

Research Progress on the Association between Sedentary Behavior and Musculoskeletal Health in Preschoolers

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Abstract: Sedentary behavior (SED) has been listed as one of the top ten causes of disease and death by the World Health Organization (WHO), and previous studies have pointed out that sedentary behavior will increase the risk of death. SED increases the prevalence of diabetes, cardiovascular disease, cancer, mental health and musculoskeletal disorders, and has a negative impact on the development of physical health. Children and adolescents are in an important period of growth and development, and their healthy is related to the future of the country, social stability, family and personal happiness. Scientific and effective guidance of the healthy development of their behavior and habits is one of the important contents to the Healthy China construction. Understanding the relationship between SED and musculoskeletal health of preschoolers is of great significance for children to establish fitness awareness and carry out targeted physical activities. The review focuses on preschool children in the critical period of growth and academic development, summarizes the association between SED and musculoskeletal system health of preschoolers, in order to enrich the research on the impact of SED on musculoskeletal system health, and provide theoretical and empirical basis for future research.

1. Introduction

Sedentary behavior is not the same as physical inactivity; it refers to the behavior of low energy expenditure with energy expenditure level of 1.0-1.5 METs when sitting or lying down, such as sedentary sitting for a long time at leisure or work[1]. SED has been listed as one of the ten leading causes of disease and death by the WHO[2]. In 2003, the WHO pointed out that more than 2 million people die from sitting every year worldwide, and it is estimated that by 2022, 70% of all diseases will be caused by sitting[3]. Sedentary behavior has become an invisible habit in people's life, and it has caused extremely adverse effects on people's health, such as increasing the prevalence of diabetes, cardiovascular disease, cancer, mental illness and musculoskeletal diseases, and has played a side effect on the development of good body posture[4].

Preschool is a period of rapid growth and development in all aspects of the human body, which is the key stage to lay the foundation of musculoskeletal system health and physical health[5]. The level of physical health development in preschool is related to the physical health status in adult. A healthy lifestyle is generally considered to be an important prerequisite for maintaining healthy physical development of children. However, the current trend of static lifestyle of children is unusually severe, with a sharp increase in sedentary behavior[6]. Population data from North America, the United Kingdom, and Europe suggest that children and adolescents spend a large portion of their day sedentary[7]. In the United States, for example, the 2003-2004 National Health and Nutrition Examination Survey found that children aged 6-11 and 12-15 spent 40 and 50 percent of their waking hours on sedentary behaviors, respectively[8]. After excluding adults aged 60 or the older, female adolescents aged 16 to 19 were the most sedentary, spending up to 60 percent of their waking hours sitting[9]. Multiple studies abroad, including in adolescents, have found independent relationships between sedentary behavior and acute and chronic problems (e.g., cardiovascular disease, metabolic syndrome, colorectal cancer, and early mortality), the increase in sedentary behavior among adolescents globally is associated with an increase in acute and chronic diseases, and some have even

speculated that, the life expectancy of the current generation of teenagers is likely to be shorter than that of their parents[10].

The bone tissue and muscle tissue of the body are closely related, and the association between bone and muscle can induce musculoskeletal system diseases, including bone mass loss accompanied by muscle atrophy, and muscle mass loss accompanied by bone mass loss. In particular, sedentary behavior induced skeletal and muscle metabolic dysfunction (Table 1). At present, there are many related research results on sedentary behavior, but there is a lack of research on the relationship between sedentary behavior and muscle health and bone mineral density in preschoolers. At the same time, the relationship between sedentary behavior and bone mineral density and muscle health has not been conclusive, and further research and discussion are needed[11]. This review summarizes the research progress on the association between sedentary behavior and musculoskeletal system health in preschool children.

