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Consequences of overweight and obesity on the musculoskeletal system in children: a review of recent literature

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Abstract
Childhood overweight and obesity are global health concerns, affecting millions of children and contributing to long-term musculoskeletal complications. This review examines the impact of excess body weight on bone health, posture, motor performance, and injury risk. Overweight and obesity increase mechanical stress on bones and joints, leading to pain, postural abnormalities, and higher fracture susceptibility. Despite increased bone mineral density (BMD), the obesity paradox highlights a paradoxical rise in fracture risk. Hormonal imbalances, chronic inflammation, vitamin D deficiencies, and reduced physical activity further exacerbate musculoskeletal challenges. Additionally, obesity-related postural changes and decreased motor function contribute to inactivity and worsening health.
This literature review was conducted using PubMed searches, selecting articles published in the last five years to ensure up-to-date findings. Keywords such as "obesity in children," "musculoskeletal system," "bone health," "posture," and "physical activity" were used. Original studies, meta-analyses, and systematic reviews were analyzed. Preventive measures, including dietary interventions, regular exercise, and early therapeutic strategies, are essential to mitigating the long-term effects of childhood obesity. Future research should focus on targeted interventions to improve musculoskeletal health and overall well-being in affected children.

Keywords: obesity, musculoskeletal system, childhood overweight, chronic inflammation, vitamin D, injury risk

1. Introduction

Obesity and overweight among children represent a global health challenge that has reached epidemic proportions in recent decades. The World Health Organization (WHO) highlights that the rate of childhood obesity is increasing at an alarming pace. These issues affect children across all age groups-from preschoolers to high school students. According to the WHO report from 2022, 37 million children under the age of five were overweight, while among older children (up to 19 years of age), 390 million had excess body weight, with 160 million suffering from obesity. This phenomenon carries consequences beyond physical health, encompassing social and emotional aspects such as stigmatization and difficulties in peer integration. Factors such as globalization, easy access to unhealthy food, lack of health education, and limited opportunities for physical activity in urban environments contribute to the escalation of this problem [1].

The musculoskeletal system, comprising bones, muscles, and joints, plays a crucial role in children's overall development. Obesity may contribute to increased mechanical load, leading to issues such as joint pain, reduced mobility, and postural deformities. Overweight and obese children are also at greater risk of injuries and chronic orthopedic disorders. In the context of aging societies, where skeletal health in adulthood is of paramount importance, preventive interventions in childhood are a key element of public health strategies [2].

The aim of this review paper is to analyze the available scientific evidence regarding the impact of overweight and obesity on the development of the musculoskeletal system in children, identifying potential research gaps and providing recommendations for prevention and treatment.

2. Results

2.1 Development of the musculoskeletal system

Adolescence is a crucial period for bone development, as nearly half of an individual's bone mass is formed during this stage [2]. Although peak bone mass is not entirely modifiable (60-80% is determined by genetic factors, while the remainder depends on hormonal balance and modifiable environmental factors such as body weight, diet, and physical activity [3]) ensuring proper skeletal development is essential. This, in turn, reduces the risk of osteopenia, osteoporosis, and fractures in adulthood [2,4].

Children with abnormal body weight exhibit the so-called "obesity paradox," in which overweight increases bone mineral density (BMD) while simultaneously being positively correlated with a higher risk of fractures. The increased BMD observed in obese children may result from a greater lean body mass, which imposes a higher mechanical load on bones, stimulating their formation. Interestingly, this association is more pronounced in girls, highlighting the need for further research on the impact of sex on BMD in childhood [5,6].

However, excess fat, particularly central adiposity, may have the opposite effect - reducing BMD in the lumbar spine region, which can contribute to bone-related issues later in life, especially in cases of persistent obesity [2,4]. Moreover, after puberty, hormonal changes may reverse the positive correlation between fat mass and bone density [3].

Vitamin D, a fat-soluble vitamin, can be sequestered by adipose tissue, explaining its lower levels in overweight individuals. Additionally, limited sun exposure due to excessive screen time exacerbates this problem [7]. Vitamin D deficiency, chronic inflammation, reduced physical activity, and insulin resistance can further impair bone synthesis and increase bone resorption [8,9]. Other studies have demonstrated an increased risk of adolescent slipped capital femoral epiphysis (SCFE), Blount's disease (tibial varus), and genu varum (bowleg deformity) in obese children [10,11].

