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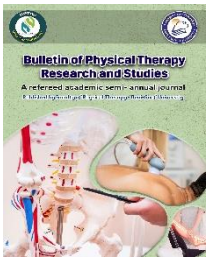

Relation Between Bone Mineral Density and Gross Motor Function In Children With Cerebral Palsy

Shimaa T.E. Emara PT[1], Alaa Al-Nemr, PT, PhD[2], Reham Osama Mahmoud, MD[3], Elham Elsayed Salem, PT, PhD [4]

[1] Pediatric Physical Therapy Department, Faculty of Physical Therapy, Cairo University, Cairo, Egypt

[2]Associate Professor of Pediatric Physical Therapy, Pediatric Physical Therapy Department, Faculty of Physical Therapy, Cairo University, Cairo, Egypt

[3] Lecturer of Radiology, Radiology Department, Faculty of Medicine, Kasr AL Ainy, Cairo University, Cairo, Egypt

[4] Professor of Pediatric Physical Therapy, Pediatric Physical Therapy Department, Faculty of Physical Therapy, Cairo University, Cairo, Egypt

Corresponding author:

Shimaa T.E. Emara PT

Pediatric physical therapy department, faculty of physical therapy Cairo University.

Email: shimaaemara2015@gmail.com

Tel: 01060279269

Running Title: Bone Mineral Density and Gross Motor Function Among CP Children

Abstract

Background: Children who suffer from cerebral palsy (CP) may face motor deficits that impact their gross motor function (GMF), resulting in restricted engagement in certain activities. These motor deficits may also negatively affect bone health, raising the risk of skeletal problems and reducing bone mineral density (BMD). **Purpose:** to study the relation between BMD and GMF in CP children (ambulant and non-ambulant).**Methods:** Cross sectional correlational study was conducted on 70 CP children (35 ambulant group A and 35 non-ambulant group B), their age were from 7-10 years old. Their level of GMF from level I to level V, their BMI were underweighted, Dual-energy X-ray absorptiometry (DEXA) was used to evaluate BMD, while GMFM-88 was used to measure GMF. An unpaired t test was used to compare the two groups' BMD and GMFM-88 scores. The association between BMD and GMFM-88 was ascertained using the Pearson association Coefficient. **Results:** The unpaired t-test analysis showed that There was a significant increase in BMD (right, left femur and spine L1-L4) and GMFM-88 of group A compared with that of group B ($p < 0.001$). The correlation between BMD and

GMFM-88 was moderate positive significant correlation with right femur BMD (r = 0.645, p = 0.001), left femur BMD (r = 0.678, p = 0.001), and with Spine L1-L4 (r = 0.452, p = 0.001). **Conclusion:** Ambulant CP children have better BMD and GMF than non-ambulant CP, there is moderate relationship between BMD and GMF in CP children, also improved GMF affect directly on bone health.

Keywords: Cerebral palsy, bone mineral density, gross motor function.

Introduction:

The main neuromotor condition affecting movement, posture, and muscle tone development is cerebral palsy (CP). An damage to the growing brain throughout the prenatal to neonatal period is the underlying pathogenesis (1). Children with CP may experience a variety of secondary conditions throughout time that will vary in how they influence their functional abilities, even when the primary neuropathologic damage is not progressing (2).A study conducted in Al-Kharga District (New Valley Governorate, Egypt) among 25,540 children examined, it was found that 52 were diagnosed with cerebral palsy. This results in a prevalence rate of 2.04 cases per 1000 live births, with a 95% confidence interval ranging from 1.48 to 2.59 cases per 1000 live births (3)**.** Different muscle groups may be affected by the mild to severe motor deficits linked to CP, which can make it difficult to carry out everyday tasks and engage in social and recreational activities (4)**.**Children with CP frequently have gross motor function impairments from their motor impairments, which limits their involvement in activities. These motor deficits may also negatively affect bone health, raising the risk of skeletal problems and reducing bone mineral density (BMD) (5)**.**The term gross motor function (GMF) describes the capacity to carry out coordinated actions involving vast muscle groups, like sprinting, jumping, and walking. For kids with CP, it is a crucial component of their physical capability and independence in everyday activities (6). Prior studies have demonstrated a strong correlation between CP patients' bone health and gross motor performance. To fully understand the nature of this link and how it relates to therapeutic measures, more research is necessary (7,8)However, BMD is a crucial indicator of bone strength and general skeletal health. Due to a variety of conditions, including decreased weight-bearing activities, muscle weakness, changed biomechanics, restricted mobility, and hormone imbalances, children with CP frequently have lower BMD than their counterparts who are usually developing (9)**.** Their functional abilities and quality of life are further impacted by this decreased BMD, which makes them more vulnerable to fractures and skeletal abnormalities (10).Our study's goal was to examine the BMD and GMF of ambulant and non-ambulant CP children and then investigate the relation between these two variables among CP children.

