Original Article

Is There Difference of BMD between Non-Obese and Obese Children? - A Cross-Sectional Study in 194 Thai Children

Sorawut Thamyongkit, MD[1,3], Ukris Ghunadham, MD[1], Paphon Sa-ngasoongsong, MD[1], Chanika Angsanuntsukh, MD[1], Umaporn Suthutvoravut, MD[2], Patarawan Woratanarat, MD, PhD[1], Pornchai Mulpruek, MD, MCh Orth[1]

[1] Department of Orthopedics, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

[2] Department of Pediatrics, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

[3] Chakri Naruebodindra Medical Institute, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Samut Prakan, Thailand

Objective: To find the correlation between the presence of childhood obesity and bone mineral density (BMD).

Materials and Methods: A cross-sectional study was conducted among children aged between 5 and 12 years old. After excluding children who had history of endocrinopathy, epilepsy, or cerebral palsy, all participants were divided into "obese group" (body mass index [BMI] at or above the 95 percentile of those with the same age and gender) and "control group" (BMI below the 95 percentile). Skeletal age, BMD, serum bone markers (osteocalcin and beta-crosslaps), and physical exercise were collected. Multivariate regression analysis was used for statistical analysis.

Results: Ninety-six obese children and 98 controls were included in the present study. The average BMI was 28.5 kg/m^2 in obese group, and 16.6±1.9 kg/m^2 in controls (p<0.001). BMDs of the spine and hip area were significantly higher in obese group compared to controls (p=0.002 and <0.001, respectively). However, there was no significant difference of skeletal age or serum bone markers level between both groups (p>0.05 all). Exercise was shown to significantly correlated with hip and distal radius BMD (p<0.001 and 0.003, respectively).

Conclusion: Obese children had significantly higher spine and hip BMD than non-obese children. Nevertheless, there were no differences between groups regarding skeletal age and bone markers. BMI and exercise activity might play an important role in higher BMD in children.

Keywords: Bone mineral density, Children obesity

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Childhood obesity is one of the major public health problems in the twenty-first century and its prevalence has increased at an alarming rate. In 2015, the number of overweight children under the age of five is estimated to be over 42 million, and almost half of these are in Asia[1,2]. In Thailand, the prevalence of childhood obesity is about 11%[3]. Obesity leads to many medical and orthopedic problems, including metabolic syndrome, tibia vara, knee deformity, slipped capital femoral epiphysis, or even having higher risk of fracture[4-6]. Peak bone mass plays an important role in osteoporosis and fracture[7]. Although this is influenced mainly by genetics, there are many other factors including nutrition, environmental factors, and exercises[8]. The effect of obesity on children's bone growth is still contradictory. While most studies demonstrated the normal or increased bone mineral content (BMC) or bone mass density (BMD) in obese children[9-13], few reports showed that obese children would have decreased BMC or BMD relative to their body weight or bone size[14,15]. Moreover, the effect of obesity on bone growth might be different on the distinctive bony area or be dependent on the children's intrinsic factors such as age, gender, and physical activity[16,17].

Correspondence to:

Woratanarat P.

Department of Orthopedics, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, 270 Rama VI Road, Ratchathewi, Bangkok 10400, Thailand.

Phone: +66-2-2011589, **Fax**: +66-2-2011599

Email: pataraw@yahoo.com

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Table 1. Baseline characteristics comparison between obese and non-obese groups

Baseline characteristics	Obese (n=96) Mean±SD	Non-obese (n=98) Mean±SD	p-value
Age (year)	9.8±1.3	10.2±1.4	0.170
Male; n (%)	33 (67.4)	43 (43.9)	0.007
Weight (kg)	64.8±27.6	34.3±7.8	<0.0001
Height (cm)	147.2±17.5	142.7±12.1	0.040
BMI (kg/m^2)	28.5±7.4	16.6±1.9	<0.0001
Adequate exercise; n (%)	30 (31.3)	37 (37.8)	0.367

SD=standard deviation; BMI=body mass index

To the authors' knowledge, no previous studies have analyzed the relationship between childhood obesity (or children's intrinsic factors) and BMD that have been conducted in Thailand or in the ASEAN region. Therefore, the objective of the present study was to determine the effect of childhood obesity on BMD and the correlation of BMD relative to skeletal age and exercise. The present study also investigated the serum bone markers, osteocalcin, and beta-crosslaps, which represent bone turnover in children. The hypothesis was that the children with obesity would have a difference in BMD from the normal group.

