Journal of
PHYSIOLOGICAL
ANTHROPOLOGY
and Applied Human Science

Bone Mineralization and Physical Development of Children

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Abstract A cross-sectional study of BMD and physical development values in children of various age-specific groups was carried out. In all, the study included 357 children (194 boys and 163 girls) aged from 5 to 16 years. The study did not include children with inherited or acquired diseases of the musculoskeletal system, chronic diseases of the liver or kidneys, diabetes, thyrotoxicosis or malabsorption syndrome or professional athletes. BMD values were estimated by dual X-ray absorbtiometry (DXA) of the lumbar part of the spine (L_2–L_4) using a "DPX-MD$^+$" device equipped with a "child" software program. Out of all the examined children, 58.9% had harmonic physical development, and 13.1% had a decreased body height and body mass. It was revealed that BMC and BMD values in the lumbar part of the spine intensively increased with age. BMC closely correlates with body height (r=0.8; p<0.000) and body mass (r=0.7; p<0.000). BMD also correlates with anthropometric parameters. The lowest BMC and BMD values and Z-score as well can be found in children with a low body height and body mass (<10th percentile). *J Physiol Anthropol Appl Human Sci 24(4): 445–450, 2005* http://www.jstage.jst.go.jp/browse/jpa
[DOI: 10.2114/jpa.24.445]

Keywords: children, DXA, BMC, BMD, physical development

Introduction

Physical development reflects the overall patterns of growth and morpho-functional maturation of a child. The linear dimensions of the body are the essential indicators of physical development. With reference to skeleton bones, growth processes are characterized with age by bone size enlargement, bone mineral accrual and increase of bone mineral density (BMD) (bone mass) (Bonjour et al., 1991; Boot et al., 1997; Theintz et al., 1992; Scheplyagina et al., 2003a, b). The processes of bone mass accrual during growth and development of a child need further investigation (Rice et al., 1993; Barsanti et al., 1996; Ellis et al., 2001). At the same time, understanding of this issue has crucial value for the prevention of osteoporosis and its complications in able-bodied and elderly adults (Kanis et al., 1994; Kulak and Bilezikian, 1998). The study was aimed at investigating age-specific indicators of BMD in children and its relationship with anthropometric parameters.

Methods

A cross-section study of BMD and physical development indicators in children of various age-specific groups was carried out. In all, the study included 357 children (194 boys and 163 girls) aged from 5 to16 years. All of them resided in the city of Moscow and Moscow Oblast and visited kindergartens and schools of general education. The children did not differ by family social status, food habits, or motor activity. They had no chronic pathology to deteriorate bone mineralization or phosphoric calcium metabolism.

The study did not include children with inherited or acquired diseases of the musculo-skeletal system, chronic diseases of the liver or kidneys, diabetes mellitus, thyrotoxicosis, malabsorption syndrome or professional athletes.

The children were examined by a pediatrician following a single protocol. Physical development was evaluated by absolute values of body height and body mass. Assessment of body height was apprised in centimeters to within 0.5 cm, and of body mass, in kilograms to within 0.1 kg. All measurements were carried out on study participants stripped to the waist.

The degree of harmonic physical development was characterized using percentile tables based on body height and body mass ratio (Doskin et al., 1997).

BMD values were estimated by dual X-ray absorptiometry (DXA) of the lumbar part of the spine (L_2–L_4) using a "DPX-MD$^+$" device equipped with a "child" software program.

Analysis included bone mineral content (BMC, in g), bone area (area, in cm^2), bone mineral density (BMD, in g/cm^2) and Z-scores of those parameters, which specify the examined child's BMD relative to average statistical values for children of the same age and gender and is evaluated in standard deviations (SD). Established individual BMC and BMD values were compared with a device reference base.

In accordance with WHO standards, diagnosis of normal BMD was accepted at Z-score>-1 SD; osteopenia at Z-score

Table 1 Anthropometric parameters of examined children (M±m)

