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Physical activity in childhood and adolescence and its effects on the development of depression

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Abstract

Background: The rising incidence of depression among the general population across the lifespan and the global crisis of sedentary lifestyle pose key challenges for public health in the 21st century. Childhood and adolescence, due to the dynamic development of brain structures, are a critical window for preventive interventions.

Aim: The aim of this work is to critically analyze scientific evidence regarding the impact of physical activity in childhood on the risk of developing depression in adulthood, with particular emphasis on biological and psychosocial mechanisms mediating this effect.

Methods: The publication is a narrative review based on the analysis of available scientific works, including literature reviews, individual research and longitudinal and cohort studies.

Results: Research confirms the positive correlation between exercise and depression prevention - high activity levels in youth act as a powerful prevention mechanism. The protective effects of exercise occur on three distinct but integrated levels:

1. Neurobiological: aerobic exercise stimulates the expression of BDNF (supporting neurogenesis in the hippocampus), induces the secretion of anti-inflammatory myokines and optimizes sleep architecture.
2. Neuroendocrine: regular exercise optimizes the functioning of the HPA axis, which moderates cortisol release in stressful situations and protects neural tissue from glucocorticoids.
3. Psychosocial: exercise works through a chain mediation model, increasing self-esteem and social support. Team sports develop social skills and psychological capital. Engaging in training also creates a sense of belonging and reduces digital escape.

Conclusions: Despite methodological challenges and the need for deeper analysis of the topic the evidence we own shows that promoting moderate and vigorous physical activity among children with family support should be considered a priority, safe and low-cost investment in mental resilience during adulthood.

Key words: depression, childhood, adolescence, adulthood, physical activity, exercise, trajectory, BDNF, hippocampus, sleep, HPA axis, psychosocial factors

Introduction and epidemiological background

Depressive disorders in children, adolescents, and adults currently represent one of the most pressing challenges for public health systems worldwide, characterized by high incidence, chronicity, and a tendency to progress to severe clinical forms. Epidemiological data indicate a sharp increase in depression incidence rates during adolescence, with a 14-20% increase in the number of diagnosed depressive episodes between the ages of 15 and 18 [1]. This period also precedes the full neurobiological development of the prefrontal cortex and limbic structures and is characterized by intense psychosocial stress, making this stage of transition to adulthood a critical point for effective preventive interventions [2]. Especially in the adult population, the consequences of this phenomenon extend far beyond individual suffering - depression generates enormous social and economic costs. These translate directly and indirectly into the burden on healthcare systems through increased diagnostics and hospitalizations, as well as into costs incurred by the state due to losses caused by sick leave and productivity losses [3][4]. At the same time, for years we have been observing a deepening crisis in physical activity among the younger generation. According to reports from the World Health Organization (WHO) and population studies covering as many as 146 countries, over 77% (and in some regions even over 80%) of children aged 11 to 17 demonstrate insufficient levels of physical activity, failing to achieve the recommended minimum of 60 minutes of moderate or vigorous physical activity per day [5]. Increasing urbanization, lifestyle changes, and the displacement of exercise by digital entertainment have led to the widespread adoption of sedentary behaviors from an early age. Epidemiological studies cited below demonstrate that activity levels decline dramatically during the transition from childhood to adulthood. Therefore, it has been observed that physical inactivity not only negatively impacts the metabolic health of the younger generation but can also be a modifiable risk factor for emotional and psychosocial disorders. Given the coexistence of these phenomena, an important question has arisen for medicine: is there truly a direct causal relationship between increasingly low levels of physical activity in childhood and the development of depression in adulthood? Although the correlation between lack of exercise and poorer mental well-being is widely established, establishing a clear direction and causes of this relationship poses numerous methodological challenges. This paper, structured as a narrative review, aims to critically analyze and summarize the available research. In particular, the focus is on identifying and describing the biological and psychosocial mechanisms mediating the development of the disease, which will allow for the assessment of the true potential of physical activity as a potentially easy and inexpensive tool for the early prevention of depression in adults on many levels.

Physical Activity Trajectories and Their Role in Research

To fully capture the true impact of physical activity on mental health, modern epidemiology is abandoning traditional screening measures in favor of analyzing long-term behavioral trajectories. It has been proven that physical activity levels exhibit a natural and steady downward trend throughout life [6]. This process is strongly determined by sociodemographic and environmental factors, such as changing educational responsibilities, the decline in the attractiveness of physical education classes, and the dramatic increase in time spent in front of digital screens. In prospective studies, the phenomenon of habit stability is crucial, describing an individual's tendency to maintain their relative position in the physical activity ranking within the population throughout subsequent stages of ontogenesis. Cohort studies demonstrate that high physical activity in childhood is a very strong predictor of an active lifestyle in adulthood, which allows for the establishment of healthy habits early in life [7]. Prospective cohort studies, such as the British Avon Longitudinal Study of Parents and Children (ALSPAC), provide essential evidence for a strong association between time spent sedentary and the risk of depression. This work helped demonstrate that each additional hour spent sedentary by children aged 12, 14, and 16 linearly increased the risk of severe depressive symptoms at age 18. Conversely, each additional hour of light physical activity in childhood protected against depressed mood in the transition to adulthood [8]. Using advanced statistical modeling, the researchers identified several classes of physical activity trajectories. The most desirable trajectory from a mental health perspective was one characterized by consistently high levels of activity in childhood, which only experienced a gentle, natural decline during adolescence (the High-Decreasers class). People belonging to this group showed significantly lower rates of depression at the age of 18-20 compared to their peers from the group with consistently low physical activity (Low-Persistent class) [7].

