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PHYSICAL EXERCISE AS A SUPPORTIVE INTERVENTION IN ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

Gabriela Kuliś[1*], Ewa Dryl-Jarmoc[2], Izabela Ślinko[3], Zuzanna Panas[4], Mateusz Zimowski[5], Jakub Dziemiańczuk[6], Mateusz Czajkowski[7], Kacper Krawczuk[8], Piotr Kadysz[9], Agata Kolanek[10]

1. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0006-8136-2661; e-mail: gabriela.kulis1356@gmail.com
2. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0007-2946-0800; e-mail: ewa.dryl96@gmail.com

3. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0002-5953-5168; e-mail: izabelaslinkoo@gmail.com
4. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0009-6850-4110; e-mail: zuzia.panas@wp.pl
5. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0003-0280-343X; e-mail: mateuszzimowski@icloud.com
6. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0007-7454-3111; e-mail: dziemianczukjakub@gmail.com
7. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0001-2924-694X; e-mail: matczajkowski24@gmail.com
8. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0009-3089-6323; e-mail: kacperkrawczuk@gmail.com
9. **Faculty of Medicine, Medical University of Białystok, Poland**; ORCID: 0009-0004-8952-3103; e-mail: lek.kadysz.piotr@gmail.com
10. **Department of Psychiatry, Medical University of Białystok, Poland**; ORCID: 0009-0002-0937-2938; e-mail: agkolanek@gmail.com

* Corresponding author: Gabriela Kuliś; e-mail: gabriela.kulis1356@gmail.com

Abstract

Background: Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders worldwide and remains an important public health concern. The disorder is characterized by persistent inattention, hyperactivity, and impulsivity that impair functioning across multiple domains. Purpose: This narrative review aimed to synthesize current evidence on the effects of physical activity and structured exercise interventions on cognitive performance, behavioral symptoms, and neurobiological mechanisms in individuals with ADHD. Materials and methods: Peer-reviewed studies published between 2010 and 2025 were identified through PubMed, Scopus, Web of Science, and ScienceDirect. Studies evaluating exercise interventions in people with ADHD and reporting cognitive, behavioral, or neuropsychological outcomes were included. Results: Available evidence suggests that physical exercise may reduce ADHD symptom severity and improve executive functions, especially working memory, inhibitory control, and cognitive flexibility. These effects are likely mediated by neurobiological adaptations involving catecholamines, neurotrophic factors, and enhanced neural efficiency.

Conclusions: Physical exercise appears to be a promising adjunctive intervention in ADHD management. Although it should not replace pharmacotherapy when indicated, regular physical activity may strengthen therapeutic outcomes and support cognitive, behavioral, and emotional functioning.

Keywords: ADHD, physical activity, exercise intervention, executive function, attention-deficit/hyperactivity disorder, neurodevelopmental disorders

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a complex neurodevelopmental condition characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with normal functioning across multiple domains of life. The disorder is typically diagnosed in childhood but often persists into adolescence and adulthood. Epidemiological studies estimate that ADHD affects approximately 5–7% of children and about 2–4% of adults globally (Liu et al., 2021; Yang et al., 2022; Halperin & Healey, 2011).

ADHD is associated with substantial functional impairments. Children with ADHD frequently experience academic difficulties, behavioral problems in school settings, and challenges in peer relationships. In adulthood, the disorder may contribute to occupational difficulties, reduced educational attainment, and increased risk of psychiatric comorbidities such as depression, anxiety disorders, and substance abuse (Firth et al., 2020; Yang et al., 2022).

The etiology of ADHD is multifactorial and involves complex interactions between genetic predisposition, neurobiological mechanisms, and environmental influences. Neuroimaging studies have identified structural and functional abnormalities in several brain regions, including the prefrontal cortex, basal ganglia, cerebellum, and anterior cingulate cortex (Firth et al., 2020; Den Heijer et al., 2017; Halperin & Healey, 2011). These brain regions are responsible for executive functioning, behavioral regulation, and attention control.

Executive function deficits represent one of the central cognitive characteristics of ADHD and are considered a key target for therapeutic interventions. Executive functions include cognitive processes such as working memory, inhibitory control, and cognitive flexibility, all

of which are essential for goal-directed behavior and adaptive functioning (Sun et al., 2022; Liu et al., 2021).

