

BONE MINERAL DENSITY ASSOCIATED WITH PHYSICAL TRAITS AND LIFESTYLE IN ADOLESCENTS



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ABSTRACT

Introduction: Just a few studies have evaluated physical traits, lifestyle and bone mineral density (BMD) acquisition in Brazilian female adolescents. **Objective:** To identify physical traits and lifestyle factors related to BMD in Brazilian female adolescents. **Methods:** 329 healthy adolescent girls aged between 10 and 20 years participated in this study. The physical characteristics evaluated were: body weight, stature, body mass index, pubertal stage, self-declared ethnicity and skin color. Concerning lifestyle, the following factors were evaluated: socioeconomic status (SES), physical activity level (PAL) and daily calcium intake. Additionally, total body, lumbar spine and femoral neck bone mineral density (BMD) was assessed by bone densitometry. Pearson's coefficient of correlation (r) and stepwise regression analysis were employed to check dependent and independent variables correlation ($p \leq 0.05$). **Results:** Total body, lumbar spine and femoral neck BMD increase as body weight, height, BMI, age and pubertal stage increase ($r \geq 0.43$; $p < 0.01$). On the other hand, only SES ($r = 0.14$; $p < 0.05$) and PAL ($r = 0.12$; $p < 0.05$) were correlated. After stepwise regression, body weight, pubertal stage, age, height, calcium intake, SES, and PAL explained around 48-68% for BMD variation in female adolescents. **Conclusion:** The results suggest body weight, age and pubertal stage should be used as control variables for BMD variations in female adolescents. Furthermore, SES, PAL and daily calcium intake were less important than physical traits for BMD during adolescence.

Keywords: bone mineral density, adolescents, body weight, puberty.

INTRODUCTION

The quantity of bone mineral density (BMD) acquired during childhood and adolescence may be crucial in reducing the risk of osteoporosis in the future¹. This fact is related to the peak of bone mass, which can be reached in the end of adolescence, and the femoral neck bone BMD may reach its peak before the other bone sites^{1,2}. Therefore, the identification of the mechanisms which optimize BMD gain during adolescence may be the best response for osteoporosis prevention.

Thus, according to Jouanny *et al.*³, heredity may estimate between 60 and 80% of BMD and the remaining of this variation is influenced by physical traits and factors related to lifestyle. Many studies have supported the participation of the factors related to lifestyle and physical traits^{1,2,4-11}. Among the physical traits which directly influence on the acquisition of bone mass we can mention factors related to puberty¹, race^{1,6} and body mass, while among the factors related to lifestyle are the physical activity levels (PAL), calcium intake and socioeconomic status (SES).

However, the amount of contribution of the physical traits and lifestyle on the gain of BMD may vary according to the studied population. In Brazil, there are still few studies which present relevant data about these factors related to physical traits or lifestyle and BMD of female adolescents¹²⁻¹⁴. Moreover, no study which considers phenotype characteristics of race and/or skin color and BMD in the Brazilian population has been found. Thus, the aim of this study was to identify and verify the contribution of the physical traits and lifestyle related to BMD of female adolescents.

METHODOLOGY

Sample

The population considered for this study includes pairs of sisters, and at least one of them should study in the public educational system of Brasília – Federal District. These adolescents were firstly recruited to participate in a broader study which analyzed the chromosome connection of the 1q and 11q regions with the BMD in pairs of sisters. Thus, the convenience sample comprised 329 girls aged between 10 and 20 years. The inclusion criteria adopted in the sample selection were: absence of chronic-degenerative disease; negative history of diseases or use of medication which affected bone development; and absence immobilization of any body segment for a long period in the year previous to the research.

Moreover, for sample characterization, all of the adolescents answered some questions about regular consumption of cigarettes and/or alcohol and use of oral contraceptives. The participants and their parents/legal tutors (for the ones with age below 18 years) filled out and signed a Free and Clarified Consent Form before the participation in the study. The study was approved by the Ethics in Research Committee of the Catholic University of Brasília (CEP/UCB # 078/2006), according to Resolution 196/96 from CONEP.

Anthropometry and sexual maturation

Body weight and stature were evaluated according to standard procedures. Stature was measured with a wall-mounted Seca stadiometer with resolution of 0.1 cm, and body weight was measured

on a Plena digital scale with resolution of 100g. Body mass index (BMI) was obtained with the formula: body mass (kg) ÷ height² (m). The sexual maturation level was determined by self-evaluation of pubic hair as described by Tanner¹⁵.