Table 1. Metabolic changes in musculoskeletal system induced by sedentary behavior

Research category	Research indicators	Published Time	Research objects	Results
musculoskeletal system	Bone	2020[12]	Male: 1856 Female: 1815	Sedentary behavior is a risk factor for knee pain in men and hip pain in women
		2019[13]	Adults: 22948	Sedentary behavior of more than 10 hours per day was significantly associated with chronic knee pain.
	Muscle	2019[14]	Male: 497	Moderate exercise increases bone mineral density levels by strengthening muscle mass and muscle strength

2. Association between Sedentary Behavior and Musculoskeletal System Health

2.1 Sedentary Behavior and Inadequate Muscle Strength

One of the hallmarks of social development and progress is the physical health of children and adolescents[15]. As an important criterion for the physical health of children and adolescents, muscle strength has attracted the attention of researchers[16]. The muscle strength of children and adolescents is largely determined by their behavioral habits. However, with the development of social economy, socioeconomic factors such as family socioeconomic status (SES) and place of residence have gradually become the key factors leading to the decline of muscle strength in children and adolescents[17]. Muscle strength is a component of healthy physical fitness. More importantly, muscle strength and basic motor skill proficiency are considered as basic physical activities that continue to be involved throughout the life cycle and have a profound impact on disease prevention and health promotion. The consequences of poor health may only become apparent as we get older[17].

Muscle strength refers to the force produced by the contraction of the muscle fibers, which is the force produced by a muscle or a muscle group to the resistance force with a maximum force[18]. Different countries and regions choose different indexes to evaluate upper limbs, trunk and lower limbs. Grip strength is a good index for evaluating upper limb strength due to its convenience, high reliability and validity, and its high correlation with muscle strength and bone mineral density[19]. Sit-ups are an indicator of trunk strength. The study found that sit-ups had good validity and reliability

in all age groups, and there was no gender difference[20]. Vertical jumps, standing long jumps, and repeated spans have all been widely used to assess lower limb strength[21]. The standing long jump, by contrast, has more to do with lower limb and trunk strength, which is characterized by the convenience, practicality, reliability and low cost of testing[22]. The above studies show that grip strength, sit-ups and standing long jump are good indicators to evaluate muscle strength.

Muscle strength is an important marker of lifelong health and an essential indicator for monitoring the health of children and adolescents[23]. Numerous studies have shown that muscle strength has been declining in children and adolescents who are less physically active[24-26]. Researchers looked at trends in lower body muscle strength in Spanish boys over a 47-year period, much of the evidence examining temporal trends in physical activity in boys showed a decline in measures of muscle strength[27]. One study used data from 34 data sets to estimate the standing long jump performance of hundreds of thousands of children and adolescents from multiple countries between 1960 and 2017[28]. The data showed that the standing long jump performance of children and adolescents varied from country to country, but their muscle strength declined in most countries[28]. Zhang et al. investigated the muscle strength of 626 students (300 boys and 326 girls). The results showed that from the indicator of standing long jump, which reflects the strength of lower limbs, the performance of standing long jump of teenagers was positively correlated with the time of daily moderate to high intensity physical activity[29]. These studies all show that physical activity has an obvious correlation with muscle strength. Current literature shows that the factors affecting muscle strength of children and adolescents come from many aspects, including personal and social environment factors, such as age, gender, daily behavior and habits, which belong to individual factors; and family structure, school, place of residence, etc., belong to social environment level factors[30]. Sedentary behavior is thought to be a direct cause of muscle weakness in preschoolers[31]. Of concern, the decline in muscle strength in children and adolescents has been documented worldwide. Previous studies have found that prolonged sedentary behavior may increase the risk of sarcopenia[32]. In the study of Gianoudis et al., physical activities and sedentary time of the subjects were obtained through questionnaire survey, and the lower extremity muscle strength and muscle mass of the subjects were measured[33]. Total sedentary time per day was found to be associated with an increased risk of sarcopenia, with each additional hour of sedentary time per day associated with a 33% increased risk, independent of MVPA, total body fat mass, and other confounders[34]. In the study of Reid et al., subjects wore activPAL3™ for 7 consecutive days to obtain sedentary time, and dual-energy X-ray was used to measure the muscle tissue and fat of subjects[35]. It was also found that the increase of sedentary time was associated with the increased risk of sarcopenia, and it was also positively correlated with muscle mass and muscle strength[36].