A central neurobiological feature of ADHD is dysregulation of catecholamine neurotransmitter systems, particularly dopamine and norepinephrine. These neurotransmitters play crucial roles in cognitive processes such as attention, working memory, and behavioral inhibition. Reduced dopaminergic activity within frontostriatal pathways has been widely implicated in ADHD pathophysiology (Firth et al., 2020; Den Heijer et al., 2017).

Pharmacological treatment, especially stimulant medications such as methylphenidate and amphetamine derivatives, remains the most widely used therapeutic approach. Although pharmacotherapy is often effective in reducing core ADHD symptoms, it may be associated with adverse effects and does not always address all functional impairments associated with the disorder (Cortese et al., 2015).

Consequently, increasing attention has been directed toward complementary and non-pharmacological interventions, including behavioral therapy, cognitive training, and lifestyle-based approaches such as physical activity (Cortese et al., 2015). In recent years, physical exercise has gained growing scientific interest as a potential supportive intervention for individuals with ADHD.

Regular physical activity has been consistently associated with improvements in cognitive functioning, emotional regulation, and overall mental health across both clinical and non-clinical populations (Firth et al., 2020). Exercise has been shown to promote neuroplastic changes in the brain, including increased levels of brain-derived neurotrophic factor (BDNF), improved synaptic plasticity, and enhanced neural connectivity. These neurobiological adaptations may support cognitive processes that are often impaired in ADHD.

Several studies have suggested that both acute and long-term exercise interventions may improve executive functioning, attention regulation, and behavioral control in individuals with ADHD (Cerrillo-Urbina et al., 2015; Chang et al., 2012; Sun et al., 2022; Liu et al., 2021). However, despite the increasing number of studies examining the role of physical activity in ADHD, the available evidence remains heterogeneous with respect to study design, exercise protocols, and outcome measures.

Therefore, the aim of the present narrative review was to synthesize and critically discuss current scientific evidence regarding the effects of physical exercise on cognitive functioning, behavioral symptoms, and potential neurobiological mechanisms in individuals with ADHD.

2. Materials and Methods

This study was conducted as a narrative review of the scientific literature examining the relationship between physical activity and outcomes associated with attention-deficit/hyperactivity disorder (ADHD). The aim of this review was to provide a qualitative synthesis of current evidence regarding the potential role of physical exercise as a supportive intervention in ADHD management.

The literature search was conducted between March and December 2025 using four major scientific databases: PubMed, Web of Science, Scopus, and ScienceDirect. The search strategy included combinations of keywords and Medical Subject Headings (MeSH) terms related to ADHD and physical activity. The following search terms were used in different combinations: ADHD, attention-deficit/hyperactivity disorder, physical activity, exercise, sport, executive function, cognition, and neurodevelopmental disorders. Boolean operators such as AND and OR were used to combine search terms and broaden the scope of the search.

Studies were included in the review if they met the following criteria:

- participants diagnosed with ADHD according to recognized diagnostic criteria (e.g., DSM or ICD);
- studies examining physical activity, sport participation, or structured exercise interventions;
- evaluation of cognitive, behavioral, or psychological outcomes associated with physical activity;
- articles published in peer-reviewed scientific journals;
- publications written in English.

Studies were excluded if ADHD was not the primary population studied, if physical activity was not analyzed as a key variable or intervention, or if the publications consisted of conference abstracts, editorials, or commentaries without original research data.

Titles and abstracts of the identified records were initially screened to determine their relevance. Subsequently, full-text articles were assessed for eligibility according to the predefined inclusion criteria. Particular emphasis was placed on randomized controlled trials, experimental studies, systematic reviews, and meta-analyses examining the effects of physical activity on ADHD-related outcomes.

After screening and eligibility assessment, 19 studies were included in the final qualitative synthesis. The study selection process is presented in Figure 1.

Figure 1. Flow diagram illustrating the process of identification, screening, and selection of studies included in the narrative review.

Records identified

n = 145

↓

Records screened

n = 145

↓

Full-text articles assessed

n = 43

↓

Studies included in the review

n = 19

3. Results

A total of 19 studies met the inclusion criteria and were included in the qualitative synthesis. The characteristics of the studies included in the review are summarized in Table 1. The analyzed studies varied in design, sample size, and type of exercise intervention. Overall, the findings suggest that physical activity may have beneficial effects on cognitive functioning, behavioral regulation, and ADHD symptom severity (Cerrillo-Urbina et al., 2015; Sun et al., 2022; Ren et al., 2023; Liu et al., 2021).

