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Exercise, Physical Activity, and Cognitive Development in Childhood and Adolescence: A Review

Çocukluk ve Ergenlikte Egzersiz, Fiziksel Aktivite ve Bilişsel Gelişim: Bir Derleme

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Özet

Egzersiz ve fiziksel aktivite, çocukluk ve ergenlik döneminde yalnızca fiziksel uygunluğu geliştirmekle kalmayıp, yürütücü işlevler, dikkat, hafıza ve akademik başarı gibi bilişsel süreçleri de desteklemektedir. Modern yaşamın getirdiği dijitalleşme, geleneksel oyunların kaybolması ve hareketsiz yaşam biçiminin yaygınlaşması çocukların hem fiziksel hem de zihinsel gelişimlerini olumsuz yönde etkilemektedir. Bu bağlamda yapılan araştırmalar, özellikle aerobik egzersizlerin hipokampal hacmi artırarak öğrenme ve hafıza süreçlerini güçlendirdiğini ve bilişsel performansı geliştirdiğini ortaya koymaktadır. Bununla birlikte, ülkemizde konuya yönelik çalışmaların sınırlı olduğu, mevcut literatürün büyük oranda yurt dışı araştırmalara dayandığı görülmektedir. Çocukluk ve ergenlik döneminde kazanılan hareket alışkanlıkları, bireyin yaşam boyu sağlığı, akademik başarısı ve toplumsal uyumu açısından kritik bir öneme sahiptir. Bu nedenle erken yaşlardan itibaren oyun ve egzersiz temelli programlarla çocuklara hareket alışkanlığı kazandırılması, hem bireysel hem de toplumsal düzeyde stratejik bir gereklilik olarak öne çıkmaktadır.

Anahtar Kelimeler: Egzersiz, Fiziksel Aktivite, Bilişsel İşlevler, Çocukluk, Ergenlik

Abstract

Exercise and physical activity during childhood and adolescence not only enhance physical fitness but also play a pivotal role in supporting cognitive processes such as executive functions, attention, memory, and academic achievement. The increasing prevalence of sedentary lifestyles, driven by digitalization, the decline of traditional play, and the conveniences of modern living, has negatively affected both the physical and mental development of young populations. Recent research highlights that especially aerobic exercise stimulates neurobiological mechanisms, including hippocampal volume expansion and elevated brain-derived neurotrophic factor (BDNF) levels, thereby strengthening learning and memory processes while improving overall cognitive performance. Nevertheless, in Turkey, research on this subject remains limited, with much of the current knowledge derived from international studies. Developing movement habits during early childhood is therefore of critical importance, as these habits significantly shape lifelong health, academic success, and social integration. Consequently, implementing play- and exercise-based programs from the earliest stages of education should be considered a strategic necessity, both at the individual and societal level.

Keywords: Exercise, Physical Activity, Cognitive Functions, Childhood, Adolescence

Introduction

Exercise has emerged as a crucial parameter for sustaining a healthy lifestyle, particularly in societies characterised by sedentary behavioural patterns. As individuals increasingly recognise the benefits of an active lifestyle, they attempt to dedicate time—even if limited—to physical activity or exercise (Tuzcu, 2022). Nevertheless, the conveniences of modern life and the widespread accessibility of information have gradually distanced people from movement, contributing to the growing prevalence of chronic conditions such as obesity (Drigny et al., 2014).

Within the transformations of modern lifestyles, phenomena such as the digitalisation of education, the decline of traditional games, and the changing structure of peer groups play a significant role in shaping the physical development of children and adolescents (Lillard et al., 2015; Linebarger et

al., 2014). Significantly, these changes influence metabolic and cardiovascular health and affect mental development during childhood and adolescence (Viir & Veraksit, 2012). Among cognitive domains, executive functions are reported to be most strongly associated with physical growth and fitness (Diamond, 2000). Physical fitness, defined as the integrated functioning of cardiopulmonary capacity, muscular strength, posture, flexibility, agility, balance, coordination, speed, power, and reaction time, can synergistically interact with specific cognitive abilities, thereby fostering overall development (Mullen & Hall, 2015). Accordingly, when applied with appropriate evaluation and implementation criteria, exercise contributes to enhancing both physical and cognitive functions (Farina et al., 2014; Galimberti & Scarpini, 2010; Haskell et al., 2007).