It might offer insightful information on the musculoskeletal effects of motor deficits and direct treatments aimed at promoting bone health.

Methods

Ethical considerations

The study was conducted after approval by the Ethical Committee at the Faculty of Physical Therapy, Cairo University (No: P.T.REC/012/004992) and ethical principles of the Declarations of Helsinki were followed. Informed consent was signed from each child's parent regarding participation of their children in the study.

Study design

The study was cross-sectional and correlational. In accordance with GMFCS, seventy CP children were split into two groups: Thirty-five children with CP, categorized as levels I, II, and III by the GMFCS, made up Group 1 (Ambulant).35 CP patients, categorized by GMFCS into levels IV and V, made up Group 2 (non-ambulant).After measuring every variable for both groups, we compared them and determined the correlation between BMD and gross motor function among the 70 CP children as a single group.

Sample size estimation

The sample size was predetermined by performing a prior power test via the G*POWER software (ver. 3.1.9.7; Heinrich-Heine-Universität, Düsseldorf, Germany) (11). The data entered were Exact, Correlation: Bivariate Normal Model. A priori: compute required sample size-given α power and effect size; correlation p H1 =.33 (according to the results of a pilot study from Jung et al. (2018) (12); a power of 80%; α = .05. According to the power analysis, 70 participants (CP spastic diplegia and quadriplegia) were required. Children were selected from the Out-patient Clinic of Faculty of Physical Therapy, Cairo university and Abu Elrish Pediatric Hospital from 15/12/ 2023 to 15/6/2024.

Inclusion criteria

Children with CP of both sexes, whose chronological ages varied from 7 to 10 years, had motor function at any level as determined by the GMFCS, and whose body mass index (BMI) was underweight.

Exclusion criteria

Any of the following conditions prevented children from participating in the study: Normal, Overweight, or Obese, Epilepsy, kidney problems with taking hormonal treatments or medications that alter bone

density, as well as using calcium, vitamin D, or steroids six months before the research, fracture in the measuring regions, a hip flexion deformity that is more than thirty degrees when measured, It often prohibit the DEXA measurements at the desired region of interest (proximal neck femur) , because measurement of DEXA was technically unfeasible as neck of femur was moved inferiorly during hip flexion contracture than 30 degree, which prevent beam of x-ray to provide accurate scan of bone mineral content (13)(14). Internal metallic fixations within the measurement regions (femur neck and lumber vertebrae from L1 to L4), hypotonia, hyperthyroidism, or hypothyroidism.

Procedures

Tools for sample selection:

-Weight and height scale measurement.

It was used to assess weight in kilograms and height in centimeters to identify BMI (w/cm^2).

Percentile Growth curves for girls and boys:

It was used to identify BMI (underweight subjects were included only).

Goniometer:

It was used to measure hip joint angles (children were excluded if they had more than 30-degree fixed hip flexion).

The Gross Motor Function Classification System (GMFCS) between 6^{th} and 12^{th} birthday

It is a reliable and valid five-level ordinal classification system for measuring the age-related severity of gross motor limitations from CP, it is 5 levels from level 1 (children had mild limitations of higher functions as running) to level V(children lack head control and sitting balance), we included all levels at our study (15)**.**

Tools for assessment:

1- **Dual Energy X-ray Absorptiometry (DEXA)**

DEXA (DEXA bone densitometer MEDIX DR , Medilink, France) was used to measure bone density in neck of femur of both limbs (rt and lt) and lumber vertebra from L1-L4 of CP children (16)**.** DEXA Machine Description as shown in figure 1**.**

Figure (1): **Dual Energy X-ray Absorptiometry (DEXA)**

2- Gross Motor Function Measure (GMFM-88)

GMFM-88 is a specialized assessment tool designed to evaluate the functional level and progress in children with CP. It is one of the few standardized tests specifically developed to measure the functional abilities of this population. Its reliability, validity, and sensitivity to changes in gross motor function make it an essential instrument in both clinical and research settings (17).Structure of GMFM-88: The GMFM-88 consists of 88 items organized into five dimensions, each representing a different aspect of gross motor function. These dimensions are: Lying and Rolling (17 items): Sitting (20 items): Crawling and Kneeling (14 items): Standing (13 items): Walking, Running, and Jumping (24 items) (18).

