J. Phys. Ther. Sci.
24: 877–880, 2012

Bone Mineral Density Variation in Children with Cerebral Palsy Based on the Differences in Weight Bearing

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Abstract. [Purpose] Many children with cerebral palsy have diminished bone mineral density and a propensity to fracture with minimal trauma. The aim of this study was to provide a detailed evaluation of bone mineral density(BMD) and to assess the relationship of BMD with mobility. [Subjects and Methods] The subjects were 16 children with cerebral palsy and 16 healthy children we measured the bone mineral density of the lumbar spine, and three femur parts, the femoral neck, the greater trochanter, and Ward's triangle of the two groups. In addition, we categorized the 16 children with cerebral palsy into three sub-groups − wheelchair group, walker group, and independent gait group − in order to measure the bone mineral density variation based on the degree of mobility. [Results] It was found that healthy children's bone mineral density of the femoral neck was significantly higher than that of children with cerebral palsy. [Conclusion] The results suggest it is necessary to stimulate muscle bone with proper weight bearing, a physical exercise program and the intake of calcium and vitamin D so as to prevent bone mineral density decrease in children with cerebral palsy.
Key words: Cerebral palsy, Bone mineral density, Weight bearing

(This article was submitted Apr. 2, 2012, and was accepted May 5, 2012)

INTRODUCTION

It has become possible to check the loss of BMD, the beginning point of loss of BMD, the rate of decline and to differentiate the data according to bone type due to the diversification and development of the measurement methods of BMD. The primary purpose of measuring BMD is to prevent bone fracture by calculating and evaluating the fracture risk, but a secondary one is prevent secondary diseases by early diagnosis of congenital or acquired disease. It is usual to diagnose osteoporosis by measuring the BMD of the lumbar spine and femur, and locating areas of low BMD is important, because fracture generally occurs in the vertebral column and femur[7)]. Although radiographic BMD measurement is considered an important tool for diagnosing osteopenia and determining the effect of therapy, there is a limitation in that it can detect abnormalities when the loss of BMD progresses 30–40%.

Bone growth primarily occurs during infancy and early childhood, especially with the development of muscles, making various physical movements and activities possible[2, 9)]. The maximum bone mass is present between the ages of 25 and 35, and the loss of BMD begins from this period on[5, 8)]. The BMD of one's whole life is determined by the bone mass acquired in childhood and adolescence when the bone mass increases most. Furthermore, bone growth is found to be largely affected and determined by internal factors, such as growth hormones and sex hormones, coupled with external factors, e.g. nutrition, and exercise[5)]. In particular, it has been shown that congenital problems or diseases occurring during childhood affect the complicated procedure of bone mineral resorption. In general, children with a low exercise capacity caused by brain disorder have difficulty in physical activity and in making meaningful gestures, and this leads to disuse muscle atrophy. In turn, this muscle atrophy reduces stresses on the bones, leading to less bone mineral resorption. Therefore, children with cerebral palsy experience loss of BMD because of hindered bone remodeling, due to a lack of physical activity combined with normal weight bearing and muscle contraction, and are more likely to suffer from bone fracture and have problems with daily activities and mobility. The purpose of this research was to provide basic data for the prevention and therapy of bone disease in children with cerebral palsy by assessing the weight bearing of cerebral palsy according to their method of locomotion and to compare the differences between their BMD with that of healthy children.

SUBJECTS AND METHODS

The subjects were 16 children (10.1 ± 2.96 year) with cerebral palsy and 16 healthy children (9.6 ± 1.70 year) all living in Dae-jeon, South Korea. The healthy group consisted of children without any underlying diseases, and the cerebral palsy group consisted of children who were diagnosed with cerebral palsy in a hospital. We divided the 16 children with cerebral palsy into three groups − a wheelchair group (9.5 ± 3.69 year) of six, a walker group (10.6 ± 1.51 year) of five, and an independent group (10.2 ± 1.92 year) of five − to analyze the difference in BMD based on the method of locomotion. In choosing children with cerebral palsy, we chose only those who had no medical history of taking calcium, vitamin D, or hormonal treatments such as steroids, for 6 months prior to the study. This group had no record of fracture in the measurement areas, the flexion contracture of each child's hip joint was no more than 30° when posed to measure, and none of the children had internal metallic fixtures in the measurement areas.

