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Other Review

Paediatric obesity, physical activity and the musculoskeletal system

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Summary

The current epidemic of paediatric obesity is consistent with a myriad of health-related comorbid conditions. Despite the higher prevalence of orthopaedic conditions in overweight children, a paucity of published research has considered the influence of these conditions on the ability to undertake physical activity. As physical activity participation is directly related to improvements in physical fitness, skeletal health and metabolic conditions, higher levels of physical activity are encouraged, and exercise is commonly prescribed in the treatment and management of childhood obesity. However, research has not correlated orthopaedic conditions, including the increased joint pain and discomfort that is commonly reported by overweight children, with decreases in physical activity. Research has confirmed that overweight children typically display a slower, more tentative walking pattern with increased forces to the hip, knee and ankle during 'normal' gait. This research, combined with anthropometric data indicating a higher prevalence of musculoskeletal malalignment in overweight children, suggests that such individuals are poorly equipped to undertake certain forms of physical activity. Concomitant increases in obesity and decreases in physical activity level strongly support the need to better understand the musculoskeletal factors associated with the performance of motor tasks by overweight and obese children.

Keywords: Childhood, orthopaedic, overweight, physical function.

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Introduction

Obesity is the most common chronic illness in Western countries (1), and the prevalence of paediatric obesity is rising significantly worldwide. Globally, it has been estimated that approximately 10% of all school-aged children become overweight (2), and in the United States, the prevalence of paediatric obesity has more than doubled since 1980 (3). Correspondingly, significant increases have been reported for Canada, Chile, Brazil, Egypt, Morocco, Tunisia, Cyprus, Saudi Arabia, Australia, Japan and China (2). Paediatric obesity has also increased throughout Europe, with the highest prevalence seen in Portugal (4), Spain, Italy, Sicily and Greece (2). Because of the substantial increases in worldwide prevalence, public health officials have consistently referred to paediatric obesity as a serious 'epidemic' (1,5). The consequences of paediatric obesity are far-reaching and include all aspects of health. This review focuses on the specific implications of paediatric obesity on the musculoskeletal system and the resulting decline in physical activity within this population (Fig. 1).

Orthopaedic complications in paediatric obesity

A commonly reported consequence of being overweight in the paediatric population is the greater impairment of mobility that may result in several orthopaedic conditions (6). Early maturation is often associated with increased fatness, and overweight children are commonly taller and have a more advanced bone age (7,8). Total bone mineral

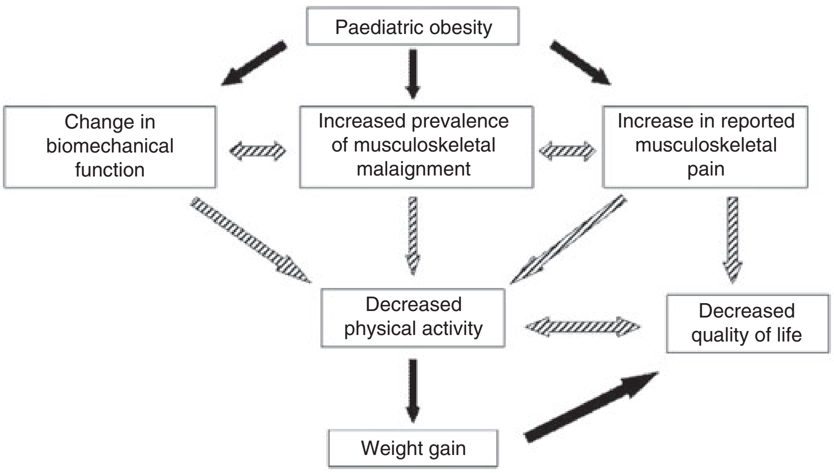

Figure 1 Implications of paediatric obesity on the musculoskeletal system and physical activity. Solid arrows represent correlations shown in previous research. Striped arrows represent associations that need to be investigated in future research.