Age	Boys					Girls				
		Body height (cm)		Body mass (kg)			Body height (cm)		Body mass (kg)	
	n	M±m	*p*	M±m	*p*	*n*	M±m	*p*	M±m	*p*
5	13	116.46±1.56		20.61±0.85		1	—	—	—	
6	15	120.67±1.53	*	23.4±1.02	*	9	120.3±1.63		22.9±1.28	
7	6	128.2±2.68	*	25.27±1.74		4	124.5±3.66		24.87±1.7	
8	6	135.17±2.87		29.58±3.1		7	132.4±3.6		27.36±1.57	
9	6	137.92±1.71		31.5±3.31		7	136±2.01		29.57±1.3	
10	25	146.83±1.09	*	36.55±0.82	*	40	145.27±2.9	*	39.32±3.18	*
11	23	148.7±2.28		40.8±1.91	*	33	150±1.99		41.25±2.67	
12	17	157.25±2.61	*	50.77±4.79	*	18	160.5±3.85		42.14±4.18	
13	37	162.3±1.64	*	51.78±2.14		32	159.69±2.6	*	47.42±2.25	
14	36	169.6±2.26	*	60.25±2.94	*	26	165.5±1.36	*	53.68±2.72	
15	43	172.2±1.85		60.65±1.57		38	165.9±1.09		53.59±1.55	
16	14	178.2±2.09		62.5±2.19	*	35	165.5±1.77		53.86±1.92	

* $p<0.05$

<−1 SD and Z-score>−2.5 SD; and osteoporosis at Z-score< −2.5 SD.

Data statistical processing was carried out using the integrated software package "Statistica 6.0". Techniques of parametric and non-parametric statistics were applied. Data analysis included estimation of simple mean (M) and mean square (s). Pearson and Spearman correlation indices were also calculated, and regression analysis applied. According to standards accepted in biology and medicine, indicator differences were considered reliable at $p<0.05$.

Results and Discussion

Physical development of examined children

Within even-aged groups, significant variability of indicators of body height and body mass was noted. It was established that the mean values of body height and body mass of the examined children were characterized by typical age and gender differences (Table 1).

Out of all the examined children, 58.9% had harmonic physical development and 3/4 of these children had indicators of body height and body mass within the limits of the 25–75th percentile. One quarter of them surpassed their coevals in body height and body mass and had harmonic physical development. The rest of the children had disharmonic development, including 5.4% with decreased indicators of body height (<10th percentile) and 7.7% with decreased body mass (<10th percentile). It was established that before puberty children more often developed harmoniously. This means that at the onset of puberty the number of children with harmonious development decreased and contrariwise the number of children with various types of disharmonious development increased. The number of harmoniously developed children increased again up to the age of 16.

Bone mass (L_2–L_4)

Densitometry of the spine (L_2–L_4) established the variation of individual values of BMC and BMD (Fig. 1). It was revealed that BMC in the lumbar part of the spine intensively increased with age. During the period from 6 to 16 years, the BMC level increased in boys from 13.5 g to 47.4 g (243.7%) and in girls from 13.72 g to 46.23 g (236.9%) (Table 2). The most significant accretion rates of BMC were registered in boys at the ages of 8 to 9 years (37%), 12 to 13 years (32%), and 13 to 14 years (26%). In girls, that sort of dynamic was established at the ages of 9 to 10 years (29.6%) and 12 to 13 years (42.4%). It is noteworthy that prior to the age of 14 years, the mean values of BMC of the lumbar part of the spine are mainly higher in girls than in boys with a reliable difference at the age of 11 and 13 years ($p<0.05$). After the age of 15 years, values of BMC in boys exceeded the respective values in girls.

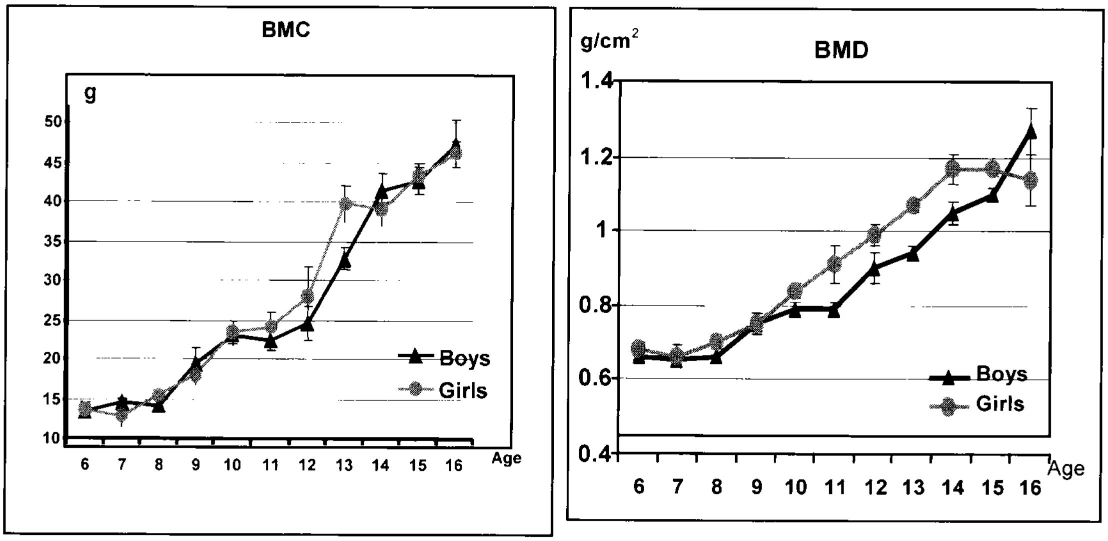

Fig. 1 Age-specific BMC values (L_2–L_4) of examined children (M±m).