Skin color self-determination and measurement of skin color

Ethnicity was classified by self-evaluation, according to the skin color or race classification system adopted by the home research of the Brazilian Institute of Geography and Statistics (IBGE) – white, black, mulatto/mixed, yellow or native. Additionally, skin color was measured by a hand refractometer. This device emits two light beams, one blue and one green, and measures the quantity of light reflected, pointing hence number values for skin color.

Lifestyle factors

Questionnaires

Physical activity level (PAL) was measured by the short Portuguese version of the International Physical Activity Questionnaire (IPAQ). Estimation of daily calcium intake was based on food record of one day. Calcium consumption analysis was performed with the nutritional software Diet pro, version 5.1i.

The socioeconomic status of the participants was identified using the Brazil Classification Criteria of the Brazilian Association of Statistics Enterprises (ABEP, 2009 – www.abep.org). This questionnaire is based on the possession of appliances and rooms in the household as well as educational level of the head of the family. The quantity of items corresponds to a punctuation and the sum of the points classifies the subjects in A (highest class – monthly income ≥ R\$ 4,648), B (monthly income ≥ R\$ 1,669), C (monthly income ≥ R\$ 927), D (monthly income ≥ R\$ 424) and E (monthly income ≥ R\$ 207).

Bone mineral density and bone mineral content (BMD / BMC)

Lumbar spine, total and femoral neck bone BMD were measured by a Lunar, model DPX-IQ (software version 4.7e) double energy X-ray absorptiometry device (DXA). The variation coefficient found in the evaluations for all bone sites was within 0.7% and 2.4%¹².

Statistical Analysis

Firstly, the variables were analyzed in a descriptive way in means and standard deviations. Normality was verified by Skewness and Kurtosis. Estimation of daily calcium intake was positively biased and was corrected by its own square root (\sqrt{x}) before being used in the subsequent analyses. The Pearson (r) correlation coefficient was used for verification of correlations with the physical traits, lifestyle and lumbar spine, femoral neck bone and total BMD. A stepwise multiple regression model was used with lumbar spine, femoral neck bone and total BMD as independent variables and body weight, height, puberty stage, age, self-reported skin color, skin color, physical activity level, calcium intake and socioeconomic status were used to identify the prediction factors for BMD. Since BMI is established by body weight and height, it was not used in the analyses to avoid co-linearity. Data analysis was performed in the SPSS statistical package for Windows, version 16. Significance level adopted was $p \leq 0.05$.

RESULTS

The main traits of all participants are found in table 1. None of the adolescents smoked and only four have reported weekly alcohol intake. Moreover, 23 girls reported use of oral contraceptive; however, their bone parameters were similar to the ones of the other girls. Mean menarche age was 12.2 ± 1.28 (mean ± standard deviation).

Table 2 presents the results of the correlation matrix between dependent and independent variables. The results demonstrate that the BMD of the adolescents tend to increase according to body weight gain, stature, BMI, age and puberty stage. On the other hand, among the factors related to lifestyle, only the PAL and SES positively correlated with BMD (table 2). Body weight, puberty stage, age, calcium intake, SES and PAL explained from 48 to 68% of the BMD variation of the adolescents (table 3).

Table 1. General traits of the participants (mean± standard deviation).

	Girls (n = 329)
Age (years)	14.8 ± 2.5
Body weight (kg)	50.4 ± 10.0
Stature (cm)	158.1 ± 7.9
BMI (kg/m ²)	20 ± 3.28
Skin color	37.9 ± 4.8
Total body BMD (g/cm ²)	1.086 ± 0.105
Lumbar spine BMD (g/cm ²)	1.015 ± 0.176
Femoral neck bone BMD (g/cm ²)	1.019 ± 0.150
Calcium consumption (mg/dia)	446.8 ± 306.6
Puberty stage	
I	32 (9.7%)
II	25 (7.6%)
III	49 (14.9%)
IV	86 (26.1%)
V	137 (41.6%)
Socioeconomic status	
A (≥ R\$ 8,295)	16 (4.9%)
B (≥ R\$ 2,656)	136 (41.3%)
C (≥ R\$ 1,459)	145 (44.1%)
D (≥ R\$ 680)	32 (9.7%)
Physical activity level	
Low (< 600 MET – min/week)	118 (35.9%)
Moderate (≥ 600 MET – min/week)	129 (39.2%)
High (≥ 3,000 MET – min/week)	82 (24.9%)
Self-reported race	
White	108 (32.8%)
Black	24 (7.3%)
Mulatto (mixed)	185 (56.2%)
Yellow	5 (1.5%)
Native	7 (2.1%)

Table 2. Correlation matrix between physical traits, lifestyle factors and bone parameters of the girls.