The reviewed literature suggests that physical exercise may influence ADHD symptoms through several mechanisms, including neurobiological adaptations, improvements in executive functioning, and behavioral regulation.

3.1. Neurobiological mechanisms of exercise in ADHD

Physical exercise influences several neurobiological processes relevant to ADHD symptomatology. One of the most important mechanisms involves modulation of catecholamine neurotransmitter systems, particularly dopamine and norepinephrine, which play key roles in attention regulation and behavioral inhibition (Pontifex et al., 2013; Sun et al., 2022; Den Heijer et al., 2017). Increased availability of these neurotransmitters during and after exercise may enhance cognitive control and improve executive functioning.

Another important mechanism involves stimulation of neurotrophic factors, particularly brain-derived neurotrophic factor (BDNF). BDNF plays a crucial role in neuronal growth, synaptic plasticity, and learning processes. Elevated BDNF levels following physical activity

may promote neuroplastic changes in brain regions responsible for executive functioning and enhance neural connectivity (Firth et al., 2020).

Exercise has also been shown to increase cerebral blood flow and oxygen delivery to brain tissue, supporting neural efficiency and cognitive processing. Increased perfusion of the prefrontal cortex may be particularly relevant for attention regulation and decision-making processes (Firth et al., 2020; Den Heijer et al., 2017).

In addition, physical activity may influence the regulation of stress-related hormonal responses through modulation of the hypothalamic–pituitary–adrenal (HPA) axis and may reduce systemic inflammation and oxidative stress, factors increasingly recognized as contributors to neuropsychiatric disorders (Firth et al., 2020).

3.2. Effects of exercise on executive functioning

Executive functions include cognitive processes such as working memory, cognitive flexibility, planning, and inhibitory control. Deficits in these processes are considered a central feature of ADHD and represent an important target for therapeutic interventions.

A growing body of evidence suggests that physical exercise may improve executive functioning in individuals with ADHD. Several experimental studies have demonstrated that acute exercise sessions lasting approximately 20–30 minutes can produce immediate improvements in attention and inhibitory control (Chang et al., 2012; Pontifex et al., 2013; Sun et al., 2022).

Long-term exercise programs may produce more sustained cognitive benefits. Structured physical activity programs lasting several weeks or months have been associated with improvements in working memory, classroom behavior, and academic performance (Cerrillo-Urbina et al., 2015; Ren et al., 2023; Montalva-Valenzuela et al., 2023; Liu et al., 2021).

Aerobic exercise appears particularly beneficial; however, activities requiring coordination and complex motor skills may provide additional cognitive stimulation. Sports involving strategic decision-making and motor planning may engage neural networks responsible for executive control and cognitive flexibility more strongly than repetitive aerobic exercise alone (Ren et al., 2023; Montalva-Valenzuela et al., 2023).

3.3. Behavioral and emotional outcomes

Exercise interventions may also influence behavioral and emotional symptoms associated with ADHD. Several studies have reported reductions in hyperactivity, impulsivity, and

behavioral dysregulation following participation in structured physical activity programs (Verret et al., 2012; Sun et al., 2022; Hattabi et al., 2023; Liu et al., 2021; Liu et al., 2025).

Participation in organized sports and structured exercise programs may promote social development and emotional regulation in children with ADHD. Team-based activities encourage cooperation, communication, and adherence to rules, which may support the development of social competence and behavioral self-regulation (Hattabi et al., 2023; Smith et al., 2013).

In addition to behavioral improvements, physical activity has been associated with broader psychological benefits. Exercise demonstrates well-documented antidepressant and anxiolytic effects, which may be mediated by increased endorphin release, improved self-esteem, and enhanced stress resilience (Firth et al., 2020).

3.4. Mental health, adherence, and implementation-related aspects of physical activity in ADHD

Recent evidence suggests that the therapeutic role of physical activity in ADHD extends beyond core behavioral symptoms and executive dysfunction. In particular, newer studies indicate that exercise may also influence broader dimensions of mental health, including internalizing symptoms, psychological well-being, and the feasibility of long-term participation in structured activity programs. These aspects are especially important in adolescents, in whom ADHD is frequently accompanied by emotional dysregulation, anxiety, stress, and reduced resilience.