Materials and Methods

The present study was designed as a cross-sectional study during a 4-year period (2009 to 2012). The study was approved by the Institutional Review Board, based on the Declaration of Helsinki (Protocol number 02-53-11). The eligible participants in the present study were children from either the authors pediatric clinic or the nearby primary school. Obese children were defined as children who have body mass index (BMI) more than 95th percentile in the same age and gender. Non-obese children were defined as BMI less than 95th percentile in the same age, gender, and height. BMI was calculated based on the following formula: body weight in kilograms (kg) divided by height in meters squared (m^2). All participants' parents or guardians gave their informed written consents before participation in the present study.

All participants in the present study were interviewed and received physical examination by orthopedists. Children who had history of endocrinopathy, brain trauma, brain tumor, epilepsy, or cerebral palsy were excluded. Baseline characteristic factors included age, gender, height, weight, BMI, and physical activity were collected. Skeletal age was measured by radiographs of non-dominant hand and wrist using Greulich and Pile Atlas of Bone Age[18], which was assessed by one of the authors (Mulpruek P). Bone markers were determined by the serum level of osteocalcin and beta-crosslaps, using a total of 10 mL of blood stored in EDTA tube and sent to laboratory at Ramathibodi Hospital. All blood analyses were performed by a standard automated hematology analyzer [Cobas 6000: model: E601 (Roche Diagnostics USA, Indianapolis, USA)]. Participants' skeletal age was considered as high, normal, or low when their skeletal age was above, the same, or below their chronological age, respectively. Adequate exercise was defined, using the standard guideline[19], as the moderate to vigorous physical activity of more than 30 minutes per time and more than three times per week. Primary outcome was BMD measured by Discovery DXA system (APEX version 3.2, Hologic, Inc., Bedford Maryland, USA). Secondary outcomes were skeletal age and bone markers.

Statistical analyses were performed using Stata, version 12.0 (StataCorp LP, College Station, TX, USA). Continuous data were presented as mean and standard deviation and compared with an unpaired t-test. Categorical data were presented as proportion and compared with Fisher's exact test or chi-square test as appropriate. Skeletal age, gender, BMI, and adequate exercise were all analyzed by multiple regression analysis to find the relationship to BMD. Significance was defined as values of p less than 0.05.

Results

One hundred ninety-four children were recruited into the present study, including 96 obese children and 98 non-obese children. Table 1 shows the baseline characteristics of both groups. The average age of obese children and non-obese children were 9.8±1.3 and 10.2±1.4 years, respectively. There was no significant difference in chronological age,

Table 2. The relationship of bone mass density, bone markers and skeletal age between obese and non-obese groups

Bone-related factors	Obese (n=96) Mean±SD	Non-obese (n=98) Mean±SD	p-value
BMD (g/cm^2)			
Spine	0.7±0.1	0.6±0.1	0.002
Total hip	0.8±0.1	0.7±0.1	<0.0001
Femoral neck	0.7±0.1	0.6±0.1	<0.0001
Wrist	0.54±0.4	0.52±0.005	0.105
BMD (Z-score)			
Spine	0.1±1	–0.8±1	<0.0001
Total hip	0.004±0.15	–0.957±0.09	<0.0001
Femoral neck	–0.2±1	–1.2±0.8	<0.0001
Wrist	0.5±0.9	–0.2±1.0	0.0002
Osteocalcin (ng/mL)	88.0±44.5	97.6±43.8	0.152
Beta-crosslaps (ng/L)	1.1±0.6	1.0±0.4	0.464
Skeletal age (year)	10.7±3.3	10.0±1.4	0.053

SD=standard deviation; BMD=bone mass density

Table 3. Regression analysis of BMD and other factors

Factors	Spinal BMD					Total hip BMD					Distal radius BMD				
	Coefficient	95% CI	SE	t	p-value	Coefficient	95% CI	SE	t	p-value	Coefficient	95% CI	SE	t	p-value
Skeletal age	0.12	0.00 to 0.02	0.01	2.43	0.017	0.08	–0.00 to 0.16	0.00	1.79	0.08	0.01	0.00 to 0.13	0.00	2.45	0.016
Sex: male	–0.04	0.00 to 0.05	0.02	–3.11	0.002	0.05	0.03 to 0.07	0.01	4.08	<0.001	0.01	–0.01 to 0.02	0.01	0.64	0.52
BMI	0.01	0.01 to 0.13	0.00	6.97	<0.001	0.01	0.01 to 0.01	0.00	8.28	<0.001	0.00	0.00 to 0.01	0.00	2.93	0.004
Exercise	0.01	0.00 to 0.26	0.02	0.23	0.82	0.32	0.23 to 0.41	0.00	7.05	<0.001	0.03	0.01 to 0.05	0.01	3.00	<0.001
Constant	0.29	0.18 to 0.39	0.53	5.49	<0.001	0.29	0.18 to 0.39	0.53	5.49	<0.001	0.37	0.32 to 0.43	0.03	12.73	<0.001
Adjusted R-squared		0.35					0.50					0.24			