	Total body BMD	Lumbar spine	Femoral neck
Age (years)	0.58**	0.63**	0.43**
Body weight (kg)	0.75**	0.65**	0.64**
Stature (cm)	0.53**	0.57**	0.47**
BMI (kg/m ²)	0.64**	0.49**	0.54**
Puberty stage	0.59**	0.62**	0.44**
Self-reported race	0.00	0.00	0.00
Skin color	-0.17**	-0.21**	-0.10
Calcium consumption(mg/dia)	-0.05	-0.01	0.01
Socioeconomic status	0.10	0.09	0.14*
Physical activity level	0.12*	0.09	0.12*

BMD: Bone mineral density (g/cm³)

* $p < 0.05$; ** $p < 0.01$.

Table 3. Beta coefficient and cumulative R²*, derived from the Stepwise of multiple regression models.

	Full body BMD	Low back BMD	Femur shaft BMD
	R ² *(β)	R ² *(β)	R ² *(β)
Body weight	55,6 (0,557)	41,7 (0,407)	41,1 (0,560)
Age	8,8 (0,242)	15,6 (0,325)	3,1 (0,218)
Puberty stage	2,5 (0,193)	3,9 (0,250)	–
Socioeconomic status	1,1 (–0,100)	0,5 (–0,073)	2,3 (–0,148)
Calcium consumption	–	0,8 (0,089)	0,9 (0,095)
Physical activity level	0,8 (0,099)	0,4 (0,070)	0,6 (0,089)
ΣR ² (%)	68,8	62,7	48

*R² cumulative: The R² on each line presents the percentage of contribution which the variable added to the model.

DISCUSSION

Physical traits

The mean stature, body weight and BMI values of the sample evaluated are according to the data found in a national sample with students from the five Brazilian regions¹⁶. However, the BMD values found may present differences when compared with regional studies¹⁴.

Pearson correlation analysis demonstrated that BMD of the adolescents tends to increase according to increase in body weight, stature, BMI, age and puberty stage (table 2). Additionally, body weight was the main explanation factor for the BMD in all sites evaluated, being responsible for almost 56% of total BMD variation (table 3). Other studies also found associations between body weight and BMD, both in girls¹⁷ and young women¹⁸. Bone mineralization and resistance, both in adults and children, constitute in stress which produces compression on the skeleton and since body weight provides the most constant mechanical stress to bones¹⁹, the correlation of BMD and body weight is understandable.

Age was the second explanation factor for BMD, followed by sexual maturation stage. Besides being correlated with BMD in all bone sites, these two variables together could add up almost 20% in the lumbar spine BMD explanation. However, only age was an explanation factor for the femoral neck bone BMD. In a previous study¹⁴, BMD of adolescents was compared concerning age and sexual maturation and significant increase of BMD between 10 and 14 years of age and sexual maturation stages (classified as pre-puberty, puberty and post-puberty) was observed. This fact was also observed in adolescents from other countries^{1,2,7}. Concerning the femoral neck bone BMD, sexual maturation did not present any contribution for the regression model, which must be related to the effect of the sexual hormones being more pronounced in the trabecular bones than in the cortical ones⁷. Therefore, the factors which can influence mechanical stress on the femoral neck bone BMD are possibly more important for its acquisition/maintenance.

Conversely, other studies which demonstrated differences in BMD of subjects of different races^{1,6}, both self-reported and skin color, were not explanation factors for BMD of adolescents. Moreover, only skin color presented a weak association with BMD and it was a negative association. Such fact caused a clue which can only be explained by the understanding about genetic heredity of the Brazilian population. The Brazilian population was composed of mixing of Europeans, Africans and native Brazilians, where an individual classified as white, according to many phenotype characteristics, presents African heredity, while another classified as black, presents

European heredity²⁰. Moreover, the genes related to the BMD variation usually specifically act according to race, age and sex²¹ and the BMD variation may be influenced by genetic heredity²².