Common sedentary behaviors (e.g., using computers and electronic devices) have been increasing over the past few decades. Screen time is often used as a proxy for sedentary behavior in studies, while this behavior has been linked to a variety of negative health outcomes in children and adolescents[37]. Research showed that screen-based sedentary time is linked not only to cardiopulmonary fitness, but also to lower body muscle strength[38]. Screen time may also influence exercise levels in young people through direct physiological effects or other health-promoting activities, and previous studies have reported a link between muscle strength and screen time[39]. The cross-sectional study of 6045 Australian children and adolescents by Hardy et al. showed that screen time led to differences in cardiopulmonary endurance, and the muscle strength of girls in the less screen time group was significantly better than that in the longer screen time group[40].

2.2 Association between Sedentary Behavior and Bone Mineral Density

Osteoporosis is characterized by abnormally low bone mass and structural defects, leading to an increased probability of fracture and bone fragility[41]. The most commonly used diagnosis and classification method of osteoporosis is based on the bone mineral density of different sites. Bone mineral density (BMD) is an important indicator of human bone health[42]. Based on the adverse effects of sedentary behavior on human body, the relationship between sedentary behavior and BMD is also a hot topic of concern[43]. Previous studies have shown a negative association between

average daily sedentary time and BMD[44]. Wu et al. found that every 60-minute increase in sitting time was associated with a decrease in BMD[45]. Research suggested that sedentary time and insufficient physical activity reduced the bone mineral density of the human body[46]. Braun et al. found that moderate to vigorous recreational physical activity for at least 60 minutes per day increased bone mineral density in the femur and bone minerals in the femur and spine[47]. Another study has analyzed the BMD and sedentary time of female subjects and found that the BMD of femoral neck decreased with the increase of sedentary time for 60 minutes, indicating that there was a negative correlation between sedentary time and BMD[48]. Additionally, it was also found that the bone mineral density of female sedentary group showed a downward trend with the development of central obesity[49]. Chastin et al. split the gender of the subjects and found that sedentary time was negatively correlated with bone mineral density in femur region ($B = -0.159$, $P < 0.001$), independent of physical activity level and moderate and vigorous activity time[50]. There was no correlation between sedentary behavior and BMD in men, but moderate physical activity ($B = 0.306$, $P < 0.05$) and vigorous exercise ($B = 0.320$, $P < 0.05$) had a greater impact on BMD[50]. Gabel et al. found a negative association between sedentary time and bone in a longitudinal study[51]. However, other findings have shown that the association between sedentary behavior and BMD is influenced by the body part measured[52]. As noted above, Chastin's study measured bone mineral density in the femur, but did not show an inverse association between sedentary behavior and bone mineral density when measuring bone mineral density in children's fingers. Therefore, in future studies on the relationship between sedentary behavior and BMD, it is necessary to further determine whether there are differences in the relationship between sedentary behavior and BMD at different locations. At the same time, the relationship between sedentary behavior and bone mineral density may also be affected by physical activity, and some studies suggested that the potential harm to bone health caused by prolonged sitting can be offset by a small amount of weight-bearing physical activity. Chastin et al. found that increased exercise and vigorous exercise attenuated the association between sitting time and bone mineral density[50]. The study by Braun et al. suggested that 60 minutes of moderate recreational physical activity per day was associated with increased bone mineral density in children[53]. Therefore, physical activity should be an issue that researchers should pay attention to in future studies of sedentary behavior. In addition, the nutritional intake of the subjects (such as calcium, vitamin D, and vitamin K) may also have influenced the results of this study[54].

3. Sedentary Behavior and the Structure and Function of the Musculoskeletal System

At present, there are few studies on the mechanism behind the relationship between sedentary behavior and the structure and function of the musculoskeletal system, and no direct imaging evidence of sedentary behavior affecting the structure of the musculoskeletal system in school-age children has been retrieved. Studies have shown that sedentary behavior is one of the environmental factors for the growth and development of musculoskeletal system, which provides a certain reference and basis for exploring and revealing the potential mechanism of sedentary behavior on the growth and development of musculoskeletal function in preschoolers.