After measuring the subjects', height, and weight of, we measured the BMD of the lumbar spine (LS), which is a site of heavy weight bearing, and three femur parts, the femoral neck, the greater trochanter, and Ward's triangle, using Dual energy X-ray absorptionmetry, DEXA; DEXXUM 3, Korea. The BMD of LS by radiographic projection of front and back AP measurement was used to calculate the average BMD of the first lumbar vertebra (L1) to the fourth lumbar vertebra (L4). The Mann-Whitney U test was used as a nonparametric test to measure the difference between the BMD of the children with cerebral palsy and that of healthy children, and the Kruskal-Wallis test was used as a nonparametric test to examine BMD difference among the wheelchair, walker, and independent gait group. For the post-hoc test, the Mann-Whitney U test was used. Using Pearson's correlation coefficient, we checked the correlation of parameters taken from children with cerebral palsy. For statistical analysis of the data, we used the statistical program SPSSWIN (ver. 12.0), and a significance level of a=0.05.

RESULTS

For the lumbar spine, the BMD of the children with cerebral palsy was 0.43 g/cm^3 on average, while the BMD of the healthy children was 0.45 g/cm^3 on average, with no significant difference between the two groups. In the case of the femur, specifically the femoral neck, the BMD of the group of children with cerebral palsy was 0.40 g/cm^3, and that of the group of normal children was 0.57 g/cm^3, and the BMD of the healthy group was significantly higher than that of the cerebral palsy group ($p<0.001$). For the greater trochanter (GT), the BMD of the children with cerebral palsy was 0.33 g/cm^3, while that of the healthy children was 0.45 g/cm^3. Here again, the difference in BMD between the two groups was statistically significant ($p<0.001$). For Ward's triangle, the BMD of the children with cerebral palsy was 0.40 g/cm^3, and the BMD of the healthy children is 0.55 g/cm^3, a statistically significant result ($p<0.001$; Table 1).

We also compared the BMD of the cerebral palsy group among the methods of locomotion, the wheelchai, walker and independent gait groups. The BMD of the lumbar spine of these three groups were similar: 0.39 g/cm^3 for the wheelchair group, 0.47 g/cm^2 for the walker group, and 0.44 g/cm^3 for the independent gait group. For the femoral neck, measurements were 0.30 g/cm^3 for the wheelchair group, 0.46 g/cm^2 for the walker group, and 0.44 g/cm^3 for the independent gait group, and there were significant differences among the three groups ($p<0.05$). More specifically, there was a statistically significant difference between the wheelchair group and the walker group, and between the wheelchair group and the independent gait group.

The BMD of the greater trochanter of the wheelchair group was 0.24 g/cm^3, that of the walker group was 0.36 g/cm^3, and that of the independent gait group was 0.40 g/cm^3, again with significant differences ($p<0.01$). For Ward's triangle,the BMD of the wheelchair group was 0.32 g/cm^3, that of the walker group was 0.45 g/cm^3, and that of the independent gait group was 0.44 g/cm^3, once again showing with significant differences among the three groups ($p<0.05$). In considering data from the three groups, we can see there were significant statistical differences among children with cerebral palsy according to their degree of mobility ($p<0.01$; Table 2).

We also examined correlations between the cerebral palsy group's BMD and general characteristics. The results reveal that lumbar spine BMD and height were related, $r=0.767$, a significant correlation ($p<0.001$). The lumbar spine BMD and weight were also significantly correlated, $r=0.872$ ($p<0.001$). Furthermore, the femoral neck BMD and weight were significantly correlated, $r=0.558$ ($p<0.05$), the BMDs of the femoral neck and lumbar spine, $r=0.524$ ($p<0.05$), and the femoral neck and greater trochanter were also significantly correlated $r=0.725$ ($p<0.001$; Table 3).

DISCUSSION

Most of the research into BMD has involved the elderly and older postmenopausal women, and these studies report that the BMD of the elderly decreases due to a lack of physical activity and, in the case of postmenopausal women, due to hormonal changes. However, it is reported that when the maximum bone mass formed is low in adolescence and young adulthood, it indicates a greater possibility of suffering from osteoporosis in later years[5)]. While this highlights the need for continuous research on the BMD of adolescents, there are few studies in this area and, needless to say, even fewer related to children with cerebral palsy. Hence, this study was designed to investigate the necessity of therapies for enhancing the BMD of children with cerebral palsy, by first checking their BMD.

BMD is a very important criterion in the diagnosis of osteoporosis. Currently, dual energy X-ray absorptiometry is most widely used for the measurement of BMD, as this method is useful for the diagnosis of osteoporosis and subsequent follow-up[3)]. This method of measurement is advantageous as it measures BMD with accuracy, reproducibility, and sensitivity of up to 2–3% in BMD variation. A further benefit especially for children is that the test does not take much time and radiation exposure is minimal[12)]. For these reasons, dual energy X-ray absorptiometry was selected as the method of measurement for this study. In osteopenia, it is reported that fractures of the lumbar spine and femur occur often, and that bone loss takes place first in