Procedures for selection

1. Assessment of Body Mass I

BMI is a widely used screening tool that helps determine whether a child is at a healthy weight in relation to their height, BMI is interpreted using age- and sex-specific percentile charts known as growth charts. Growth charts are percentile curves that show the distribution of selected body measurements, such as weight, height, and BMI, in children from ages 2 to 19 years. These charts are essential tools used by pediatricians, nurses, and parents to monitor the growth and development of children and adolescents over time.For our study, only children who fall within the underweight category were included. This means their BMI must be Less than the 5th percentile for their age and sex. that is because most of children especially in GMFC 4 and 5 or cp children in form of quadriplegia and non-ambulant cp were usually underweight (19)

2. Assessment of Hip Flexion

The goniometer could simply measure the joint angles. Hip flexion is one of the hip motions that could be measured with a goniometer according to Yazdifar et al. (20)**.** If the hip flexion angle of any child after assessment by goniometer was more than 30-degree flexion, the child was excluded from the study.

3. Gross Motor Function Classification System

Each child could be allowed to perform functional activities without any interruption from the caregiver or therapist. The level of his or her activities was recorded using GMFCS according to his or her age. Children with diplegic and quadriplegic CP at all levels were included (15)**.**

Procedures for Assessment:

1- Assessment of bone mineral density using DEXA:

The DEXA technique was used to measure the bone mineral density of the neck of the femur (both right and left) and the lumbar vertebrae from L1 to L4. This method involves the emission of two low-dose X-ray beams with different energy levels aimed at the bones being measured. The difference in absorption of these beams by the bone and soft tissue was used to calculate BMD. During the test, each child lied on a padded platform while the scanner passes over the body without touching it, emitting radiation through the exposed part of the body (neck of the femur and lumbar vertebrae from L1 to L4). The equipment converts the information received by the detector into an image of the spine and femur, which was then analyzed to determine the quantity of bone. BMD is derived from BMC (gm) divided by the area of the bone measured (in cm^2). This value is crucial for determining bone strength and diagnosing conditions like osteoporosis. The results were presented as BMD and standardized scores (z-scores), which compare the patient's BMD to age- and sex-matched norms for normally developing children. A z-score of -2.0 or lower was typically considered indicative of low bone density (16)**.**

2- Assessment of gross motor function:

The motor function skills of all children in the study were be evaluated using the GMFM-88, a criterion-based observational measure. The test manual provides detailed descriptions and guidelines for scoring each item. Administering the GMFM-88 typically took around 45 minutes. Each GMFM item was scored on a 4-point scale:- 0: Cannot do, 1: Initiates, 2: Partially completes, 3: Completes the task.The scores for each dimension were summed to provide a dimension-specific score, and the overall score was obtained by summing the scores across all dimensions. A one-page score sheet was used to record

the results, following specific scoring guidelines provided in the test manual. A percent score was calculated for each dimension using the formula:

$$\text{Percent Score} = (\text{Child's Score} / \text{Maximum Score}) \times 100$$

This scoring method allows for a detailed and quantifiable assessment of each child's motor function abilities (17).

Statistical analysis

An unpaired t test was used to compare the characteristics of the participants between groups. The Fisher's Exact Test, also known as the Chi-Squared test, was utilized to compare categorical data between groups. The GMFCS was compared between groups using the Mann-Whitney test. The Shapiro-Wilk test was used to verify that the data was normal. To evaluate the homogeneity between groups, Levene's test for homogeneity of variances was used. An unpaired t-test was used to compare the BMD and GMFM-88 scores between the groups. The association between BMD and GMFM-88 was ascertained using the Pearson association Coefficient. All statistical tests were conducted with a significance level of $p < 0.05$. Version 25 of the Statistical Package for Social Sciences (SPSS) for Windows was used to conduct all statistical analyses.

Results

Subject characteristics

Thirty-five ambulant (group A) and thirty-five non-ambulant (group B) CP participated in this study. Subjects' characteristics were demonstrated in table 1. There was no significant difference between groups in age, weight, height, BMI, and sex distribution ($p > 0.05$). There was a significant increase in spasticity grade and GMFCS of group B compared with group A ($p < 0.001$).

Table 1. Basic characteristics of participants.