Overweight and obesity also increase the prevalence of obstructive sleep apnea (OSA). Hypoxia, a characteristic feature of this syndrome, contributes to increased osteoclast activity, leading to greater bone resorption. A positive correlation has been observed between OSA during adolescence and reduced peak bone mass, which may predispose individuals to osteopenia and osteoporosis [12].

2.2 Postural abnormalities

Obesity significantly affects postural development and musculoskeletal health in children. Overweight children are approximately 1.5 times more likely to develop postural abnormalities. Excess weight contributes to postural imbalances such as lumbar hyperlordosis, thoracic kyphosis, genu valgum, and flatfoot due to compensatory mechanisms in overloaded joints and muscles [13,14,15]. Limited mobility of the spine and hip joints has also been documented [16]. These postural abnormalities often arise during critical growth periods, such as early school years and puberty, when the body is particularly susceptible to structural deformation.

Low levels of physical activity, prolonged sedentary behavior, and improper postural habits further exacerbate these issues, increasing the risk of back pain, balance disorders, and functional limitations in adulthood. Early intervention strategies, including the promotion of physical activity, are crucial for mitigating these consequences [14,15].

2.3 Motor performance and coordination

Excess body mass disrupts biomechanical balance, forcing the somatosensory system to adapt to altered postural conditions. As a result, physical activities that require such adaptations become particularly challenging for obese children [17]. Studies have demonstrated a correlation between higher fat mass percentage and lower levels of moderate-to-vigorous physical activity. Obesity is associated with impaired motor performance, including a reduced ability to perform dynamic movements (e.g., long jumps, short-distance sprints), diminished balance, and lower muscle strength. Performance declines have been measured using tests such as the Timed Up and Go (TUG), Six-Minute Walk Test (6MWT), and Timed Up and Down Stairs (TUDS) [13]. Notably, obese children exhibit reduced muscular strength and a diminished capacity for high-effort physical activities.

Decreased physical activity leads to impaired motor skills, fostering a sedentary lifestyle and perpetuating a cycle of physical inactivity [14,18]. Early intervention through individually tailored physical activity programs is essential to prevent motor dysfunctions associated with obesity [19].

2.4 Injury incidence

Weight gain in obese individuals may have a positive effect on bone health, as moderate mechanical stress can support bone formation processes. From a clinical perspective, increased bone density may provide a protective effect, reducing the risk of leg fractures; however, this protective effect does not extend to spinal fractures [20]. Despite the observed increase in bone density among obese children, research has demonstrated that they have a higher risk of fractures. The strongest evidence pertains to limb fractures, including tibial fractures, resulting from low-energy trauma, which occurs twice as frequently in obese children compared to their peers with normal weight or underweight [3,21,22]. Not only does the frequency of injuries increase, but their severity also escalates-compared to children with a healthy body mass, obese children experience complete fractures more often [2,23]. What accounts for this paradox? While some studies suggest that excess weight enhances bone quality, others indicate an inverse correlation [10,21]. Additionally, excessive body weight alters body mechanics, leading to movement difficulties such as slower gait, shortened and widened steps to enhance stability, and reduced balance, all of which contribute to an increased risk of falls [14].

Table 1. Impact of overweight on the musculoskeletal system in children.

Aspect	Mechanism	Health Consequences	References
Increased mechanical load	Greater body mass exerts higher pressure on joints, including knees and hips	Joint pain, reduced mobility, postural deformities	10, 13, 14, 18
Chronic inflammation	Higher adipose tissue levels promote inflammatory processes in the body	Bone tissue damage, increased risk of osteoporosis, reduced quality of life	8, 21
Hormonal disorders	Obesity may lead to insulin resistance and decreased vitamin D levels	Increased fracture risk	3, 7, 8, 9
Increased risk of injuries	Altered body mechanics, higher risk of falls	Limb fractures, balance problems, reduced physical fitness	2, 3, 10, 14, 21, 22, 23
Postural abnormalities	Compensatory postural changes due to excessive body weight	Hyperlordosis, flatfoot, kyphosis	13, 14, 15, 16

2.5 Consequences in adulthood

It is estimated that at least 40% of children and 70% of adolescents with obesity will remain obese in adulthood, which will have negative health consequences and contribute to an increased burden of diseases. A key factor here is that dietary, physical activity, and postural habits are shaped during adolescence, and most young people maintain these habits into adulthood [24]. A study conducted by D. Ying and M. Ying demonstrated a causal relationship between childhood obesity and an increased risk of osteoporosis in adulthood, highlighting the long-term consequences of early excess weight on bone health.