content has a positive relationship with fat mass and fat-free mass; however, there is a much stronger association with the latter (9). A quantitative computed tomography study in healthy children suggested that weight-bearing and mechanical stresses are important determinants for increasing cortical bone mass (10) and creating higher absolute bone mineral content in overweight children. However, the increased bone density is insufficient to overcome the significantly greater forces found in overweight children (11,12). This leads to a disparity between high body weight and bone development that results in less predicted bone mineral content and bone area (11,13). The consequence is especially dangerous in the spinal column, as overweight girls have 8% less bone mineral in the lumbar spine for bone area (14,15). Approximately one-third of 65 studies reviewed presented a statistically significant positive correlation between weight and low back pain (14,16). The excessive loads and associated stress on the lumbar spine diminishes as adiposity decreases (14).

Increased fat mass and body mass index (BMI) are also associated with an increased risk of fractures during childhood (17–20). Several factors have been postulated for the higher risk of skeletal fracture in the overweight paediatric population. If an increase in excess weight occurs during the period where the density ratio between the metaphysis and the diaphysis is the lowest, there is an increased risk of fracture. When bone growth and development cannot adequately cope with the excess weight, a dissociation between longitudinal growth and mineral accrual occurs (14,15,21). The dissociation alters bone quality and increases bone fragility (14,21). In addition, lack of exercise adversely affects bone mineral accrual and can further exacerbate the obesity problem and the increased risk of fracture (13,14,22). While there is no data to confirm that overweight children fall more frequently than normal-weight individuals, it has been suggested that they fall with more force and in more awkward positions (14,15). Regardless of the contributing factors, a higher fat mass can increase the risk of skeletal bone fracture twofold (13,20).

In the first cohort to examine the musculoskeletal consequences of paediatric obesity, Taylor *et al.* (12) found anatomical implications for the lower extremity, including a higher prevalence of abnormal lower extremity alignment. The detrimental effects of paediatric obesity on the musculoskeletal system within the lower extremity extend to the hip, knee and ankle (23,24). In children and adolescents between 10 and 17 years, obesity causes an increased load to the cartilaginous growth plate of the femoral head that creates compressive and shear forces on this growth plate for longer time periods. The additional force on the femoral neck can exceed failure loads of the proximal femoral physis and result in slipped capital femoral epiphysis (25,26). The age of slipped capital femoral epiphysis diagnosis decreases with increasing obesity (14,27), and accordingly, the problem is recognized as a health risk for overweight children (12,28,29). Of 1337 children assessed with slipped capital femoral epiphysis, 51.5% and 11.7% had a BMI greater than the 95th and 90th percentile for their age and gender, respectively (27). Other studies have reported the prevalence of obesity in slipped capital femoral epiphysis patients to be as high as 72% (25).

The knee is the most common site for musculoskeletal pain in the overweight paediatric population (12), and knee joint position and alignment are crucial aspects to joint trauma and injury inflicted by excess mass. It has been suggested that a change in the force distribution within the knee joint can increase the progression of osteoarthritis in the obese population (30). Because dynamic gait deviations in obese children result in pathological and compressive forces in the medial compartment of the knee, even a mild malalignment can increase musculoskeletal discomfort in the overweight paediatric population (6,12,30,31). Bilateral measurements of the metaphyseal–diaphyseal angle in the tibia, as well as intermalleolar distance measurements, indicate a significantly higher prevalence of valgus alignment in overweight children when compared with normal-weight counterparts (12,32). Valgus alignment, or genu valgum, affects the overweight child during walking through increased support time and decreased velocity and cadence. Within the kinetic chain, genu valgum will also cause the position of the tarsus to be distorted, which will clinically present as greater step width (33). Overweight children who are predisposed to varus alignment will have exacerbated symptoms because of the excess load on the medial compartment. Dynamic loading with excess weight can create forces of a sufficient magnitude to alter physeal growth and lead to tibia vara (14,28,30). Tibia vara is the term commonly used to describe Blount's disease in the adolescent, a skeletal disorder that affects the medial side of the tibial epiphysis (14,28,30). The overweight child with physiologic genu varum has abnormal weight-bearing forces on the medial aspect of the knee, inhibiting growth of the medial tibial physis (14,34). While adolescent Blount's disease is uncommon, the reported cases identify the patients as being above the 95th percentile for BMI and age (12,14,28–30).

