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Research Article

The Role of Physical Activity in Children's Brain Development and Learning: A Systematic Review

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Abstract

Childhood is an important and sensitive period for cognitive development. Since most of the special learning disabilities are neurological in nature and all learning functions are formed in the brain, any defect in the functioning of the central nervous system can be considered one of the most important causes of learning disabilities. Regular physical activity leads to adjustment of adaptations in the hippocampus. The hippocampus is the main center of learning and memory in the brain, which is very effective in the cognitive development of children. Although researches have shown that physical activity can increase the levels of neurotransmitters and thus the cognitive function of the brain by increasing the growth of cerebral capillaries and the growth of nerve cells in the hippocampus, however, there is still less awareness and practical measures in relation to This issue exists among parents, educators and all those involved in the education of children. In this article, we reviewed the research related to this topic from 2000 to 2023. The results show that participation in sports in late childhood has a positive effect on cognitive and emotional functions. There are few publications that examine the effect of sports on cognitive functions during adolescence, or which cognitive functions are developed by which sports. These results can be useful for sports coaches who train children and also guide researchers and clinicians regarding the wide range of benefits of physical activity.

Key Words: brain; exercise; activity; health; childhood

1. Introduction

In recent years, many changes have been made in the lifestyle of different periods of life, especially in childhood. Unlike children a few decades ago, today's children increasingly lead sedentary lifestyles that include time spent on computers, watching television, and using cell phones a lot. This lifestyle makes them neglect the physical activity that is necessary during this period of growth [1,2]. In times when children are less active, the significance of studies on the positive impact of sport on physical health, mental health, and cognitive functioning, is critical [3–7]. The aim of such research is to raise awareness of the gravity of the problem, as well as to create a holistic health program that promotes being physically active in different contexts, including with family and in school [8]. Limited physical activity, or often a complete lack thereof, leads to various health problems, including posture problems (such as idiopathic scoliosis), somatic conditions, being overweight and obese, problems with circulation, and even premature death [6,9–12]. There is increasing empirical evidence of a relationship between a lack of physical activity and mental health measures. For instance, research suggests that overweight adolescents who do not practice sports are more prone to risk behaviors, including suicide attempts and addiction to both alcohol and illicit drugs [13,14]. The guidelines referring to physical activity in a report from the National Association for Sport and Physical Education [2] emphasize that children should spend as much time as possible engaging in activities that require physical movement. The World Health Organization and Fonds Gesunde Osterreich [15] further specify guidelines indicating that children should devote at least 60 min a day to physical activity (such as going to school on foot, walking up-stairs, and cycling). Moreover, children should strengthen their muscles and bones with strength training at least two to three times a week [16]. The argument has been made those children who do not do physical exercise will never fully develop their genetic potential in terms of motor skills [17].

It has been shown that engaging in sports is a protective factor against somatic illnesses and pathological behaviors [18,19]. Sport provides an equilibrium between group demands and individual demands, between aggressive behaviors and self-control. It fosters a sense of belonging to a group, and teaches coping with both victory and defeat [20]. Regular physical activity also leads to better circulation and oxygen supply to the brain, an increase in bone and muscle density, and greater tolerance of stress [15]. Cadenas et al. (2023) show that Physical activity, sedentary time, and physical fitness were significantly related to the shapes of subcortical brain structures, which in turn were related to intelligence in children with overweight/obesity [21].

Increased susceptibility to risk behaviors among adolescents is associated with a not-yet-mature cognitive-control system, which is responsible for impulses associated with engaging in risk behaviors [22]

Although it is evident that physical activity is related to physical and mental health [23], the relation between physical activity and cognitive functioning requires further study. Cognitive functions include: memory, attention, visual-spatial, and executive functions, while complex cognitive processes include: thinking (abstract, cause and effect, creative thinking, and planning) and language functions [24]. Despite the importance of this issue, few studies are concerned with the relationship between sports and cognitive functioning of children in late childhood [25], and research to date (unfortunately not free of errors in sampling) provides contradictory results regarding the influence of sports on cognitive functions in children. Some report that sports have a positive influence [3,26–29], particularly on executive functions, which develop intensively in this period [28,30], as well as mention the positive impact of regular and irregular exercises which lead to an increase in the level of oxyhemoglobin that facilitates the operation of executive functions for up to 30 minutes [31]. Others, however, do not confirm this positive influence of physical activity on cognitive functioning [32,33].

2. Methods

This review was conducted using Ebsco Information Services to access two electronic databases (PsycInfo and Medline), as well as Google Scholar. The search focused on articles published from 2000 until 2023. A total of 642 articles met these original criteria. Articles included some systematic reviews, but were mostly original research. These articles were further assessed, and only those that emphasized the disciplines related to the research topic (psychology, sport, medicine) were included in the final sample. A total of 60 articles were then reviewed, given that many of the articles that emerged in the initial search were connected to attention deficit hyperactivity disorder (ADHD) and disability, rather than physical activity and cognition. Such articles were excluded from the sample. Other publications were referenced to introduce the problem and to discuss its background in the neuropsychological context.

