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The Relationship Between Bone Health and Nutrition in Children with Cerebral Palsy

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ABSTRACT
Cerebral palsy (CP) is a non-progressive motor disorder resulting from damage to the developing brain, primarily affecting motor functions. It occurs in approximately 2–3 out of every 1,000 live births. Prenatal, perinatal, and postnatal factors can contribute to its development. Children with CP often experience feeding difficulties due to conditions such as dysphagia, gastroesophageal reflux, and nausea. These issues can lead to inadequate intake of energy, protein, vitamins, and minerals, which in turn negatively affect bone health by increasing the risk of conditions like osteoporosis and fractures. In non-ambulatory children with CP, bones are not subjected to sufficient mechanical loading, which leads to decreased bone mineral density (BMD). Studies have shown that children with quadriplegic CP have significantly decrease BMD, and a positive correlation exists between low BMD and vitamin D deficiency. Nutrition plays a key role in managing CP and supporting optimal bone development. Particular attention should be given to vitamin D and calcium intake, which are essential for bone health. However, nutritional care is often overlooked in this population. Therefore, individualized nutritional therapy should be planned and monitored by both physicians and dietitians to prevent deficiencies and support overall health in children with CP.

1. INTRODUCTION

Cerebral palsy (CP) is a non-progressive musculoskeletal disease that occurs in childhood and is accompanied by damage to the brain, and is particularly common in underdeveloped countries. The prevalence of CP varies between countries. The general acceptance is that it is seen in 2-3 births in 1000 live births. Approximately 35% of CP cases are associated with premature birth, but prenatal factors also play a significant role in the etiology of the disease. The pathophysiology of CP has not been clearly identified, and research on this subject is ongoing [1].

In most cases, the diagnosis of CP is made between 12 and 24 months of age. However, earlier diagnosis can have a positive impact on disease management. Children with CP are at nutritional risk due to various factors that prevent their needs from being adequately met. Malnutrition is frequently observed in individuals with CP, leading to energy and nutrient deficiencies. These deficiencies can adversely affect bone health and significantly reduce quality of life [2].

It should be acknowledged that body composition in individuals with CP may differ from the general population. Therefore, using a single parameter to assess nutritional status is not appropriate. In cases where undernutrition and impaired bone health are present, careful monitoring is necessary. Since individuals with CP are more prone to bone health deterioration, adequate intake of vitamin D and calcium is particularly important. Meeting these nutritional needs reduces the likelihood of developing bone-related diseases [2].

Given the importance of appropriate nutrition in the management of CP, scientific studies should focus on determining the specific nutritional needs of this population. Identifying deficiencies accurately enhances the effectiveness of treatment. Therefore, the aim of this review is to evaluate the relationship between nutrition and bone health in children with CP in light of current literature.

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2. CEREBRAL PALSY (CP)

CP is a disability condition commonly seen in childhood, caused by damage to the developing brain due to various factors, and primarily affects motor functions. The condition was first described in 1843 by William John Little, and therefore it has also been referred to as "Little's disease." [**3**].

CP is a non-progressive disorder that results from brain damage occurring during the prenatal, perinatal, or postnatal period and affects both the neurological and musculoskeletal systems. These impairments can lead to postural abnormalities, limitations in physical activities, and may also be accompanied by sensory and perceptual difficulties Studies have shown that as children grow older, maturation of bodily systems may lead to improvements in certain symptoms [3].

2.1. Etiology and Pathophysiology

The causes of CP are categorized into three main periods: prenatal, perinatal, and postnatal. Studies have demonstrated that factors present during these periods are closely associated with the development of CP. Although various factors are known to contribute to the condition, the specific etiology of all cases cannot always be clearly identified [1,4].

When all cases of CP are considered, approximately 75% of the etiological factors originate from prenatal causes, while 10–18% are associated with perinatal and postnatal factors. One of the most prominent and frequently observed risk factors for CP is premature birth. In general, the frequency and severity of neurodevelopmental disorders are directly related to the length of gestation. A shorter duration of pregnancy increases both the incidence and severity of neurodevelopmental impairments [5].

2.2. Types of CP

Following the diagnosis of CP, various clinical symptoms may be observed. Based on these clinical findings, various classification systems have been developed depending on the type of movement problem, the affected area, and the severity of brain damage [3].

CP is categorized into spastic, dyskinetic, and ataxic types according to the nature of the motor dysfunction. It is also sub-classified based on the distribution of motor involvement as quadriplegic, diplegic, hemiplegic, or monoplegic, depending on whether the condition affects one side or both sides of the body [3].