Neurobiological protective mechanisms

The protective effect of physical exercise on the young brain is based on complex, interconnected neurobiological and immunological cascades that directly counteract the structural and biochemical changes underlying depression. A widely described element of this protection is the stimulation of brain-derived neurotrophic factor (BDNF) expression. BDNF is responsible for, among other things, regulating neuroplasticity, promoting neuronal survival, the formation of new synapses, and the development of new nerve cells in the hippocampus [9]. This anatomical structure undergoes significant atrophy and volume reduction in the course of depression, which is also associated with memory impairment, learning difficulties, and

impaired emotional control [10]. Systematic aerobic physical exercise significantly increases peripheral BDNF concentration, inducing retrograde transport of this factor to the central nervous system, which stimulates regeneration and increases the resistance of hippocampal structures to the toxic effects of stress hormones [11]. The invaluable role of physical activity, including short-term activity, is further evidenced by research suggesting a possible treatment for depression with sports to such an extent that it could serve as the main form of antidepression therapy [12].

At the same time, regular exercise shapes the immune profile of the young body, directly inducing changes described within the inflammatory theory of depression. Patients with mood disorders commonly experience chronic, low-grade inflammation, characterized by elevated levels of proinflammatory cytokines such as interleukin-6 and C-reactive protein, high levels of which in childhood are strongly correlated with the later occurrence of depressive episodes [13]. Physical exercise causes muscle fiber contraction, which stimulates the release of myokines (including muscle IL-6). Muscle IL-6 exhibits unique anti-inflammatory effects – it stimulates the release of potent anti-inflammatory mediators such as interleukin-10 (IL-10) and interleukin-1 receptor antagonist (IL-1ra) [14], leading to long-term reduction of systemic inflammation and protection of neurons from inflammatory cytotoxicity.

Regular physical activity during childhood and adolescence significantly modifies sleep architecture, leading to prolonged deep sleep [15] and shortened and stabilized REM sleep, as well as increased REM sleep latency [16]. These changes are crucial for prevention, as abnormalities in REM sleep structure – such as premature REM sleep onset (shortened latency) or excessive phase density – are recognized neurobiological markers of susceptibility to depression [17]. By optimizing these processes in children, physical activity provides a lasting protection for the developing nervous system against emotional dysregulation, suggesting that engaging in physical activity during adolescence reduces the likelihood of developing depressive disorders later in life. Improving sleep continuity and extending REM sleep in active children provides a crucial restorative buffer for the overloaded nervous system, protecting adolescents from emotional exhaustion and anxiety.

Regulation of the Hypothalamic-Pituitary-Adrenal (HPA) axis

The hypothalamic-pituitary-adrenal (HPA) system is the primary hormonal axis responsible for the body's adaptation to stress. In the pathophysiology of depression, dysregulation of the HPA axis is one of the most frequently described biological disorders, manifesting as chronically elevated cortisol levels (hypercortisolemia) and a decreased sensitivity of glucocorticoid

receptors in the brain to negative feedback [18]. The crucial role of cortisol and stress is demonstrated by the dendritic atrophy they cause, a decrease in neuroplasticity, and a reduction in the volume of structures crucial for well-being, including the aforementioned hippocampus. Furthermore, chronic stress has been associated with disturbances in BDNF levels, a key factor in the pathogenesis of depression. Stimulation of the HPA axis has also been shown to be associated with the induction of chronic inflammation mediated by interleukins, including IL-1 and IL-6, which, as described above, underlies depression [19]. Chronic traumatic experiences in early childhood, such as domestic violence, emotional neglect, chronic peer stress, or excessive school pressure, permanently "program" the HPA hormonal system, potentially leading to impaired reactivity to stressors later in life, paving the way for depressive and anxiety disorders in adulthood [20]. Childhood activity plays a significant role in regulating and shaping the HPA axis, and thus in preventing depression. In this context, systematic physical training acts as a controlled, repeatable physiological stressor, triggering the phenomenon of adaptation. Research conducted among students showed that acute physical exercise produces a transient, rapid release of cortisol, but regular repetition of this stimulus leads to profound regulatory adaptations [21]. The body learns to more quickly suppress the hormonal response after the stressor subsides. As a result, in the face of challenging life situations (e.g., peer conflicts or exams), assuming similar adaptational pathways in younger cohorts, the cortisol release curve in active children is expected to be moderated, and its levels return to resting values more quickly. This protects sensitive neural structures from the previously described neurotoxic effects of chronic glucocorticoid excess, preventing damage to the hippocampus and counteracting the biological anchoring of susceptibility to depressive states in adulthood.