Analysis using the MR method revealed a statistically significant, albeit small, increase in osteoporosis risk, which is relevant at the population level [4]. Other studies indicate an increased risk of developing osteoarthritis, particularly in the knee joints, which are subjected to heavy loads [10]. These findings highlight the need for early weight management interventions to prevent future musculoskeletal problems.

2.6. Effects of weight loss

A review examining the impact of weight loss on bone health in children noted that while weight loss in adults is associated with reduced bone mineral density (BMD) and an increased risk of fractures, the effects in adolescents are less clear. Some studies among obese adolescents have shown that weight loss did not significantly alter total body bone mineral content (BMC) or BMD of the spine, while in some cases, it even led to a reduction in limb bone mass. Other studies indicate that weight reduction in obese children before puberty leads to positive changes in BMC and BMD, although some bone health markers decrease with significant weight loss. The impact of physical activity, particularly the combination of aerobic exercise and resistance training, is beneficial for bone health, supporting both mineralization and bone strength. Regular physical activity, including weight-bearing exercises, helps improve lean body mass and reduce fat content. However, differences in study designs, sample sizes, and dietary habits pose challenges in determining the full impact of weight loss on bone development [3]. Findings from a study by S. López-Peralta et al. highlight the key role of muscle mass in maintaining healthy bones and emphasize the importance of physical activity in preventing obesity-related problems and promoting skeletal health [5]. Encouraging regular physical activity remains a crucial strategy for maintaining bone strength while also addressing obesity and its associated metabolic disorders in children [3,25].

3. Proposals for future research

Future research on the impact of obesity on the musculoskeletal system in children should focus on several key areas. First, it is essential to conduct a detailed analysis of how excessive body mass affects individual components of the musculoskeletal system, such as bones, joints, and muscles, across different age groups and in the context of sex differences. Such studies may contribute to a better understanding of the mechanisms leading to postural deformities, early degenerative changes in joints, and reduced bone mineral density.

Another crucial research area involves assessing the long-term effects of weight loss in children with obesity, particularly regarding the regeneration of the musculoskeletal system and potential risks associated with weight reduction. Therefore, it will also be important to investigate the effectiveness of various interventions - both medical and preventive - in improving musculoskeletal function in overweight children.

Additionally, future research should explore the impact of different types of physical activity and dietary interventions on bone and joint health to develop optimal treatment and prevention strategies for pediatric obesity. These studies will contribute to the establishment of improved guidelines for managing and preventing obesity-related musculoskeletal issues in childhood.

4. Conclusion

Childhood overweight and obesity pose a significant public health challenge due to their long-term impact on musculoskeletal development, quality of life, and future health risks. The evidence reviewed indicates that excess adiposity during development can lead to numerous biomechanical and metabolic disturbances.

Excess weight is linked to increased mechanical stress on the musculoskeletal system, resulting in joint pain, postural deformities, and chronic orthopedic conditions. The obesity paradox, whereby increased BMD coexists with a heightened risk of fractures, highlights the complexity of this phenomenon. Underlying mechanisms include altered hormonal activity, inflammation, vitamin D deficiency, and reduced physical activity. Postural abnormalities and diminished motor capacity further restrict children's ability to lead an active lifestyle, perpetuating a vicious cycle of declining health.

The consequences of childhood obesity extend into adulthood, increasing the risk of osteoporosis, osteoarthritis, and metabolic disorders. Preventive interventions, including a balanced diet, regular physical activity, and reduction of sedentary behaviors, are essential for improving children's health.

While weight loss improves overall physical fitness and mitigates metabolic complications, its impact on bone health in children remains debated. Some studies suggest that significant weight reduction may negatively affect BMD, underscoring the necessity for comprehensive interventions combining weight management, physical activity, and proper nutrient supplementation.

Despite significant research, many aspects of this issue require further investigation. Collaborative efforts among researchers, healthcare professionals, and public health specialists are crucial in developing effective strategies for the prevention and treatment of childhood obesity-related musculoskeletal complications.

Supplementary Materials: Table 1. Impact of overweight on the musculoskeletal system in children.

Disclousure

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