the intake of some micronutrients was deficient. Nutrients that support bone health (calcium, phosphorous and vitamin D) were lacking in their diets, and interventions should focus on awareness and increasing the dietary intake thereof.

Disclosure statement – The authors declare that there are no conflicts of interest.

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Received: 05-09-2017 Accepted: 08-06-2018