A recent randomized controlled trial in adolescents with ADHD demonstrated that a 12-week aerobic exercise-based physical activity program produced significant improvements in depression, anxiety, stress, and inhibitory control. Importantly, the beneficial effects on internalizing symptoms and inhibitory control were maintained at a three-month follow-up, suggesting that exercise may provide not only immediate but also sustained mental health benefits in this population (Liu et al., 2025). In contrast, no significant effect was observed for aggression, indicating that not all emotional or behavioral domains respond equally to physical activity interventions (Liu et al., 2025). These findings broaden the clinical relevance of exercise in ADHD and support the view that physical activity may serve as an adjunctive strategy not only for cognitive enhancement but also for improving emotional well-being.

At the same time, the effectiveness of physical activity in ADHD should not be evaluated solely in terms of physiological or cognitive outcomes. A qualitative meta-synthesis of studies examining experiences of children with ADHD and autism spectrum disorder in organized

physical activity showed that participation is shaped by multiple factors operating at intrapersonal, interpersonal, institutional and environmental levels (Grahn, 2025). Negative experiences were associated with distractibility, motor difficulties, sensory overload, lack of predictability and negative reactions from teachers or coaches. In contrast, positive experiences were linked to enjoyment, supportive relationships, predictable routines and well-structured environments adapted to the needs of neurodivergent children (Grahn, 2025). These findings highlight that the effectiveness of exercise-based interventions depends not only on the type or intensity of physical activity but also on the context in which the activity is delivered.

Another important consideration concerns the broader clinical context of sport participation among adolescents with ADHD. Research investigating adolescents with and without ADHD following sport-related concussion indicates that individuals with ADHD may present with higher symptom burden and different patterns of neurocognitive performance during recovery (Allen et al., 2025). Although this line of research does not directly evaluate exercise as a therapeutic intervention, it highlights the complexity of interpreting cognitive and behavioral outcomes in physically active adolescents with ADHD and suggests that neurological and contextual factors may influence how symptoms manifest in sport-related environments.

Furthermore, physical activity should be considered within the broader framework of non-pharmacological interventions targeting executive functions in ADHD. A recent systematic review and meta-analysis found that neurofeedback training may improve executive functioning in children with ADHD, particularly inhibitory control and working memory (Zhong et al., 2025). The effectiveness of neurofeedback appears to be greater when interventions are sufficiently intensive and prolonged (Zhong et al., 2025). These findings suggest that physical activity should not necessarily be viewed as a standalone alternative to other interventions but rather as one component of a broader multimodal therapeutic approach. Within such a framework, exercise may be particularly valuable because it combines neurocognitive, emotional and psychosocial benefits while also improving overall physical health.

Overall, current evidence supports a more comprehensive model of the role of physical activity in ADHD. Exercise appears to influence not only executive functioning and behavioral regulation but also internalizing symptoms, resilience-related processes and social participation. Future research should therefore extend beyond narrow symptom-based outcomes and more consistently examine adherence, participant experience and contextual factors that determine

whether exercise interventions can be successfully implemented in everyday clinical and educational settings.

Table 1. Summary of selected studies examining exercise interventions *in ADHD.*

Author	**Year**	**Study design**	**Sample**	**Intervention**	**Outcomes**
Cerrillo-Urbina et al.	2015	Systematic review	249	Aerobic exercise	Reduced ADHD symptoms
Pontifex et al.	2013	Experimental	20	Acute treadmill exercise	Improved inhibitory control
Chang et al.	2012	Experimental	40	Acute aerobic exercise	Improved executive function
Verret et al.	2012	Randomized controlled trial (RCT)	21	10-week exercise program	Improved behavior
Gapin& Etnier	2010	Experimental	18	Aerobic exercise	Improved attention
Sun et al.	2022	Meta-analysis	1753	Exercise interventions	Cognitive improvements
Ren et al.	2023	Meta-analysis	2150	Exercise interventions	Executive function improvement
Montalva-Valenzuela et al.	2023	Systematic review	14	Sport participation	Improved cognition
Hattabi et al.	2023	Randomized controlled trial (RCT)	40	Swimming program	Reduced symptoms