BMI=body mass index; BMD=bone mass density; CI=confidence interval; SE=standard error

Table 4. Relationships of chronological age and skeletal age between groups

Skeletal age compared with chronological age	Obese n (%)	Non obese n (%)	Total n (%)
High	13 (13)	8 (16)	21 (14)
Low	4 (4)	1 (2)	5 (3)
Normal	81 (83)	40 (82)	121 (83)
Total	98 (100)	49 (100)	147 (100)
Fisher's exact test		0.750	

gender, height, and exercise activities between both groups (p<0.05). However, the weight and BMI were significantly different between both groups (p<0.001).

Regarding BMD, the average BMD in the obese group was significantly greater than in non-obese group in most areas including spine, total hip, and femoral neck (p<0.05) (Table 2). However, there was no significant difference of the bone markers (osteocalcin and beta-crosslaps) in both groups. Furthermore, the skeletal age of the obese group was greater than those in non-obese group but did not reach the significant level (p=0.053).

Spinal BMD was significantly correlated with skeletal age, male gender, and BMI (p<0.05, adjusted R-squared 0.35); whereas total hip BMD was significantly correlated with male gender, BMI, and exercise (p<0.05, adjusted R-squared 0.50). The significant correlation between distal radius BMD and obesity in children was skeletal age, BMI, and exercise (p<0.05, adjusted R-squared 0.24) as shown in Table 3. However, there was no significant relationship between the distribution of skeletal age, when compared to chronological age, between obese and non-obese groups (Table 4).

Discussion

In the present study, the average T-score of BMD in both obese and non-obese children were slightly low (range –1.2 to 0.5). The present study results showed that obese Thai children have statistically significantly higher BMD compared with those non-obese ($p<0.001$). However, the serum bone markers, as osteocalcin and beta-crosslaps, did not show significant difference between both groups (Table 2). These findings were similar to the results of previous studies(11,20). The bone markers were found correlated to growth spurt in both genders but were not correlated to BMD. In contrast, estrogen level made the greatest contribution to bone mineral acquisition and sustained peak bone mass in children[21]. These could explain the higher BMD in obese children without differences in bone markers.

The results of the present study also demonstrated the other related factors that might affect the BMD of children including skeletal age, gender, and presence of adequate exercise activity. Furthermore, the present study data also showed that adequate exercise was significantly correlated with BMD, especially in the weight bearing bone on the extremities such as hip and wrist. These results were similar to the previous studies that encouraged exercise activity to optimized bone health in children[17,22]. However, obesity has been also reported as a potential risk factor associated with fracture[23-25]. This might be explained by two reasons. First, this higher incidence of fracture, especially stress fracture, might relate to high-impact activity. Secondly, although the obese children had significantly higher BMD, this skeletal response might be not sufficient to compensate for the excess load of the whole body[15]. Therefore, to protect the skeletal integrity in later life and optimize their bone health, other than exercise, maintenance of a healthy body weight during childhood and adolescence is strongly recommended[26].

The present study had some limitations. First, no previous study demonstrated the standard normal value for bone markers in Thai children. Second, the dietary factor, such as calcium and vitamin D, was not available in the present study and this might have some effect on their development, especially on BMD. Third, type and intensity of exercises might be varying in each child. The study defined adequate exercise based on duration and frequency of activities. However, the authors included a relatively large sample size and it was a community-based control group due to the selection of control subjects from the same school. Moreover, the present study also showed the specific data related to age, gender, height, and exercise. The purpose of adhering to this selection was to limit variance from the socioeconomic, diet, and day-time activities. The authors' result also provided the reference database for the assessment of BMD in Thai children.

Conclusion

The present study demonstrated significant correlation between BMI and BMD in Thai children, and various factors affected BMD on different body areas. Children with higher exercise level showed a significant positive benefit on BMD. Therefore, bone health optimization and fracture prevention in children can be indirectly promoted by the recommendation of exercises and the maintenance of proper BMI.

What is already known in this topic?

The association between obesity in children and health problem including fracture risk has been reported in previous studies. They found the obese children have higher risk of fracture compare to normal weight children. Low BMD is one of the risks for fracture. However, there is still no consensus what effect of obesity to BMD in children.

What this study adds?

Regarding relatively large sample size and community-based control group, this study documents the correlation between age, gender, height, and exercise to BMD. BMI, and in particular, higher exercise level showed a significant positive benefit on BMD. Therefore, fracture prevention in children can be indirectly promoted by the recommendation of exercises and the maintenance of proper BMI.

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Conflicts of interest

All the authors declare that they have no conflict of interest.

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