3. Results

We have evaluated the following subtopics in the articles we reviewed below: Brain development, attention, thinking, learning, and memory. Below, we review and highlight some of the most important findings in relation to each of the subthemes, followed by a model illustrating the impact of exercise on physical, mental and social resources.

3.1 Brain development

Exercising increases blood flow to the brain. Blood carries oxygen and glucose to the parts of the brain that are important for increasing alertness and mental focus. For this reason, playing sports helps to increase children's ability to learn. Research has shown that a three-month exercise regimen can increase blood flow to parts of the brain related to memory and learning by 30%. Other studies have shown that exercise creates new brain cells in a part of the brain known as the dentate gyrus, which is associated with memory and memory loss. Physical activity in children also stimulates nerve growth factors. People who have proper and regular exercise, their short-term memory is strengthened, they have a faster reaction time and benefit from a high level of creativity [22, 23]. Another benefit of children's physical activity is that it increases the level of brain-derived neurotrophic factor or BDNF. BDNF is a factor that causes nerve cells to expand, connect and communicate with each other in new ways. This leads to the child becoming more ready for motor, cognitive and social learning. MRI examination of children who have adequate physical activity has shown that these children have larger basal ganglia, which is a key part of the brain and has an effect on maintaining attention and executive control, and in other words, this area of the brain The ability to coordinate movements and complex thoughts is effective. Children with good physical condition have larger hippocampus. The hippocampus is the area of the brain that is the main center of learning and memory and is very effective in the motor and cognitive development of growing children. Also, exercising helps to develop the child's creativity. Studies have shown that a 35-minute exercise session with a treadmill improves a child's cognitive and perceptual flexibility, the brain's ability to change thoughts and create creativity and innovative thinking [22, 23].

3.2 Attention

The ability to focus attention is improved among children who participate in physical activities [34–36]. Cross-sectional studies suggest that with regards to cognitive flexibility and operational memory, the regularity and intensity of physical activity in children aged 13–14 years positively affects their ability to focus attention on a given task [37]. This effect is especially noticeable after the third hour of classroom lessons; the time at which processes related to attention and focus on a given task tend to deteriorate. Students who regularly do sports are also calmer during lessons [15]. Some researchers indicate the lack of connection between mental activity and shifting attention or flexibility of attention. They also emphasize that there is a significant deterioration of these functions among individuals who spend too much time in front of the computer screen and playing too many computer games, as defined by self-reports and objective measures [38]. They also stress that children who do some form of sport (e.g., karate) function better than those who prefer passive activity. This result is observed through better speed times and visual selective attention than in the case of children with a sedentary lifestyle [39]. Studies have also been conducted that focus on physical activity outside of class-time or school settings. These studies revealed that physical activity in non-school contexts enhances selective attention, in contrast to passive activities in non-school contexts [40]. Some studies revealed the positive impact of sport, specifically on executive functions [27,28,36], which develop intensively in the period of late childhood [4,28,39]. Research using various kinds of intervention trials confirms the beneficial influence of physical activity on attention. Even a 12 min session of aerobic exercise improved the selective attention of children [41]. Research has also demonstrated the positive impact of exercise, both regular and irregular, which leads to an increase in the level of oxyhemoglobin, facilitating the operation of executive functions for up to 30 min [31]. At the same time, the unfavorable influence of lack of physical activity on cognitive functioning is reported. It has been found that there is a negative impact of time spent in front of the computer screen on executive functions as related to inhibition [36].

It was also found that children who engaged in physical activity demonstrated better executive functions in terms of inhibition [5,35] and better planning abilities [42] than children who did not engage in any physical activity. Studies conducted with children aged 8–9 years confirmed that sport influences changes in the right anterior prefrontal cortex, which are related to cognitive control [43]. The findings suggest, that plan-structured sport activities, for example tennis play, are associated with the development of inhibitory control. Although the development of inhibitory control and cognitive flexibility is slower in males than in females, the association between tennis play and inhibitory control and cognitive flexibility appears to be larger in males [44]. Additionally, playing football has a positive influence on executive functioning, including attention, in children [45]. In the case of attention, correlational and associational studies showed much weaker effects than studies which included interventions.

3. 3 Thinking

“Thinking” is operationalized in this context as abstract thinking, conceptualizing cause-and-effect, creative thinking, and planning. Few studies have investigated the relation between physical activity and thinking. Children who participate in organized sport activities have been found to demonstrate a lower level of creativity as adults when compared to individuals participating in non-organized sport activities [46].