3.1 Effects of Sedentary Behavior on Musculoskeletal System Muscle Function

Sedentary behavior is a significant contributor to muscle mass and muscle strength loss at any age[55]. When the body is in sedentary behavior, the buttock muscles of the body are always in a relaxed state. Without stimulation for a long time, the buttock muscles cannot be effectively restored. Suddenly standing up or exercise intervention, the buttock muscles still keep the relaxed level, which is called gluteal amnesia. Sedentary behavior can cause muscle discomfort and back muscle pain. In the process of sedentary behavior, the body's muscle current is weakened, and the rate of calorie burning is decreased. After sitting for 3 hours, the arteries will contract by 50%, blood flow will decrease, insulin breakdown and glucose level will decrease by 40%, the risk of type 2 diabetes mellitus (T2DM) was increased[56].

Sedentary behavior affects the endocrine ability of muscle[57]. Muscle affects the bone resorption of osteoclasts and the bone formation of osteoblasts by releasing muscle secretory factors, which

directly act on osteocyte receptors and maintain the muscle-bone interaction[58]. Muscle secreted factors contain myostatin (MSTN), insulin-like growth factor-1 (IGF-1), fibroblast growth factor-2 (FGF-2), matrix metalloproteinase-2 (MMP2) and β -aminoisobutyric acid (BAIBA), etc. Among them, MSTN mainly exists in muscle and induces the formation of osteoclasts, leading to increased bone resorption[59]. The precursors and processing forms of MSTN in sedentary diabetic rats were higher than those in control rats[60]. Exercise can regulate MSTN expression in muscle of diabetic rats, which is involved in regulating energy homeostasis[60]. Bone and muscle co-secrete IGF-1, which is involved in tissue autocrine and paracrine signaling. IGF-1 induces muscle hypertrophy, stimulates bone progenitor cells to form bone, increases cortical thickness and trabecular volume, and promotes periosteal bone formation of osteoblasts under mechanical load[61].

3.2 Effects of Sedentary Behavior on Skeletal Function of Musculoskeletal System

In sedentary behavior, the lower extremity bones do not bear weight and cannot feel the change of the body weight, making the lower extremity bones always in a suspended weightlessness situation, which can lead to the decline of the lower extremity bone quality[62]. In the process of upright exercise, such as running, standing and jumping, the lower limb bones can feel all the weight of the body, and the bones are stimulated by continuous loading to ensure the level of bone health[63]. The stresses imposed by mechanical loads on bone tissues usually stimulate skeletal cellular responses, resulting in structural adjustments that enable the bone to withstand reasonable load changes and enable the osteocytes to perceive dynamic high-intensity load shocks[64]. In other words, the body's osteocytes have the function of pressure sensing. In the environment of sedentary behavior, the body's lower limbs are always in a relaxed state, which cannot effectively feel the process of exercise[65].

As an endocrine organ, bone fully conforms to the characteristics of the endocrine system: bone has a bone lacuna-tubule network system, and the capillaries in the bone tissue communicate with the blood flow in the circulatory system, so that the secreted substances from bone can directly reach the distal organs and cells[66]. Bone tissue is rich in capillaries, highly differentiated vascular morphology, making hormone shuttling characteristics improved; Hormones with relative molecular mass less than 70 000 can diffuse freely in bone fluid flow and circulatory system[67]. Bone, as a new secretory endocrine organ, secretes specific bone proteins: osteocalcin (OCN), fibroblast growth factor 23 (FGF23) and lipocalin 2 (LCN2)[68]. Compared with exercise intervention mice, the levels of serum OCN and 1, 25-dihydroxyvitamin D3 in sedentary behavior mice were lower than those in exercise intervention mice[69]. Insufficient exercise and prolonged sedentary behavior in growing mice can lead to the disturbance of LCN2 secretion level, energy metabolism disorder, food intake level and weight increase.