3. CP AND NUTRITION

Several factors influence the course of CP. Nutrition, an element that can either prevent or positively affect the symptoms and disorders associated with the condition, is a major component in this patient group. Proper nutrition has a positive impact on the quality of life and life expectancy of patients. Nutritional deficiencies are highly prevalent among children with CP. This group of patients is particularly prone to malnutrition. A study conducted by researchers in Turkey found that the rate of malnutrition in children with CP was 94.3%. This highlights the importance of addressing nutrition as a significant factor [6].

The degree of problems in the musculoskeletal system may play a decisive role in determining the necessary energy intake of children with CP. It is thought that children with CP who use a wheelchair require 60-70% of the energy intake needed by those who can walk independently. Research findings have shown that children with motor impairments are unable to meet their energy and nutrient requirements adequately. Researchers studying the diet of children with CP have shown that these children consume high amounts of cooked vegetables, flour products, rice and sugary drinks [7].

Inadequate protein intake among children with CP leads to various issues. The degree of movement limitation correlates with the GMFCS level and increases as motor function declines. The reduction in mobility leads to muscle atrophy and shortening of muscle length. In such cases, the protein requirements of children with CP are higher compared to healthy children [8].

The American Society for Parenteral and Enteral Nutrition (ASPEN) provides recommendations and criteria for assessing nutrition in children with CP. According to the society's guidelines, anthropometric Z-scores and upper arm circumference measurements should be considered when evaluating the nutritional status of this patient group [9].

3.1. Vitamins and Minerals

Patient groups with neurological disorders are at risk for insufficient intake of both macro and micro minerals. In this patient group, feeding treatments with low calorie intake to avoid excessive energy intake may predispose to the development of certain vitamin and mineral deficiencies. In a study conducted to determine the vitamin and mineral levels in children diagnosed with CP, children who did not consume additional nutritional supplements were found to have higher deficiencies in vitamin D, iron, calcium, and folate

compared to those who consumed supplements. This indicates that this patient group needs supplementation in terms of vitamins and minerals [10].

Children with CP generally constitute a group with low bone mineralization, which is a risk factor for bone fragility. In this patient group, ensuring adequate daily intake of vitamins and minerals like vitamin D and calcium, and managing deficiencies with appropriate nutritional interventions, positively impacts bone health [11].

Vitamin D is an essential vitamin that plays a significant role within cells. Its requirements are mostly met through exposure to sunlight, although some foods also contain vitamin D. Vitamin D has effects on the development of many diseases. Additionally, it plays a role in the utilization of other minerals obtained through food. For instance, vitamin D acts as a mediator in making calcium and phosphate, consumed through food, usable in the body. The positive effects of these vitamins and minerals on bone health have been demonstrated in studies. The pivotal role of vitamin D in these processes suggests its key role in maintaining bone health. Studies conducted by researchers have shown that the vitamin D intake of children with CP is not at a level sufficient to meet their needs. The rate of deficiency varies among children with CP in different countries [12].

In a study conducted in Turkey in 2018, it was found that 33.6% of 235 children diagnosed with CP had vitamin D levels below the recommended reference value [13]. This, in turn, predisposes patients to calcium deficiencies. Deficiencies in vitamins and minerals negatively impact bone health in children with CP, creating a foundation for the development of bone diseases such as osteopenia and rickets. In this patient group, the risk of bone fractures is high even with minor impacts [12].

Calcium plays a role in cellular signaling, the transmission of nerve impulses between neurons, and the muscle contraction mechanism. The free calcium within cells is the biologically active form. Two key hormones are involved in regulating its concentration in plasma: parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D [14].

Based on the findings obtained from studies conducted by researchers, it is important to consider the relationship between vitamin D levels and bone health in this patient group. By meeting their requirements, it should be aimed to positively influence the clinical course of the disease and quality of life.

In one study, high parathyroid hormone levels were observed in 8 cases. Insufficient calcium intake was associated with elevated parathyroid hormone levels and decreased phosphorus levels. Another key factor contributing to the increase in parathyroid hormone levels is the reduction in vitamin D levels. This study confirms this relationship. Therefore, the calcium-phosphorus-vitamin D-parathyroid hormone cycle significantly affects bone mineralization. Due to limited physical activity in CP patients, this cycle must be supported, and nutrition therapy should be planned considering these multifactorial mechanisms [13].