Apart from cross-sectional studies, a small number of studies with interventions were also conducted. Planning processes in children who attended a Football Exercise Program for at least six months were more developed in comparison to a control group of sedentary peers [45]. As in the case of attention, correlational and associational studies on thinking also showed much weaker effects than studies which included interventions.

3.4 Learning and Memory

A decided majority of studies in this domain were based on different types of intervention trials. Previous research suggests that, overall, children who are more fit were found to have greater basal ganglia and hippocampus capacities [63]. These areas are associated with cognitive control and memory [43,63]. Among children aged 3–5 years, increased physical activity was found to improve their cognitive functions, especially in the area of working memory [64]. A similar improvement was observed in children who trained in karate [39]. A positive correlation was found between physical activity and better working memory among children aged 8–12 years [4,36,65,66]. Studies conducted by Kubesch et al. [37] demonstrated that the intensity of physical activity in children aged 12–14 years positively affected cognitive flexibility and operational memory. Similar results from Ishihara et al. [44] and Alesi et al. [45] found that tennis and football are associated with the development of working memory. In addition, physical activity is said to have a positive impact on visuospatial (V-S) memory [40,45]. Classroom-based physical activity (a 10-min bout of aerobic physical activity integrated with math practice) improved both physical activity levels and academic achievement. Results showed that among overweight children, physical activity improved performance in the Standard Flanker test by preventing the decline associated with seated practice [67]. Some results [68] suggest that game-based tennis lessons have beneficial effects on inhibitory control and physical fitness levels, and a longer duration of coordination training is associated with better working memory. Research done by Mavilidi et al. [69] and Toumpaniari et al. [70] indicated that integrated physical exercises and gestures in preschool children achieved the best foreign language vocabulary learning outcomes.

4. Discussion

Key findings of most studies included in this review indicate that children's engagement in physical activity may be associated with changes to certain brain structures, leading to an improvement in memory function (working memory in particular), as well as cognitive control. Independent of the children's age category (early, mid, or late childhood), increased physical activity has been shown to improve cognitive function, especially in regard to working memory, V-S memory, and cognitive flexibility [36,37,39,65,66]. The basic development of motor, cognitive, and social skills, which are crucial in further development, is already taking place in early and mid-childhood [72]. As such, studies that concern children in late childhood, whose executive functions are largely developed, are of special importance. The most intensive development of all components of executive functions, especially cognitive flexibility, happens at school age, usually between 7 and 12 years of age.

Physical exercise increases circulation, which leads to better oxygen supply to the brain, as well as providing the brain with nutrients [73–75]. Cadenas et al. (2023) show that Physical activity, sedentary time, and physical fitness were significantly related to the shapes of subcortical brain structures, which in turn were related to intelligence in children with overweight/obesity [21]. Engaging in sports has a positive influence on all systems: the motor, cardiovascular, respiratory, hormonal, immunologic, and nervous systems. Thus, it stimulates the maturation of the motor areas in the brain, which in turn influences the motoric development and increases the speed of the conductance of nervous impulses [30,45,74]. Valenina Biino et al. (2023) in a research show that cognitively enriched physical activity foster motor competence and executive function as early as preschool age [75]. Some studies have also reported the harmful effects of lack of continuous physical activity on children's mental health [76, 77].

Physical activity also stimulates the increase of neuro-hormonal secretion (substances produced by hypothalamic neurons and transported by blood or cerebrospinal fluid), having a significant impact on the excitability of neurons forming synapses [73]. School-age children who devote at least an hour each day to intensive physical activity show much better cognitive functioning, and researchers emphasize that, despite these unquestionable benefits, only about a third of children regularly engage in sports [78-80].

Conclusions

This literature shows that cognitive performance, efficient memory, high cognitive ability, as well as academic achievement in children depend on high levels of physical activity in childhood. In addition to sports, other activities that children do, such as playing musical instruments [45], are also related to cognitive performance, but physical activity, as the most natural activity for children of that age, is the most desirable. The results show that engaging in sports in late childhood is valuable because it has a positive effect on cognitive and emotional functions. However, few studies have examined the effect of exercise on preadolescent cognitive functions or which cognitive functions are enhanced by which sports. Such knowledge can be useful in developing training programs for pre-adolescents aimed at improving cognitive functions important for a sport.

Exercising increases blood flow to the brain. Blood carries oxygen and glucose to the parts of the brain that are important for increasing alertness and mental focus. Regular physical activity leads to adjustment of adaptations in the hippocampus. The hippocampus is the main center of learning and memory in the brain, which is very effective in the cognitive development of children. Another benefit of children's physical activity is that it increases the level of brain-derived neurotrophic factor or BDNF. BDNF is a factor that causes nerve cells to expand, connect and communicate with each other in new ways. This leads to the child becoming more ready for motor, cognitive and social learning [22, 23].

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