	Group A	**Group B**		
	Mean ± SD	**Mean ± SD**	**t- value**	**p-value**
Age (years)	8.17 ± 1.16	8.09 ± 1.01	0.29	0.76
Weight (kg)	19.46 ± 3.78	18.03 ± 3.69	1.60	0.11
Height (cm)	123.80 ± 9.07	121.94 ± 9.32	0.85	0.40

BMI (kg/m²)	12.52 ± 1.02	12.06 ± 1.55	1.49	0.14
	3 (3-2)	4 (5-4)		
GMFCS, Median (IQR)	Level1=5 Level II=5 Level III=25	Level IV=18 Level V= 17	0	0.001
Sex, n (%)				
Girls	14 (40%)	14 (40%)	($\chi^2 = 0$)	1
Boys	21 (60%)	21 (60%)		
Sspasticity grades, n (%)				
Grade I	5 (14.3%)	0 (0%)	(Fisher's Exact Test = 39.09)	0.001
Grade I+	19 (54.3%)	2 (5.7%)		
Grade II	11 (31.4%)	18 (51.4%)		
Grade III	0 (0%)	15 (42.9%)		

SD, standard deviation; χ^2, Chi squared value, p-value, probability value. IQR, inter quartile range.

Comparison of BMD, GMFM-88 between groups:

There was a significant increase in BMD of right and left femur and spine L1-L4 and GMFM-88 of group A compared with that of group B ($p < 0.001$) (Table 2).

Table 2. Comparison of BMD, GMFM-88 between group A and B:

	Group A	**Group B**			
	Mean ± SD	**Mean ± SD**	**MD**	**t-value**	**p value**
BMD (g/cm2)					

Right femur	0.58 ± 0.07	0.44 ± 0.09	0.14	7.01	0.001
Left femur	0.58 ± 0.05	0.45 ± 0.08	0.13	7.99	0.001
Spine L1-L4	0.44 ± 0.08	0.36 ± 0.07	0.08	4.25	0.001
GMFM-88	65.49 ± 11.81	20.89 ± 10.53	44.6	10.68	0.001

SD, standard deviation, MD, Mean difference, p-value, probability value

Relationship between BMD and GMFM-88

The correlation between BMD and GMFM-88 was moderate positive significant correlation with right femur BMD (r = 0.645, p = 0.001), left femur BMD (r = 0.678, p = 0.001), and with Spine L1-L4 (r = 0.452, p = 0.001) (Table 3).

Table 3. Correlation between BMD and GMFM-88:

	Right femur BMD		**Left femur BMD**		**Spine L1-L4 BMD**	
	r value	**p value**	**r value**	**p value**	**r value**	**p value**
GMFM-88	0.645	0.001	0.678	0.001	0.452	0.001

r value: Pearson correlation coefficient; p value: Probability value

Discussion

The main purpose of this study was to compare between ambulant and non-ambulant CP children in BMD and GMF, then study the relationship between BMD and GMF among CP children (ambulant and non-ambulant). This study aimed to examine the differences in BMD and GMF, between ambulant and non-ambulant children with CP, as well as to investigate the correlations among these variables. The findings revealed that children in the ambulant group (Group A) exhibited significantly higher BMD in the right and left femur and lumbar spine (L1-L4) compared to their non-ambulant (Group B). Additionally, the Gross Motor Function Measure (GMFM-88) scores were significantly higher in Group A than in Group B, reflecting better motor abilities in ambulant children. The study also found a moderate positive correlation between BMD (in the right and left femur, as well as the lumbar spine) and GMFM-88 scores, indicating that higher motor function is associated with improved bone health.