In recent years, a growing body of research has focused on the relationship between aerobic capacity, aerobic exercise modalities, and cognitive performance (Ankaralı & Bayramlı, 2019). Aerobic activity is recognised as a powerful stimulus for mental health and cerebral structural changes (Thomas et al., 2012). Indeed, exercise has been found to induce specific neurological adaptations distinct from those resulting from learning or novel experiences (Black et al., 1990). Aerobic training, in particular, has been associated with increased hippocampal neuron count and cerebral blood volume. At the same time, human studies have further demonstrated hippocampal volume expansion alongside improvements in cognitive performance (Thomas et al., 2012). Consequently, children and adolescents who exercise regularly and exhibit higher aerobic capacity are expected to display superior cognitive outcomes (Haskell et al., 2007). Examining this relationship during childhood and adolescence is therefore essential, as it contributes directly to cognitive performance, academic achievement, and the overall quality of education.

In Turkey, the limited number of studies on this subject necessitates the consideration of international findings. Hence, reviewing research on aerobic exercise protocols and their effects on cognitive performance and discussing the underlying physiological mechanisms will not only provide guidance for future investigations but also inspire new insights.

Human beings, as inherently dynamic organisms, continue their development through movement. Astrand emphasised that the human body is designed for activity, broadly defined as any body part position or overall bodily posture alteration. In children, physical education and activity programs should be designed to enhance physical fitness and perceptual-motor and socio-emotional capacities (Saygın et al., 2005).

Childhood, as a concept, is closely intertwined with family, society, health, and education. Ensuring that the child healthily completes developmental processes carries strategic and societal significance. Until the 18th century, childhood was not perceived as a distinct phase of life. However, since the 19th century, scholars and educators have emphasised childhood as a critical developmental stage in which acquired behaviours shape future quality of life and social adaptation (Muratlı, 1997). Numerous studies confirm the importance of family, school, and environmental factors in children's development, highlighting the role of social relationships, learning opportunities, and movement-based activities in supporting both cognitive and behavioural growth (Reeves, 2007; Oktay et al., 2003; Topaloğlu & Çeliköz, 2018).

Early childhood represents a particularly sensitive developmental window with lasting implications for later life outcomes. Habits acquired during this stage significantly determine an individual's long-term quality of life and health status (Karaaslan, 2017). As development emerges through the interaction of genetic and environmental factors, improving environmental conditions

becomes critical for children's healthy growth. Accordingly, state institutions and educational policies should strategically implement programs that encourage physical activity from an early age.

In preschool children, play- and exercise-based activities foster physical growth, exploration, decision-making, and learning processes (Mengütay, 2005). Gallahue identified this period as critical for acquiring fundamental motor skills such as running, jumping, throwing, catching, and striking (Özer & Özer, 2004). Accordingly, promoting movement habits at an early age enhances children's coordination abilities and contributes directly to cognitive development (Göde & Susar, 1997).

Regular physical activity also promotes socialisation, protects against harmful habits, reduces the risk of chronic diseases in adulthood, and supports active ageing, thereby enhancing quality of life across the lifespan (Türkiye Fiziksel Aktivite Rehberi, 2014; Baltacı et al., 2008; Yel et al., 2024). However, technological advances have reinforced sedentary lifestyles, turning inactivity into a behavioural norm during childhood, with serious risks for physical development (Muratlı, 2007; Şakar, Güzel & Yel, 2024). Indeed, research has demonstrated a marked decline in school-aged children's physical activity levels over the past two decades (Coşkunturk et al., 2023). For this reason, instilling exercise habits during the preschool years is regarded as more effective and feasible compared to later developmental stages, such as adolescence.

Methodology of the Review

This narrative review was conducted by systematically screening PubMed, Scopus, and Web of Science databases for peer-reviewed studies published between 2000 and 2025. Search terms included combinations of *exercise*, *physical activity*, *children*, *adolescents*, *cognition*, *executive function*, and *academic performance*. Meta-analyses, systematic reviews, longitudinal studies, and experimental interventions were prioritised. Inclusion criteria required that studies (i) involved participants under 18 years, (ii) examined cognitive or academic outcomes in relation to physical activity or exercise, and (iii) were published in English or Turkish. Exclusion criteria included studies focusing solely on clinical rehabilitation or adult populations. Additionally, selected reports from major health organisations (e.g., AAP, WHO) and reputable popular-science summaries were incorporated to provide context.

In contemporary society, technological advancements, changes in living conditions, and socio-cultural factors have increasingly contributed to the prevalence of sedentary lifestyles among children. Once established at an early age, such patterns often become habitual and negatively affect physical and cognitive development (Taşçı, 2010). Development is a series of progressive and interrelated changes within the organism, shaped by internal and external factors (Muratlı, 2007). In children, the determinants of development can broadly be categorised into hereditary factors (such as genetics, race, hormones, and sex) and environmental factors (including socio-economic status, living conditions, nutrition, illness, and exercise) (Muratlı, 2007; Yıldız, 2009).