Table 2 BMC and BMD values of lumbar part of spine (L_2–L_4) in examined children

Age	BMC (g)				BMD (g/cm²)			
	Boys		Girls		Boys		Girls	
	n	M±m	*n*	M±m	*n*	M±m	*n*	M±m
5	12	11.68±0.4	1	12.0±	12	0.59±0.02	1	0.59±0.01
6	15	13.5±0.46	8	13.72±0.74	15	0.64±0.02	8	0.65±0.02
7	6	14.5±0.61	4	13.92±1.46	6	0.64±0.02	4	0.62±0.02
8	6	14.27±0.71	7	15.49±0.43	6	0.61±0.03	7	0.70±0.01
9	6	19.53±1.84*	7	18.07±1.36	6	0.75±0.03*	7	0.73±0.03
10	15	23.14±1.12	11	23.42±1.53*	15	0.78±0.05	11	0.81±0.02
11	15	22.37±1.24	17	24.16±1.78	15	0.77±0.03	17	0.79±0.04
12	12	24.56±2.12*	7	27.91±3.93	12	0.83±0.03*	7	0.86±0.05
13	18	32.81±1.54	13	39.75±2.29*	18	0.88±0.02	13	1.02±0.02*
14	22	41.39±2.25*	19	39.157±2.61	22	0.96±0.03*	19	1.04±0.03
15	22	42.64±1.69	16	43.24±1.63	22	0.99±0.03	16	1.07±0.03
16	10	47.4±3.07	20	46.23±1.48	10	1.09±0.04	20	1.09±0.04

* $p<0.05$

The changes of BMD values repeat the increase of BMC with age, but its accretion rate was lower. BMD values during the period from 6 to 16 years increased in boys from 0.64 to 1.09 g/cm² (703%) and in girls from 0.65 to 1.09 g/cm² (67.7 %). Moreover, in boys significant accrual of BMD occurred at the ages of 8 to 9 years (23%), 11 to 12 years (17%) and 13 to 14 years (10%). All this is associated with an increase both of body height and body mass. In girls, the mineralization peak was revealed at the age of 12 to 13 years (19%).

BMD mean values in spine bones (L_2–L_4) also are higher in girls during the period from 8 to 15 years with reliable differences at the ages of 8, 11, 13 and 15 years.

Bone mass (L_2–L_4) and anthropometric indicators

It was established that BMC values closely correlate with body height (r=0.8; p=0.000), body mass (r=0.7; p=0.000) and body build index (r=0.4; p=0.000) (Table 3).

In boys, BMC most closely correlated with body height at the ages of 11, 12, 14 and 15 years; with body mass at the ages of 10, 11, 12 and 13 years. In girls, BMC most closely correlated with body height at the ages of 10, 11, 12 and 13 years; with body mass at the ages of 10, 12, 13, 14 and 16 years; with body build index at the ages of 10, 12, 13 and 14 years.

Independently of gender, BMD also correlated with height (r=0.8; p=0.000), mass (r=0.8; p=0.000), and body build index (r=0.6; p=0.000).

Table 3 Correlation between BMC (L_2–L_4) and anthropometric parameters

Anthropometric parameters	BMC	BMD
Body height	r=0.8; p=0.000	r=0.8; p=0.000
Body mass	r=0.7; p=0.000	r=0.8; p=0.000

Thus, BMC and BMD are closely associated with body height and body mass. This conclusion is confirmed by the unidirectionality of the age-specific indicators of body height and body mass, BMC and BMD (Fig. 2).

Bone mass(L_2–L_4) and physical development

During the last decade, in the Russian population there has been an increased number of children with disharmonic physical development: decreased body height, body mass, with excess weight, etc. In view of this, BMD values were estimated depending on type of physical development.

It was established that frequency of occurrence of osteopenia/osteoporosis in the lumbar part of the spine differs in children with various physical development. It occurs more frequently at low body height (66.7%) and body mass (81.8 %).