3.3 Effects of Sedentary Behavior on the Overall Function of Musculoskeletal System

There is a regulatory effect between bone and muscle[70]. Sedentary behavior leads to the disorder of the expression levels of skeletal secreted factors and muscle secreted factors, leading to the formation of musculoskeletal system diseases[71]. Previous studies have pointed out that the musculoskeletal system, as a whole structure, has the functional characteristics of communication network, which jointly undertakes the functions of body movement, immunity, nutrition and so on[72]. Its occurrence and development process are mutually regulated by each other. Bone secretes prostaglandin E2(PGE2), Wnt factor, OCN and transforming growth factor β . Skeletal factors, such as TGF β and receptor for activation of nuclear factor kappa β ligand (RANKL), then regulate muscle metabolism[73]; Muscle secretes muscle factors such as MSTN, irisin, BAIBA, BDNF and IL, which then regulate bone metabolism, forming a circular mediation[74]. Bone structure and function deteriorate during sedentary behavior[75]. On the one hand, bone quality and BMD decrease, and bone fragility increases, which easily leads to osteoporosis. On the other hand, the secretion level of bone tissue decreases, leading to the disorder of skeletal factor expression level, which induces the decline of muscle mass through conduction[76]. At the same time, muscle structure and function deteriorate during sedentary behavior[77]. On the one hand, it induces the malignant development of muscle tissue; On the other hand, the decrease of secretory level of muscle tissue leads to the disorder of muscle factor expression level, which induces the decrease of bone quality through conduction,

and finally forms a vicious cycle of musculoskeletal system[78].

4. Problems in Existing Research

4.1 Insufficient Attention to Sedentary Behavior

The research on sedentary behavior is in the basic stage, mainly focused on the large-scale investigation of sedentary behavior, especially the investigation of screen time and studying sedentary time. It has not yet involved the related influencing factors of sedentary behavior and the intervention research of sedentary behavior. The Chinese Nutrition and Health Survey Project is a long-term cohort study jointly conducted by the Institute of Nutrition and Health under the Chinese Center for Disease Control and Prevention and North Carolina State University. It provides valuable data for studying the static behavior and physical health of children and adolescents in China. Future research should integrate the accuracy and convenience of the measurement tools of sedentary behavior, pay more attention to the content of sedentary behavior, investigate and collect the specific content of sedentary behavior and other information, and then more scientifically and accurately analyze the relationship between sedentary behavior and musculoskeletal system function in preschool children.

4.2 The Longitudinal Studies Conducted are Relatively Limited

The existing research is mainly based on cross-sectional research design, and the longitudinal research conducted is relatively limited. The cross-sectional study can only show whether there is a certain association between sedentary behavior and musculoskeletal system function in preschoolers, but cannot understand the causal relationship between the two. Future research should be based on a wealth of cross-sectional studies to conduct longitudinal studies of different sedentary behaviors, further understanding the long-term effects of sedentary behavior on musculoskeletal system function in preschool children and the causal relationship between them, so as to provide a more scientific and powerful theoretical basis for the formulation of relevant interventions and guidelines in the future.

5. Summary and Prospect

The key period of growth and development is childhood and adolescence. The health quality in this period is not only related to individuals, but also related to the future health quality of the whole nation, which is also the strategic basis for the country to build a powerful country with talent. The relationship between sedentary behavior and musculoskeletal system function in preschoolers is not clear. The association may be different depending on the content of sedentary behavior or the location of musculoskeletal system. Most of these studies have shown a significant negative association between prolonged sedentary behavior and musculoskeletal system function in preschoolers. Sedentary behavior can make the body weaken the function of the musculoskeletal system, decrease the bone microstructure and muscle mass in the long-term sitting behavior, induce the disorder of the secretion of bone factors and muscle factors, and eventually form osteosarcopenia syndrome or sarcopenia-osteoporosis. The intervention of appropriate physical activity on sedentary behavior can effectively improve the above functional problems, alleviate the decline of bone quality and muscle atrophy; In addition, exercise intervention also plays a significant role in regulating the physiological function and energy metabolism of the body.

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