Psychosocial protective mechanisms

The impact of physical activity on the mental health of children and adolescents extends far beyond neurobiology and chemical transmission, relying on complex, multi-level psychosocial processes. The transition from childhood to adulthood is a period of enormous psychological plasticity, during which key stress-coping resources are developed [22]. Contemporary research in community psychiatry focuses on the multi-stage mediating pathways through which exercise protects young people from the clinical manifestation of depression later in life.

One of the most important, specifically documented among high school students mechanisms is the chain mediation model, which links physical activity with increased social support and overall self-esteem [23]. According to this approach, regular exercise ought to be a primary factor initiating positive changes in a child's psychosocial structure. Engagement in sports

facilitates the formation of relationships and significantly expands the peer network, which translates directly into a stronger subjective sense of social support. According to the stress -buffering model described in Li and Hao's work, high levels of social support act as a protective shield – minimizing negative emotional reactions to life stressors (such as academic difficulties or family conflicts), thus reducing the severity of anxiety and depressive symptoms. Peer support gained through physical activity provides a direct foundation for building strong and stable self-esteem. The authors of the aforementioned publication also note that low self-esteem in childhood is one of the strongest long-term predictors of depression in adulthood. Despite ongoing social changes and the gradual shift away from established body image and appearance patterns, a relationship described as the link between physical activity and self-esteem is still noticeable, in which regular exercise increases physical self-efficacy, i.e., confidence in one's motor abilities, which in turn increases overall self-esteem [24]. For young people, good physical condition and a positive self-image provide protection against peer exclusion, stigmatization, and bullying, which are undeniable triggers of depression.

Another protective pillar is the social interaction hypothesis. Physical activity is rarely an isolated process; especially in children and adolescents, it most often takes the form of structured group activities. Research shows an interesting asymmetry between sports disciplines: youth participating in team sports demonstrate significantly lower rates of anxiety, stress, and depression compared to their peers practicing individual sports or those who are inactive [25]. Team sports naturally encourage cooperation, communication, and learning to cope with failure within a group, which directly develops players' social skills. Participation in team sports also builds a sense of belonging within a group, effectively preventing depression.

The psychosocial impact of exercise is also well explained by the concept of Positive Psychological Capital (PsyCap), which consists of four resources: self-efficacy, resilience, hope, and optimism [26]. By satisfying these components, particularly resilience and self -efficacy, exercise serves as a fuel in a young person's life, strengthening their psychological capital, enabling the safe release of tension, frustration, and accumulated aggression while simultaneously positively impacting mental well-being.

From a cognitive psychology perspective, the distraction hypothesis [27] is crucial. Intensive engagement in sports activities utilizes a child's attention resources, occupied with positive associations and experiences. In today's world, this mechanism plays an additional role in preventing social media addiction. According to the mood enhancement hypothesis, adolescents struggling with depression and anxiety about face-to-face interactions often escape into the

digital world, seeking easier forms of self-presentation there [28]. Physical activity effectively breaks this vicious cycle by offering a safe, real social space, improving mood, and thus reducing the psychological motivation to escape into the virtual world, which is, after all, a factor contributing to the development of poor well-being.

Finally, it is important to emphasize the importance of family bonds through parental support for physical activity. Family is the primary and crucial environment in which children's health habits are formed. Research shows that active parental support through encouragement and joint exercise has a strong negative correlation with depression in adulthood [29]. This support works in two ways: directly reducing depression through a sense of closeness and care, and indirectly by helping children develop lasting exercise habits that protect their mental health throughout adulthood. Interestingly, analyses show that it is parents (not physical education teachers) who exert the strongest and most lasting influence on modeling active behaviors in adolescents.

Methodological Challenges and Research Directions

This paper sheds new light on the crucial relationship between physical activity during childhood and adolescence and susceptibility to developing depressive disorders in adulthood. The collected evidence clearly demonstrates that early childhood exercise is not only a factor improving overall somatic fitness, but also constitutes a fundamental, multidimensional protective buffer for the developing brain. The protective effects of regular physical activity occur on three integrated levels: neurobiological (stimulation of neurotrophic factors and reduction of inflammation), neuroendocrine (optimization of the HPA axis and increased stress resistance), and psychosocial (enhancing self-esteem, increasing the perception of peer support, and developing psychological capital).

While the evidence from available prospective cohort studies is very strong, this synthesis also highlights significant methodological challenges that should be addressed in future research projects. Traditional approaches based on self-report questionnaires may tend to overestimate time spent in exercise, necessitating the widespread implementation of objective accelerometric measurements. In summary, promoting various types of physical activity in children should not be considered solely as a preventative measure against metabolic lifestyle diseases, but rather as a priority, cost-effective, and safe investment in the mental resilience of future generations. In an era of growing mental health crisis among young people, the widespread use of structured sports—with particular emphasis on team sports—is a key step toward building a healthier and more resilient society. Understanding the dynamic mechanisms behind the pathogenesis of

depression and translating them into specific preventive programs offers a real opportunity to effectively counter the depression epidemic.

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