These results are in line with previous research suggesting that motor function plays a crucial role in enhancing the physical and psychosocial health of children with CP (21) (22). Additionally, the positive link between motor abilities and bone health may indicate the importance of maintaining mobility to prevent conditions like osteoporosis, which are common in children with limited physical activity (23)**.** These results align with prior research by Chen et al. (2012)**,** which showed that weight-bearing activities contribute significantly to bone strength in children with CP (24). On the other hand, non-ambulant children, due to prolonged immobility, experience reduced mechanical loading on bones, which may lead to lower BMD and a higher risk of fractures as they age. This reinforces the need for proactive interventions, such as physical therapy and tailored exercises, to alleviate the loss of bone density in non-ambulant children (22)**.** Interestingly, studies like those by Jung et al. (2018), which support the notion that maintaining any level of physical activity in CP children, even if minimal, can have a profound effect on bone health (12). However, our results differ somewhat from research conducted by Yoon et al. (2012), who found no significant improvement in BMD with mobility training in some non-ambulant children (25). This suggests that while mobility and weight-bearing activities generally benefit skeletal health, the degree of impact may vary depending on the severity of the child's physical limitations and the type of interventions applied (26)**.** In comparing ambulant and non-ambulant children with CP, our findings highlight that mobility has an impact on physical health and overall quality of life QOL. Children who are able to walk independently (Group A) not only showed better BMD but also demonstrated greater gross motor abilities compared to their non-ambulant peers (Group B). This supports understanding that movement and weight-bearing activities are essential for healthy bone development. In children with CP, maintaining mobility, even at minimal levels, could be a crucial factor in preventing long-term complications such as osteoporosis or bone fractures, which are common in this population due to reduced physical activity (27). By contrast, non-ambulant children are more likely to experience secondary complications, such as contractures, pressure sores, and poor cardiopulmonary function due to prolonged immobility. This suggests that promoting even minimal movement could play a fundamental role in preventing some of these complications (28)**.** However, it's worth noting that not all studies fully support the connection between motor function and improved bone health. For example, Dalén et al. (2010) found that some non-ambulant children with high levels of muscle spasticity did not exhibit significant improvements in BMD despite increased physical activity (29). This suggests that the relationship between motor function and bone health may not be straightforward and could be influenced by other factors, such as muscle tone, nutritional status, and the severity of the neurological impairment. These contrasting results point to the need for further research to fully understand how best to support bone health in non-ambulant children with CP (25).

The moderate positive correlation between BMD and motor function (as measured by GMFM-88) suggests that improving mobility in CP children could have a direct impact on their skeletal health. This relationship highlights the potential benefits of early physical interventions aimed at preserving or enhancing mobility. Physical therapy and adaptive equipment that promote weight-bearing exercises may not only improve motor abilities but also contribute to stronger bones, reducing the risk of future fractures. Another important aspect of our findings is the moderate correlation between bone health and motor function, which highlights the interplay between mobility and skeletal development. This is supported by previous research from Han et al. (2017), who showed that children with higher motor function not only have stronger bones but are also at reduced risk for fractures and other bone-related conditions as they age. This positive link reinforces the idea that improving motor function, even incrementally, could have far-reaching benefits for a child's overall physical health (30). Our study's Gross Motor Function Measure (GMFM-88) results for ambulant children shown a significant improvement, which is in line with the body of literature currently in publication. Novak et al. (2020) found that children with higher levels of mobility generally perform better on the GMFM-88 scale. This is because ambulant children often engage more in physical therapy, which enhances their muscle strength, coordination, and overall motor abilities (31). This finding is supported by research from Livingstone and Field (2014), which emphasizes the positive impact of mobility on social interactions and participation in everyday life. Ambulant children are often able to engage more freely with peers, participate in group activities, and navigate their environments more independently, all of which contribute to a higher sense of self-worth and life satisfaction (32).Lastly, while this study underscores the physical advantages of being ambulant, it also highlights the broader issue of healthcare access for children with CP. Our findings show that ambulant children had better access to healthcare services, a factor that could influence not just their physical outcomes but also their overall quality of life. This suggests that non-ambulant children might be facing barriers to healthcare, whether due to physical limitations, logistical challenges, or even socio-economic factors. Studies by Davis et al. (2006) corroborate this, showing that children with more severe physical limitations often face greater difficulties in accessing specialized care. Addressing these disparities is crucial in ensuring that all children, regardless of their mobility status, receive the healthcare and rehabilitation services they need (33).

Study Implications

This study provides valuable insights into the differences between ambulant and non-ambulant children with CP concerning BMD and GMF. The findings suggest that ambulant children exhibit significantly

higher BMD and motor function, emphasizing the role of mobility in maintaining skeletal health and physical abilities. These results suggest that promoting mobility through physical therapy, adaptive equipment, and weight-bearing activities is crucial for both ambulant and non-ambulant children to improve long-term health outcomes.

Study Limitations

The study's shortcomings should be taken into account when evaluating the findings. First, there is a chance that the sample size was insufficient to adequately reflect the heterogeneity within the CP population, which would have limited how broadly the results could be applied. Second, the cross-sectional design of the study makes it difficult to determine if motor function, BMD, and overall health outcomes are causally related. Confirming the long-term impact of mobility programs on bone health would require longitudinal research. Furthermore, the study did not take into consideration additional variables that could affect both motor performance and bone health, such as dietary condition or the degree of neurological impairment. These factors should be investigated in future studies to give a more thorough understanding of the connection between mobility and health.

Conclusion

This research adds to the increasing amount of data showing how mobility benefits children with CP in terms of their physical health and quality of life. The results imply that children who can walk have improved bone health and motor function, most likely as a result of the advantages of weight-bearing exercises.

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