4. BONE HEALTH IN CHILDREN WITH CP

Children diagnosed with CP are at risk for impaired growth and development due to disruptions in motor functions. Increases in the severity of motor dysfunction reflected by higher levels in the GMFCS negatively influence physical development. In addition to motor impairments, the presence of factors that adversely affect nutritional intake further contributes to the development of malnutrition in these individuals. In children with CP, inadequate nutrition does not only impair bone health; it can also negatively impact social life, lead to delays in educational attainment, cause problems with attention, and contribute to insufficient social interactions [15].

There are three important factors in the assessment of bone health in children with CP . These are: bone length, bone density, and bone growth. Studies conducted on children with CP have shown that in cases with poor nutritional status, bone mineralization is reduced in both the outer regions of the femur and the lumbar vertebrae. In addition to nutrition, another significant factor affecting bone health is the use of medications. Specifically, antiepileptic drugs, frequently used by individuals with CP due to the common comorbidity of epilepsy, have been shown to negatively influence bone health [15].

Another crucial factor in bone health is mobility. Depending on the type of CP involvement, some children are ambulatory while others are non-ambulatory. The most significant factor affecting bone health between ambulatory and non-ambulatory children is whether or not the bones are subjected to mechanical loading. Under normal circumstances, bone health is maintained through a balance of osteoblastic and osteoclastic activity, which helps shape and remodel the bone. Predominant osteoblastic activity indicates increased bone formation, whereas an increase in osteoclastic activity leads to decreased bone mass. In children with CP who are wheelchair-dependent, the lack of regular mechanical loading negatively affects bone mineralization [15].

5. THE RELATIONSHIP BETWEEN NUTRITION AND BONE HEALTH IN CHILDREN WITH CP

Ensuring optimal nutrition in children diagnosed with CP can have a significant impact on various aspects of health, including physical well-being and psychological wellness. Nutritional interventions should be tailored according to the patient's symptoms and must meet their daily energy and nutrient requirements. Although oral feeding is the most physiologically appropriate method, feeding via tubes may be necessary in CP patients due to frequent problems such as chewing and swallowing difficulties [16].

In a study conducted on this patient group, inadequate nutrient intake in children with quadriplegic-type CP was found to increase the likelihood of low bone mineral density by nine times. Therefore, ensuring adequate nutritional intake is crucial for bone health in this population [16].

In another study conducted on children diagnosed with CP, when children with normal and low bone mineral density were compared, it was observed that vitamin D deficiency and low bone mineral density were closely associated and appeared to reinforce each other. Inadequate vitamin D levels adversely affect calcium bioavailability in the body, which in turn stimulates the secretion of parathyroid hormone, triggering a complex and interrelated physiological response [17].

Further research has confirmed that mineralization deficits tend to worsen during growth (compared to healthy children of the same age), highlighting the urgent need for preventive interventions. It has been found that combined calcium and vitamin D supplementation, weight management, and monitoring of pubertal development have a positive effect on overall bone health in children [18].

6. Conclusion

Children diagnosed with CP may experience various gastrointestinal comorbidities such as dysphagia, gastroesophageal reflux, nausea, and vomiting, which can negatively impact their ability to meet energy and protein requirements. In CP, the nutritional needs of children may vary depending on the overall condition of the patient. Inadequate intake of vitamins and minerals is common among children with CP. Insufficient intake of vitamin D and calcium leads to decreased levels of these nutrients, which in turn contributes to poor bone health.

Particularly in children with quadriplegic CP, immobility significantly impairs bone health. In conclusion, the fracture rate in this group is higher compared to children with other types of CP. Bone health in children with CP should be closely monitored, and appropriate nutritional therapy should be provided to meet their needs. It is essential that healthcare professionals possess adequate knowledge in this area. The post-diagnosis management of CP requires a multidisciplinary team approach.

Nutritional plans should be developed by a dietitian to ensure that the child's energy and nutrient needs are met. In addition to healthcare professionals, the involvement of family members in providing psychological support to the child is also important. In conclusion, nutrition has a critical role in CP treatment and is sometimes overlooked. Considering its potential impact on the onset of various complications, it is vital that appropriate nutritional interventions be implemented by qualified health professionals to improve the quality of life of affected individuals.

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Conflict of Interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Author Contributions

Conception and design of the study: BÖK and BNB; Data collection: BÖK and BNB; Data analysis: BÖK and BNB; Data Interpretation: BÖK and BNB; Drafting the article and/or its critical revision: BÖK and BNB; All authors have read and agreed to the published version of the manuscript.

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