Table 1. The comparison of bone mineral density between CP and normal children

	Group	Mean ± SD	Mean of Rank	Sum of Rank
LS	CP children	0.43 ± 0.13	15.41	246.50
	Normal children	0.45 ± 0.07	17.59	281.50
FN	CP children	0.40 ± 0.10	10.94	175.00
	Normal children	0.57 ± 0.13***	22.06	353.00
GT	CP children	0.33 ± 0.07	21.59	182.50
	Normal children	0.45 ± 0.10***	11.41	345.50
WT	CP children	0.40 ± 0.09	21.66	181.50
	Normal children	0.55 ± 0.11***	11.34	346.50

(unit: g/cm^3) ***p<0.001. LS: Lumbar Spine, FN: Femoral Neck, GT: Greater Trochanter, WT: Ward's Triangle

Table 2. The comparison of bone mineral density among means of locomotion of CP children

	Group	Mean ± SD	Mean Rank
LS	Wheelchair	0.39 ± 0.17	6.92
	Walker	0.47 ± 0.11	9.90
	Independent	0.44 ± 0.10	9.00
FN	Wheelchair	0.30 ± 0.06	4.00
	Walker	0.46 ± 0.04	11.40
	Independent†	0.44 ± 0.08	11.00
GT	Wheelchair	0.24 ± 0.03	4.42
	Walker	0.36 ± 0.01	11.10
	Independent†	0.40 ± 0.03	10.80
WT	Wheelchair	0.32 ± 0.06	3.50
	Walker	0.45 ± 0.06	9.50
	Independent†	0.44 ± 0.07	13.50

(unit: g/cm^3), †: statistically significant difference within each group (p<0.05), No statistically significant difference between groups.

Table 3. Correlation of bone mineral densities and physical characteristics

	Height	Weight	LS	FN	GT	WT
Height	1					
Weight	0.917***	1				
LS	0.767***	0.872***	1			
FN	0.305	0.558*	0.524*	1		
GT	0.232	0.486	0.436	0.879***	1	
WT	0.319	0.481	0.377	0.750***	0.725***	1

* p<0.05, *** p<0.001

the lumbar spine, which is made of spongy bone, and then in the femur[11]. Accordingly, osteoporosis can be confirmed by the lowest BMD value found after measuring these two areas[1]. Thus, this study measured the BMD of the lumbar spine and femurs.

The result of this study show that the BMD of children with cerebral palsy is very low − up to 58% of that of femur measurements of healthy children − but there was no difference in BMD of the lumbar spine. This data means that children with cerebral palsy suffer a greater loss of bone mass in the femur. According to the research of Bass and others[9], development of the bone is considerably affected by physical activity, especially during the growth of period, and the BMD of bones directly related to physical activity is up to 10–20% higher than that of bones not directly related to physical activity. According to the research of Kim Hyung-don[4], the BMD of the bones which are directly loaded by weight while doing physical activity and exercise is up to 10–20% higher than that of other bones. In addition, the research of Byun Jae-chul[6] shows that lack of physical activity during childhood causes slow development of muscle and bone and weakens them. Moreover, the study of

Kim Mi-kyung[1] reveals that physical gravity load caused by weight increases bone mass in the lumbar spine and femur more than in terminal bones of the limbs, and it affects the BMD of the femur more than that of the lumbar spine. The research of Galli and others[10] and Ruck and others[12] reports that the decrease of weight-bearing movements is the decisive factor in the decrease of BMD. Therefore, children with cerebral palsy would have low BMD in the femur because of a lack weight-bearing movement and less stress on their bones due to muscular atrophy. In line with this finding, the BMD of the wheelchair group, who could not move on their own, was significantly lower than that of the other children with cerebral palsy. Consequently, we can understand the necessity of encouraging weight-bearing in children in the early stages of cerebral palsy to prevent them from suffering BMD loss. The correlation between the cerebral palsy group's physical characteristics and BMD shows that, although there is a correlation between height and the lumbar spine BMD, weight has a correlation with both the lumbar spine and the femoral neck BMD. This result is in agreement with Kim Hyung-don's[4] research which reported that weight has a close correlation with BMD, and confirms that not only physical load-bearing resulting from gravity but also weight-bearing significantly affects BMD. However, according to recent research by Zhao et al.[13], an increase of weight is not a uniquely positive influence on BMD since it could negatively affect bone mass due to an increase of fat mass. This should be taken into account when considering prevention of BMD loss in children with cerebral palsy.

In view of these results, children with cerebral palsy experience greater loss of bone mass in the femur than healthy children. This takes place because children with cerebral palsy do not get sufficient weight-bearing exercise and have less stress on bones due to muscular atrophy. Hence, we consider it is highly necessary that children with cerebral palsy have their bones and muscles stimulated through exercise programs with appropriate weight-bearing, complemented with an appropriate intake of calcium and vitamin D, to prevent the loss of BMD.

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