Zang et al.	2021	Experimental	58	Coordinative training	Improved executive function
Liu et al.	2021	Meta-analysis	1120	Exercise interventions	Improved attention
Hoza et al.	2015	Intervention study	202	Physical activity program	Behavioral improvement
Smith et al.	2013	Intervention study	17	Physical activity program	Reduced ADHD symptom severity
Neudecker et al.	2019	Systematic review	11	Exercise interventions	Positive cognitive and behavioral effects
Archer & Kostrzewa	2012	Review	-	Physical exercise	Neurobiological mechanisms related to ADHD
Liu et al.	2025	Randomized controlled trial (RCT)	80	Aerobic physical activity program	Reduced depression, anxiety and stress; improved inhibitory control
Grahn	2025	Qualitative meta-synthesis	12	Experiences of organized	Identified barriers and facilitators of

				physical activity	participation in physical activity
Allen et al.	2025	Observational study	146	Sport-related concussion assessment	ADHD associated with higher symptom burden and different neurocognitive outcomes
Zhong et al.	2025	Systematic review and meta-analysis	18	Neurofeedback training	Improvement in inhibitory control and working memory

4. Discussion

The findings of this narrative review indicate that physical exercise represents a promising complementary intervention in the management of attention-deficit/hyperactivity disorder. The available evidence suggests that regular physical activity may positively influence both cognitive and behavioral outcomes, potentially addressing several core features of ADHD (Cerrillo-Urbina et al., 2015; Sun et al., 2022; Ren et al., 2023).

One of the most consistently reported benefits of exercise is the improvement of executive functioning. Executive functions, including working memory, inhibitory control, and cognitive flexibility, play a fundamental role in learning processes, academic performance, and everyday task management. Because impairments in executive functioning are considered a central characteristic of ADHD, interventions targeting these processes may significantly improve daily functioning and overall quality of life in affected individuals (Sun et al., 2022; Ren et al., 2023; Liu et al., 2021).

Both acute and long-term exercise interventions appear to produce beneficial cognitive effects in individuals with ADHD. Acute bouts of moderate-intensity aerobic exercise have been shown to produce immediate improvements in attention and inhibitory control. These short-term effects are likely associated with transient increases in catecholamine levels,

including dopamine and norepinephrine, as well as enhanced cortical activation in brain regions responsible for executive control (Chang et al., 2012; Pontifex et al., 2013; Sun et al., 2022). In contrast, long-term exercise programs may induce more persistent neurobiological adaptations. Regular participation in physical activity has been associated with neuroplastic changes, including increased levels of brain-derived neurotrophic factor (BDNF), improved synaptic plasticity, and enhanced connectivity within prefrontal and frontostriatal networks, which are critically involved in executive functioning and behavioral inhibition (Firth et al., 2020).

Another important factor in interpreting the effects of physical exercise in ADHD is the type and complexity of the activity performed. While aerobic exercise has been widely studied, activities requiring complex motor coordination and cognitive engagement may provide additional benefits. Sports that involve rapid decision-making, motor planning, and attentional shifting may activate neural networks associated with cognitive flexibility and behavioral regulation more strongly than repetitive aerobic exercise alone (Ren et al., 2023; Montalva-Valenzuela et al., 2023). Activities such as team sports, martial arts, dance, or coordination-based training programs may therefore provide particularly strong stimulation of both motor and executive control systems.

Physical exercise may also play an important role in self regulation mechanisms in individuals with ADHD. Increased motor activity observed in children with ADHD has been proposed as a compensatory mechanism aimed at regulating cortical arousal levels. Structured physical activity may therefore provide an adaptive outlet for this natural need for movement while simultaneously improving behavioral regulation and attentional control.

In addition to cognitive benefits, physical activity may contribute to improvements in psychosocial functioning. Participation in organized sports and group-based activities may promote social interaction, cooperation, and adherence to structured rules, which are important developmental skills for children and adolescents with ADHD (Hattabi et al., 2023; Smith et al., 2013). These experiences may enhance self-confidence, social competence, and emotional well-being. Recent research also suggests that physical activity may influence broader aspects of mental health in individuals with ADHD. Exercise interventions have been associated with reductions in depressive and anxiety symptoms and improvements in emotional regulation (Liu et al., 2025). These findings highlight the potential role of physical activity not only in cognitive functioning but also in supporting overall psychological well-being.

Another important consideration concerns age-related differences in response to exercise interventions. Most studies examining physical activity in ADHD populations have focused primarily on children and adolescents, whereas evidence regarding adult populations remains

relatively limited. Further research is therefore needed to determine whether similar neurocognitive benefits of exercise can be observed across different stages of development.

Despite the promising findings, several methodological limitations should be acknowledged. Many studies examining exercise interventions in ADHD populations involve relatively small sample sizes, short intervention durations, and heterogeneous exercise protocols. These methodological differences make it difficult to determine the optimal type, intensity, and duration of exercise interventions for individuals with ADHD.