It was established that the lowest BMC and BMD values and Z-score as well can be found in children with lower body height and body mass (<10th percentile) (Fig. 3). In children with harmonious development and high body height and body

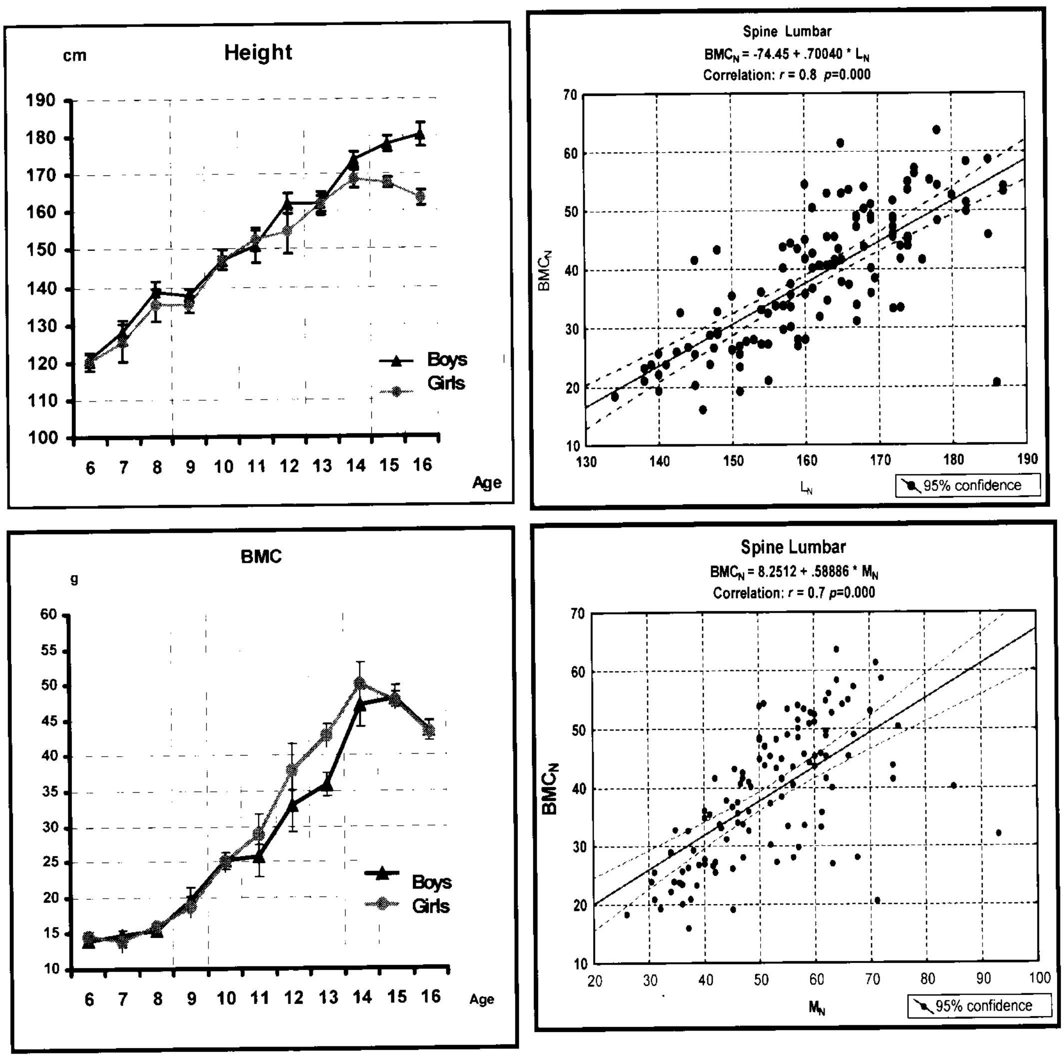

Fig. 2 Relationship between BMC and physical development parameters.