Over the past two decades, research has consistently demonstrated a marked decline in physical activity levels among school-aged children (Janssen, Katzmarzyk, Boyce, & Pickett, 2004). Consequently, the establishment of regular exercise habits in early childhood is of paramount importance. Gallahue and Donnely (2003) emphasise that instilling physical activity routines during preschool is easier and more effective than during adolescence.

Studies involving children across different age groups have revealed the multidimensional benefits of exercise for health and development. For instance, Tolfrey et al. (2000) evaluated 14 studies on the effects of exercise on lipid-lipoprotein levels in children and concluded that regular exercise contributes positively to cardiovascular health. Similarly, Yörükoğlu and Koz (2007) found that children

aged 10–13 who engaged in basketball training five days per week demonstrated higher physical, physiological, and anthropometric values than peers who participated in sports school programs only twice weekly. In another study, Sardinha et al. (2008) reported that engaging in at least 25 minutes of vigorous daily physical activity enhances bone strength in children. In contrast, Altındağ and Sert (2009) demonstrated that everyday activities such as stair climbing, running, and participation in sports significantly influence children's body composition. Furthermore, Sevimli and Koçyiğit (2009) investigated the effects of aerobic exercise on the cardiopulmonary system in children aged 11–17, concluding that improvements were most pronounced among adolescents aged 15–17.

Childhood obesity and excessive weight gain have also emerged as central themes within exercise research. Economos (2012), in a study involving 1,224 children aged 8–18, demonstrated that weight problems in childhood significantly increase the risk of chronic diseases such as diabetes and cardiovascular disorders in adulthood. The study further revealed that obese children often face social stigma, which in turn discourages their participation in sports and physical activities.

Research conducted in Turkey has yielded similarly noteworthy findings. Akalan (2013) examined changes in body composition among boys aged 7–14 between 1995 and 2010, emphasising the necessity of promoting healthy nutrition and physical activity behaviours at an early stage. Likewise, Cinemre, Turnagöl, and Okut (2017) compared female volleyball players who regularly train with their non-athlete peers, concluding that volleyball—as a high-impact sport—positively influenced bone health in preadolescent girls. During the Covid-19 pandemic, the confinement of preschool children to their homes and the consequent restriction of opportunities for physical activity adversely affected the development of motor skills, particularly hindering the adequate acquisition of fundamental movement patterns (Ceyhan, 2022a).

School-based studies have provided additional insight. Chow, McKenzie, and Louie (2015), in their research conducted in Hong Kong, investigated physical activity during physical education classes in children aged 3–6. Their findings indicated that children generally engaged in moderate-intensity physical activity; however, lesson content and teacher behaviour variations influenced overall activity levels. Moreover, the study revealed that the duration of physical activity during classes remained below recommended standards.

Meta-analyses and systematic reviews have further reinforced the robust link between exercise and cognitive functions. Liu et al. (2025), in a comprehensive meta-analysis covering more than 70 studies on children and adolescents, reported significant positive effects of regular physical activity on executive functions, attention, cognitive flexibility, working memory, and inhibitory control. Similarly, Cui (2024) highlighted that regular adolescent exercise enhances antioxidant capacity, strengthens brain activation, and promotes hippocampal plasticity. Ceyhan (2022b) asserts that physical activity contributes not only to physical and cognitive development but also to the acquisition of moral and social values; in this regard, it serves as a means of integrating theoretical knowledge with real-life practice. Christiansen et al. (2019) compared children with ADHD and their typically developing peers, demonstrating that regular physical activity improved attention and executive functions across groups. In addition, Lees and Hopkins (2013) concluded that aerobic exercise supports memory, attention, and problem-solving skills. Haverkamp et al. (2020) found that school-based exercise interventions significantly improved academic achievement and executive functions. Furthermore, the American Academy of Paediatrics (2016) reported that physical activity reduces depression and anxiety, enhances self-regulation, and contributes positively to academic performance.

These findings underscore that exercise and physical activity during childhood and adolescence play a decisive role in physical health, cognitive functioning, social development, and academic achievement.

Development and Long-Term Effects

Longitudinal studies further support the enduring impact of exercise on cognitive performance. In a Brazilian birth cohort, Esteban-Cornejo et al. (2015) demonstrated that physical activity levels assessed at ages 11, 15, and 18 were directly associated with cognitive performance at age 18. Similarly, Herting and Chu (2017) reported that regular adolescent physical activity enhances structural brain plasticity, improving cognitive functions and academic performance.