Foot structure can also be affected by excess mass, and at an age as early as 3–5 years (35). The foot dimensions of overweight children, including breadth and circumference, are larger than those of normal-weight children (6,35–37). Studies have included assessments of footprints during weight-bearing and indicated a greater contact area (35,38–40). Several studies have also reported that overweight children have a lower longitudinal medial arch and mean arch height that is associated with a decrease in the integrity of the foot as a weight-bearing structure (41–44). The excess weight-bearing in overweight children may cause structural dysfunction, leading to the collapse of the longitudinal arch (41). These structural changes increase pressures within the foot (42,43) and higher pressures have been measured under the forefoot, as well as increased dynamic mean peak pressures and pressure–time integrals under the midfoot and second through fifth metatarsal heads (41,43). The increased pressures on the small bones of the forefoot could cause stress fractures or skin ulcerations in the feet of overweight children (41,43).

Biomechanics

As the individual matures single-limb support time, step length and velocity increase during normal walking gait, while cadence and double-limb support time decrease (45). The early skeletal maturation associated with excess fat mass (7,8) should encourage the generalizations of normal gait parameters in overweight children. However, overweight children have decreased velocity with the normal decrease in cadence, along with an increase in the time duration of a gait cycle, spending more time in double-limb support stance. If walking speed is altered (outside of the normal range), the time spent in the stance phase is increased (46,47). An increase in either the step width or the base of support has consistently been reported in overweight children during various walking speeds (44,46,47). This suggests that alterations in normal gait are consequences of excess fat mass leading overweight children to have a slower, more tentative walking pattern.

At a normal, self-selected speed of walking, overweight children have less knee and hip flexion, indicating a more rigid posture during walking (46,48). Similarly, plantarflexion during the swing phase occurs more quickly in overweight children, resulting in a flatter foot during heel strike (46). Foot contact patterns also vary more in overweight children, diminishing the toe clearance during the swing phase (46).

The consequence of excess mass in overweight children is an increase in both the absolute amount of force applied to the joint and the muscular force needed to move the additional mass during ambulation. In both the sagittal and frontal planes, peak joint moments at the hip, knee and ankle are significantly higher in overweight children than normal-weight children (44). As no kinematic differences have been reported in the frontal plane motion of overweight children, it is believed that the kinetic changes are a result of excess fat mass. The larger forces in the frontal plane could increase lower extremity joint stability in a population that has a reported loss of functional balance (49). Greater thigh girth caused by increased amounts of adipose tissue has also been suggested as a contributing factor to the larger knee abduction moments (48). The significance of increased joint moments is presented as increases in orthopaedic conditions. For example, the increased compressive and shear forces at the capital femoral growth plate can alter the femoral angle in overweight children (14,25,50). The larger peak joint moments in the knee increases the force with which tibiofemoral contact is made during the screw home mechanism (51) that can increase the risk of early onset osteoarthritis in the overweight population (6).

The cost of energy transport during locomotion is increased by 50% in obese individuals, with an additional 30% increase in external work for this population (52). Concentric contraction of hip flexors occurs more frequently in the gait cycle of overweight children than does eccentric contraction, which creates a higher energy transfer ratio (53). These findings suggest a change in gait style that is mechanically easier to produce but causes higher metabolic costs. Combined with the changes in joint kinematics and kinetics, it is postulated that overweight children create alternative gait strategies for coping with the additional mass.