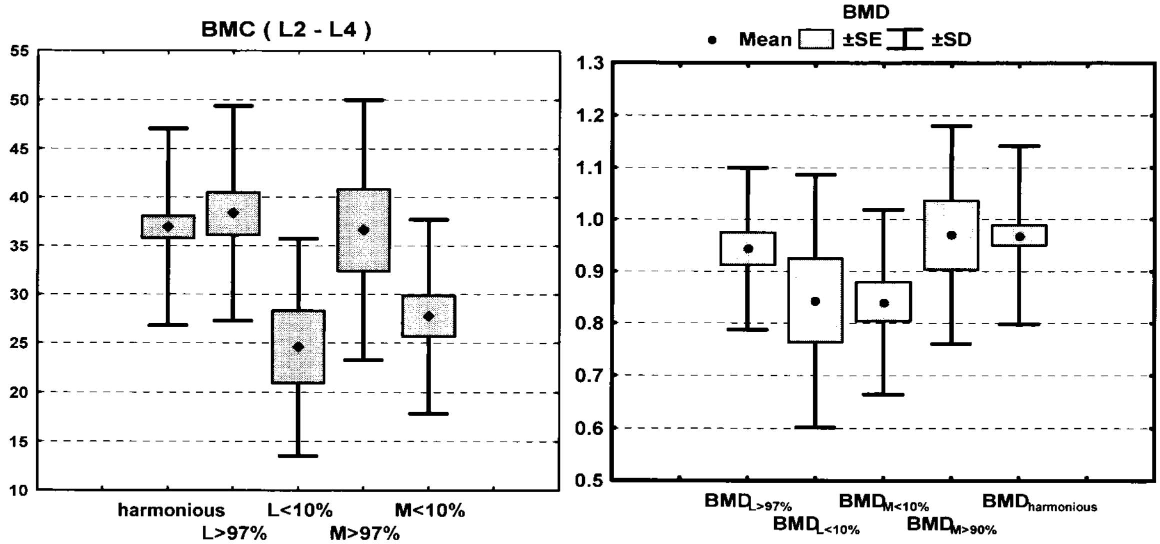

Fig. 3 BMC values (L_2–L_4) in various types of physical development.

mass BMC and BMD values did not differ significantly.

Clinical assessment of bone mass indicators in children

Within the framework of the present study, BMD values were standardized against body height. The reasons for this were marked variation of indicators of physical development (Buckler and Green, 1999) and bone mass within each age-specific group (Scheplyagina et al., 2003a, b) and the closest relationship of BMD with body height (Gordon et al., 1991; Katzman et al., 1991).

Whereas bone mineral accrual has a nonlinear dependence from growth processes, age-specific BMC and BMD values were estimated using regression scales (Fig. 4).

Application of BMD indicators standardized by body height became very important to specify the causes of lower BMD (Leonard et al., 1999; Gafni and Baron, 2004) values in children with disharmonic physical development, primarily in children with body height and body mass$<$10th percentile.

The present study proved the great effectiveness of the application of BMD indicators standardized by body height to verify the frequency of occurrence of osteopenia in healthy children during periods of intensive growth and in children against a background of diseases adversely affecting physical development, primarily the linear growth of the child.

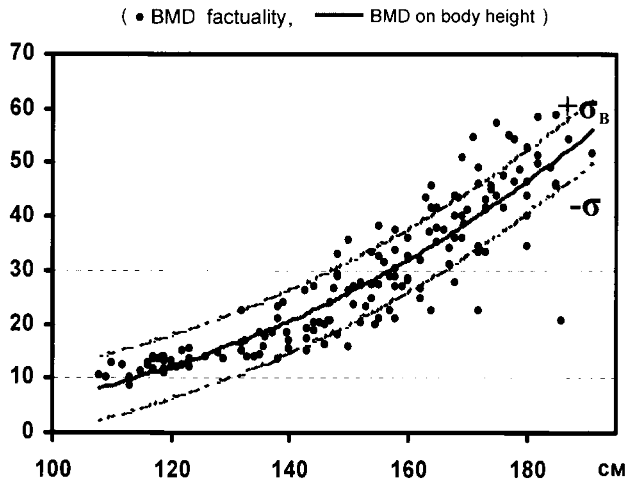

Fig. 4 Regression curve (BMD on body height, in boys).

Conclusions

1. The present cross-sectional epidemiological study provided age-specific (from 6 to 16 years) indicators of body height and body mass which reflect the physiological processes of an age-dependent increase of anthropometric indicators in an actual population of children.
2. A significant variation of individual indicators of body height and body mass; the higher proportion of children with disharmonic physical development was marked. In 13.1% of children's body height and body mass values were $<$10th percentile.
3. During the period from 6 to 16 years, an increase of BMC and BMD in skeleton bones occurs (L_2–L_4), with its peak value during the period from 11 to 14 years.
4. Bone mineral accrual and BMD increase are unidirectional and closely correlate with body height and body mass.
5. Bone mass indicators standardized by body height are very valuable for the specification of the causes of lower BMD values in children with disharmonic physical development.

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Received: March 27, 2005
Accepted: March 31, 2005

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