Specific Findings and Neurobiological Mechanisms

Research has also explored the mechanisms through which exercise influences cognitive functioning. Altermann et al. (2024) examined various components of physical fitness in adolescents—including flexibility, endurance, coordination, and strength—and found that cardiorespiratory endurance was the strongest predictor of attentional performance. Additionally, the summary provided by Wikipedia contributors (2025) on the *Neurobiological Effects of Physical Exercise* highlights that aerobic activity promotes increased BDNF levels, synaptic plasticity, neurogenesis, and elevated growth factors, leading to an expansion of grey matter in the prefrontal cortex, hippocampus, and cerebellum.

Media and Popular Science Sources (Supporting Evidence)

Recent findings have also been reflected in media and popular science outlets. Tom's Guide (2025) reported that as little as nine minutes of high-intensity interval exercise significantly enhanced attention and working memory in children aged 7–13. Similarly, Health.com (2025) emphasised that alternative exercise modalities such as yoga, Tai Chi, and exergaming can strengthen memory and executive functions. Furthermore, a study published in Nature (2024) demonstrated that physical fitness strongly predicts attentional performance in adolescents, underscoring the direct relationship between physical conditioning and cognitive processes.

Research Gaps and Directions for Future Studies

Although studies examining the effects of exercise and physical activity on cognitive functioning in childhood and adolescence have steadily increased, a critical literature review reveals several noteworthy limitations. Identifying these gaps is essential to ensure that future research is methodologically more rigorous and practically more applicable.

Lack of Longitudinal Research

Much of the current literature is based on cross-sectional or short-term experimental studies that assess the immediate effects of exercise interventions on cognitive outcomes. For instance, systematic reviews by Liu et al. (2025) and Lees and Hopkins (2013) demonstrate the benefits of aerobic or endurance exercise on executive functions and academic performance. However, it remains largely unknown whether these effects persist across years. Given that habits formed during childhood and adolescence are often carried into adulthood and old age, there is a pressing need for longitudinal studies exploring how early physical activity shapes cognitive functions across the lifespan (Esteban-Cornejo et al., 2015; Herting & Chu, 2017).

Limited Exploration of Exercise Modalities

Most studies have focused on aerobic training, which has repeatedly been shown to enhance memory, attention, and problem-solving skills (Lees & Hopkins, 2013; Haverkamp et al., 2020). In contrast, far less attention has been paid to resistance training, coordination-based activities, play-centred interventions, or mind–body approaches such as yoga and Tai Chi. Popular science sources, such as Health.com (2025), suggest that these modalities also strengthen memory and executive functions. However, the evidence remains anecdotal or preliminary; randomised controlled trials are urgently needed. Comparative research could illuminate which types of exercise are most effective for specific cognitive domains, thereby enabling age- and context-appropriate program design.

Insufficient Examination of Neurobiological Mechanisms

While robust evidence supports the positive influence of exercise on cognitive functioning, the underlying neurobiological mechanisms remain only partially understood. Current findings indicate increased BDNF, hippocampal volume expansion, synaptic plasticity, and neurogenesis (Cui, 2024; Wikipedia contributors, 2025). However, much of this evidence derives from animal studies or small-scale human samples. To establish firmer conclusions, future research should incorporate large-scale longitudinal neuroimaging and biomarker-based studies across different age groups, thereby clarifying the biological underpinnings of the exercise–cognition link.

Socio-Cultural and Economic Diversity

The overwhelming majority of existing research has been conducted in Western contexts. However, socio-economic conditions, cultural practices, educational systems, and lifestyle patterns directly influence physical activity levels and cognitive development. The scarcity of studies conducted in developing countries, including Turkey, presents a severe limitation. Cross-cultural investigations are crucial for testing the universality of exercise–cognition associations and informing locally relevant policy interventions. In particular, the comparative evaluation of school-based physical education programs across diverse cultural contexts could yield important insights.

Technology, Sedentary Behaviour, and Modern Lifestyles

With digitalisation reshaping everyday life, sedentary behaviour has become increasingly pervasive among children and adolescents. Consequently, future research must extend beyond traditional exercise modalities to examine the potential of technology-assisted interventions. Promising examples include exergames, virtual reality–based exercise platforms, and online physical activity programs. However, the cognitive benefits of such approaches remain underexplored. Investigating these modalities could provide innovative strategies to counteract the challenges of modern sedentary lifestyles (Tom’s Guide, 2025).