Thus, the results found in the present study suggest that the BMD stratification of Brazilian girls by race, simply considering phenotype traits, may present inaccurate results, and while studies comparing the BMD of girls and women stratified according to genetic heredity markers are not conducted, it will be impossible to understand the correlation between race and BMD in the Brazilian population. Furthermore, it is possible to suggest that the use of criteria such as body weight, age and sexual maturation are the best recommendation to control the BMD variations of female adolescents.

Factors related to lifestyle

The socioeconomic status (SES) of the evaluated sample is in agreement with the expectation for the population of the Federal District, since the majority of the female adolescents was classified in classes C and B, which despite agreeing with the national mean, is different from other capitals, such as Fortaleza, Recife and Salvador which present the majority of the population in classes D and C (ABEP, 2009 – www.abep.org). Regarding the daily calcium intake, the mean values found in this study represent only 34% of the recommendation for adolescents (1,300mg/day)²³. On the other hand, 64% of the adolescents practiced physical activities in moderate to high levels. These three factors related to lifestyle presented low correlation with BMD of the bone sites analyzed; however, the three together could add up to 4.4% of explanation for the BMD in the regression models used, with the greatest contribution for the femoral neck bone BMD.

In the present study, the SES was an explanation factor for all the bone sites analyzed. Other studies presented association between SES and BMD of children and adolescents from the United Kingdom⁸, South Africa⁹ and Lebanon⁷. These results as a whole suggest that the influence of the SES in the BMD is a consequence of the correlation between SES and longitudinal growth. The adolescents from the higher social classes would have BMD gain related to higher dimensions of stature and bone size, while those from lower classes, even with lower stature, would present increase of BMD provided by the greater quantity of body fat⁸ which directly influences on body weight gain and its osteogenic effects, as previously mentioned in the present study.

Daily calcium intake did not present any significant association with BMD of the three bone sites analyzed; however, it was an explanation factor for lumbar spine and femoral neck bone BMD. Approximately 99% of the body calcium is stored in the bones⁴ and about 26% of the calcium of an adult is acquired two year after the growth peak²⁴, which denotes the importance of this nutrient for bone health. Therefore, the results which did not present significance in the present study should be carefully analyzed. Firstly, daily calcium intake was not an explanation factor for all the analyzed bone sites, which can be the effect of a possible compensation mechanism between the trabecular and cortical bones in insufficient presence of calcium. In that mechanism, a type of bone "lends" the mineral from another to be compensated later, when the demand is balanced²⁴, which corroborates other studies which

suggest that the calcium consumption/supplementation acts in a specific manner for each bone site^{5,11}.

In addition to that, the insufficient calcium quantity must be also contributing to the weak associations found in the PAL and BMD, since the benefits induced by physical activity in the bone tissue during growth are only seen when the calcium intake is around 1,300mg per day¹⁰. Despite of that, the PAL was an explanation factor for all bone sites and their osteogenic effects may be explained by the mechanostat theory proposed by Frost²⁵, in which workload and tension intensity may influence bone gain or loss. When the activity is below the minimum tension physiological values, bone mass loss occurs; within the physiological workload zone, the bone is kept and gain will occur only when the load intensity is increased.

Thus, the results suggest that the SES, the PEL and daily calcium in take play a small role in the BMD variation during adolescence when compared with physical traits as body weight, age and sexual maturation stage. However, they were never unimportant, since this part of contribution may be the difference between the early onset of osteoporosis or not. Furthermore, it is worth mentioning the importance of the replication of this study with women in other age groups so that the contribution of each factor, physical feature or lifestyle during all phases of life can be determined.

The present study had some important limitations. The effects of the calcium intake in the bone metabolism were only evaluated by the analysis of its consumption, whereas the best way would be the analysis of calcium absorption and excretion rates⁵ which

could not be performed in this study. Besides that, stratification by race was performed only with phenotype characteristics, when for the Brazilian population the most suitable method would be the use of genetic heredity markers. However, these limitations do not make the found conclusions impossible and present new aspects which should be considered in future research.

To sum it up, the present study identified the physical traits and lifestyle related to BMD of female adolescents. Among all the factors analyzed in the present study, body weight, age and sexual maturation were the main factors related to BMD of adolescents, which suggests that the future studies should consider these factors to control the BMD variations of female adolescents. Furthermore, the factors related to lifestyle, despite presenting low contribution concerning the physical traits, can also influence the BMD gain during adolescence; however, new studies should be conducted to identify if the contribution of these factors can be altered in other phases of life.

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