Physical activity

In the United States, there is widespread physical inactivity in both adults and children (54). A recent study showed that only 42% of children (6–11 years of age) and 8% of adolescents (12–19 years of age) meet the United States Surgeon General's recommendation for 60 min of physical activity each day (55). Within Europe, approximately one-third of adolescents (11–15 years of age) meet the guidelines set by the United Kingdom Heath Education Authority for 1 h of moderate physical activity each day (56–58). Contributing factors to lower levels of physical activity include increased motorized transport, increased sedentary activity and decreased opportunity for recreational physical activity (2). Internationally, studies have consistently found associations between physical activity levels, gender and age. Boys participate in more physical activity than girls, with a decrease in physical activity occurring as children get older (55,56). The association with physical activity and gender also extends to paediatric obesity with overweight boys participating in more physical activity than overweight girls (59). Overweight children spend more time in sedentary activities than normal-weight children (60), and sedentary activity in such individuals often includes watching TV. When combined with decreased levels of physical activity, the risk of significant positive energy balance increases (61–63).

Prevention and treatment of obesity requires a decrease in sedentary activity and an increase in physical activity (64,65). Physical activity can increase the quality of life of children, including physical and psychosocial perceptions (59,66). In addition, physical activity increases physical fitness (67) that is negatively correlated to metabolic risk factors and inflammatory markers (68–70). Physical activity also decreases adiposity and enhances skeletal muscle heath (67,71–73). However, overweight children have more difficulty sustaining bouts of high-intensity physical activity (74), which may be the result of the negative association between adipose tissue and physical fitness (75,76). The difficulty in participating in physical activity can also be influenced by musculoskeletal pain. The majority of participants in a study focused on overweight children and adolescents (5–18 years of age) reported musculoskeletal pain in at least one joint. The most commonly reported musculoskeletal pain occurs in the back, feet and knees (50,77–79). While fitness parameters such as flexibility and coordination are not affected by obesity (80–82), moving or lifting extra body mass may overload the joints and discourage exercise participation (41,81,83–86). Finally, because overweight children have more self-reported musculoskeletal discomfort and impairment of mobility than normal-weight children, adequate levels of physical activity become more difficult for this population to achieve.

Future research

There is a dearth of information in the literature regarding the musculoskeletal consequences of excess mass and the implications for exercise intervention (Fig. 1). Before one can provide appropriate individualized exercise prescriptions to minimize the risk of joint trauma and pain, musculoskeletal characteristics must be thoroughly understood. In this regard, translational research may be particularly useful in the overweight paediatric population. For example, previous research (12,31) has identified musculoskeletal malalignment in overweight children; however, anthropometric measurements of bone and the correlated biophysiological markers need to be compared across different body composition levels and throughout the growth stages of children and adolescents to produce definitive explanations for the potential joint injury in overweight children. Further, quality of life has been shown to decrease in overweight children; however, no research to date has identified the major contributing factors, including the causes of pain and discomfort. More comprehensive biomechanical studies involving a wider range of physical activities are needed to establish correlations between decreased function, increased pain and decreased quality of life. It is now well established that overweight children are less physically active (60) – future research to assess the determinants of physical activity level and predisposition to inactive behaviours should include considerations such as differences in the musculoskeletal system.

Conclusion

As the prevalence of obesity increases in children and adolescents, the likelihood of associated medical conditions also increases. A complex range of psychosocial, metabolic, cardiorespiratory and orthopaedic factors influence the overweight child's ability to undertake physical activity. The pain and discomfort overweight children commonly report during physical activity may stem from skeletal malalignment and/or changes in muscular function. This feature is correlated with research that has shown an increase in the prevalence of musculoskeletal malalignments (12,31), increases in joint moments throughout the lower extremity kinetic chain (44,48) and difficulty with movement tasks during fitness assessments.

Participation in physical activity increases physical fitness (67), skeletal health and quality of life (59,66) while decreasing metabolic and anti-inflammatory markers (67,71–73). However, the majority of children today do not meet physical activity guidelines (55–58) and overweight children often demonstrate more sedentary behaviours (60). The increased pain in the back, knees and feet (50,77–79) of overweight children could decrease motivation to exercise; however, research to support this postulate remains incomplete. To fully understand the musculoskeletal implications of the overweight condition on quality of life and physical function in children, more comprehensive research must be undertaken.

Conflict of Interest Statement

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