Methodological Constraints

Finally, methodological limitations hinder the reliability and generalizability of existing findings. Many studies rely on small sample sizes, heterogeneous intervention protocols, and varied cognitive assessment tools, making cross-study comparisons difficult. Future research should adopt larger and more representative samples, employ standardised cognitive testing batteries, and incorporate extended follow-up periods to advance the field. Such improvements would enhance the robustness of findings and facilitate meta-analytic synthesis and evidence-based policymaking.

Conclusion

Exercise and physical activity constitute the foundation of physical fitness during childhood and adolescence. They are key determinants of higher-order cognitive processes such as executive functions, working memory, attentional control, and academic achievement. The accumulated body of evidence supports that children and adolescents who engage in regular physical activity exhibit superior cognitive performance compared to their sedentary peers. These findings confirm that exercise is a health-promoting behaviour and a developmental catalyst that directly influences learning capacity and academic success.

Beyond its immediate effects, physical activity has been shown to facilitate long-term neurodevelopmental benefits. Aerobic training, in particular, contributes to structural and functional brain changes, including increased hippocampal volume, enhanced neurogenesis, and improved cerebral blood flow, all of which underpin cognitive flexibility and memory consolidation. Furthermore, exercise protects against the negative consequences of sedentary behaviour and excessive screen use, which are increasingly prevalent in modern childhood and adolescence.

Nevertheless, the literature is not without its limitations. Much of the current evidence is derived from short-term or cross-sectional studies, which restricts our ability to draw firm conclusions about the enduring impact of physical activity across the lifespan. Moreover, the predominance of research in Western contexts raises questions about the generalisability of findings, especially when socio-economic and cultural variations are considered. The scarcity of studies conducted in developing countries such as Turkey highlights an important gap that future research must address.

The implications of this body of research extend beyond academia. For educators, integrating structured exercise and movement-based play into school curricula offers a practical pathway to enhance physical health, attention, self-regulation, and academic outcomes. For policymakers, recognising exercise as a determinant of cognitive health underscores the need to promote physical activity in national health and education strategies. For families and communities, fostering active lifestyles in children provides a foundation for lifelong health, resilience, and learning.

In conclusion, exercise and physical activity are powerful yet underutilised tools for optimising childhood and adolescent development. To fully harness their potential, future research should prioritise longitudinal designs, comparative investigations of exercise modalities, and neurobiological studies that reveal underlying mechanisms. Equally, greater attention must be given to cultural and socio-economic diversity, ensuring that findings can inform globally relevant yet locally adaptable strategies. By addressing these gaps, scholars and practitioners alike will advance scientific understanding and contribute to building healthier, more cognitively resilient generations prepared to meet the challenges of the twenty-first century.

Recommendations

Future research on the relationship between exercise, physical activity, and cognitive development in childhood and adolescence should prioritise several key directions. First, there is a clear need for longitudinal research to clarify whether early exercise habits' cognitive benefits persist into adulthood and old age. Large-scale prospective studies supported by universities, research institutions, and funding agencies will be critical to understanding the long-term trajectory of physical activity and cognition across the lifespan.

Second, comparative analyses of different exercise modalities should be expanded. While aerobic exercise has been extensively studied, the cognitive effects of resistance training, coordination-based activities, dance, and mind–body practices such as yoga and Tai Chi remain relatively underexplored. Randomised controlled trials that systematically compare these modalities will allow the development of age-appropriate and individualised programs designed to enhance specific domains of cognition.

Third, greater attention must be given to the neurobiological mechanisms underlying the exercise–cognition link. Advanced techniques such as fMRI, EEG, and biomarker analysis can provide valuable insights into how exercise influences synaptic plasticity, BDNF expression, and hippocampal growth. Strengthening this line of research will provide more robust scientific foundations for recognising exercise as both a lifestyle choice and a neurocognitive intervention.

Another essential consideration is cultural and socio-economic diversity. Current findings are predominantly derived from Western societies, limiting their generalisability. Expanding research into developing countries such as Turkey will generate critical insights into how local cultural practices, educational systems, and socio-economic conditions shape the outcomes of exercise and physical activity. Cross-cultural comparisons will also ensure that universal findings can be translated into context-specific strategies and policies.

Finally, it is important to integrate modern contexts into research and practice. School-based interventions should be reinforced by embedding structured physical education and play-based movement programs into curricula, as schools provide the most equitable setting for reaching children. At the same time, the digital lifestyles of today's children call for innovative, technology-assisted exercise interventions such as exergames, virtual reality–based activities, and mobile health applications. Alongside these institutional efforts, strengthening the involvement of families and communities will help establish supportive environments that promote healthy movement habits. In parallel, policymakers should embed physical activity strategies into early-childhood education and public health frameworks, ensuring that exercise becomes a central pillar for physical well-being and cognitive resilience in future generations.

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