Nevertheless, the available evidence suggests that physical exercise may represent a valuable complementary strategy in ADHD management. When integrated into multidisciplinary treatment approaches, including pharmacotherapy and behavioral interventions, structured physical activity programs may contribute to improved cognitive functioning, behavioral regulation, and overall well-being.

Limitations

Several limitations should be considered when interpreting the findings of this review. Many studies examining exercise interventions in ADHD populations involve relatively small sample sizes and short intervention durations, which may limit the generalizability of the findings.

Furthermore, considerable heterogeneity exists across studies with regard to exercise type, intensity, frequency, and outcome measures. These methodological differences make it difficult to directly compare findings across studies and to determine optimal exercise protocols for individuals with ADHD. In addition, most available studies focus on children and adolescents, while evidence regarding adult populations remains limited.

Future research directions

Future research should focus on large randomized controlled trials investigating standardized exercise protocols in ADHD populations (Ren et al., 2023; Montalva-Valenzuela et al., 2023). In particular, future studies should aim to determine the optimal type, intensity, frequency, and duration of exercise interventions. Further research is also needed to investigate long-term cognitive and behavioral outcomes associated with regular physical activity in both pediatric and adult ADHD populations.

Practical implications

The findings of this review have important implications for clinical practice, education, and sport science. Physical activity may be incorporated as a supportive intervention within comprehensive ADHD treatment plans alongside pharmacological and behavioral therapies.

Schools and educational institutions may play an important role in promoting physical activity among children with ADHD. Incorporating regular movement breaks, structured physical education programs, and opportunities for active play during the school day may help improve attention and classroom behavior.

In addition, exercise-based interventions may be particularly useful for children who experience adverse effects from pharmacological treatment or who prefer non-pharmacological approaches. Structured sport programs designed specifically for children with ADHD may provide both cognitive and psychosocial benefits.

Healthcare professionals, including physicians, psychologists, and physiotherapists, may consider recommending regular physical activity as part of lifestyle-based ADHD management strategies. Future interdisciplinary collaboration between sport scientists and clinical researchers may help develop evidence-based exercise protocols tailored to the needs of individuals with ADHD.

5. Conclusions

Physical exercise appears to be a promising supportive intervention in the management of attention-deficit/hyperactivity disorder. The available evidence suggests that regular physical activity may improve executive functioning, enhance attention regulation, and contribute to reductions in behavioral symptoms associated with ADHD.

In addition to its cognitive benefits, physical activity may also support emotional well-being, behavioral regulation, and psychosocial functioning in individuals with ADHD. These effects are likely mediated through a combination of neurobiological adaptations, including modulation of catecholamine neurotransmitter systems, increased neurotrophic factors, and improved neural connectivity.

However, the available evidence remains heterogeneous with respect to study design, exercise protocols, and outcome measures. Consequently, further high-quality randomized controlled trials are needed to better determine the optimal type, intensity, frequency, and duration of exercise interventions for individuals with ADHD.

Overall, physical activity should be considered a valuable component of multimodal ADHD management strategies and may provide meaningful benefits when integrated alongside pharmacological and behavioral treatments.

Author Contributions

Conceptualization, Gabriela Kuliś, Ewa Dryl-Jarmoc and Agata Kolanek; methodology, Gabriela Kuliś, Ewa Dryl-Jarmoc, Piotr Kadysz and Agata Kolanek; formal analysis, Gabriela

Kuliś, Izabela Ślinko, Zuzanna Panas, Mateusz Zimowski and Jakub Dziemiańczuk; investigation, Gabriela Kuliś, Ewa Dryl-Jarmoc, Izabela Ślinko, Zuzanna Panas, Mateusz Zimowski, Jakub Dziemiańczuk, Mateusz Czajkowski and Kacper Krawczuk; writing - original draft preparation, Gabriela Kuliś, Ewa Dryl-Jarmoc, Izabela Ślinko, Zuzanna Panas, Mateusz Zimowski, Jakub Dziemiańczuk, Mateusz Czajkowski and Kacper Krawczuk; writing - review and editing, Piotr Kadysz, Agata Kolanek and Gabriela Kuliś; visualization, Gabriela Kuliś and Mateusz Czajkowski; supervision, Piotr Kadysz and Agata Kolanek; project administration, Gabriela Kuliś and Agata Kolanek. All authors have read and agreed to the published version of the manuscript.

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