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The Role of Physical Activity in the Comprehensive Management of Attention Deficit Hyperactivity Disorder (ADHD): A Narrative Review

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ABSTRACT

Introduction and Purpose: Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders affecting children and adolescents. In addition to pharmacological treatment and cognitive behavioral therapy, increasing attention has been paid to the role of physical activity as a complementary therapeutic intervention. The aim of this review was to summarize the current evidence regarding the effects of physical activity on concentration and cognitive functioning in children with ADHD.

Research Objective: A narrative review of the literature was conducted using the PubMed database. Relevant publications were identified using the following keywords: attention-deficit/hyperactivity disorder (ADHD), children, physical activity, exercise, concentration, attention, and sport. Clinical trials, observational studies, systematic reviews, and meta-analyses investigating the effects of physical activity on children with ADHD were included.

Results: The available evidence indicates that regular physical activity improves attention, concentration, executive functions, and behavioral control in children with ADHD. The greatest benefits have been observed following aerobic exercise and activities combining physical and cognitive engagement. Physical activity may also reduce impulsivity and hyperactivity while improving social functioning and overall quality of life. These effects are thought to be associated with increased dopaminergic and noradrenergic neurotransmission, which plays a key role in attention regulation and executive functioning.

Conclusions: Regular physical activity appears to be an effective complementary intervention for children with ADHD. Although it should not replace evidence-based pharmacological treatment or cognitive behavioral therapy, it may enhance treatment outcomes by improving concentration, cognitive performance, behavioral regulation, and quality of life. Incorporating structured physical activity into comprehensive ADHD management may provide additional clinical benefits.

Keywords: attention-deficit/hyperactivity disorder (ADHD), children, physical activity, exercise, concentration, narrative review

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized primarily by inattention, hyperactivity, and impulsivity [1]. The first description of symptoms resembling the contemporary clinical presentation of ADHD is attributed to the German physician Melchior Adam Weikard. However, the first comprehensive clinical description of the disorder was published in 1902 by Sir George Frederic Still [2].

The diagnosis of ADHD in children is based on established diagnostic criteria. Symptoms must be present before the age of 12 years, persist for at least six months, and significantly impair functioning in multiple settings of everyday life. ADHD affects numerous aspects of an individual's functioning, exerting a substantial negative impact on social relationships, academic achievement, and occupational performance [3].

Growing public awareness and improved access to specialized diagnostic services have contributed to a steady increase in the number of individuals diagnosed with ADHD. Epidemiological data indicate that the overall prevalence of ADHD among children is approximately 15.9%. Age-specific analyses demonstrate that the prevalence ranges from 11% to 25.8% among preschool children and from 3.9% to 25.1% among school-aged children [4].

2. Etiology of Attention-Deficit/Hyperactivity Disorder

The etiology of ADHD is complex and multifactorial. Its pathogenesis involves the interaction of genetic, environmental, prenatal, and perinatal factors. Considerable interindividual variability has been observed regarding both the presence and the severity of risk factors associated with the development of the disorder [5].

2.1. Environmental Factors

Among perinatal risk factors, gestational age plays a significant role. Evidence suggests that children born preterm, particularly those with low or very low birth weight, are 2.6 to 4 times more likely to develop ADHD than children born at term. Another important perinatal factor associated with an increased risk of ADHD is perinatal hypoxia. Hypoxic injury may induce alterations in dopaminergic neurotransmission and neurotrophic signaling within the brain, thereby contributing to the development of ADHD symptoms.

Maternal exposure to pesticides during pregnancy or breastfeeding has also been identified as a potential environmental risk factor for ADHD. Experimental studies conducted in rodents have demonstrated that exposure to deltamethrin during pregnancy and lactation induces behavioral changes resembling ADHD, including impaired attention and memory, hyperactivity, impulsivity, and alterations in the brain dopaminergic system. Furthermore, epidemiological studies in humans have shown that children aged 6–15 years with detectable urinary pyrethroid metabolites were more than twice as likely to be diagnosed with ADHD compared with children without such exposure [6].

2.2. Genetic Factors

Genetic factors constitute another key component of ADHD etiology. Their contribution appears to be comparable in both children and adults. The high genetic correlation between childhood-onset ADHD and adult ADHD suggests that these conditions represent the same disorder persisting across different stages of life rather than distinct clinical entities. Family and twin studies estimate the heritability of ADHD to be approximately 74%. ADHD is considered a highly polygenic disorder, with susceptibility resulting from the combined effects of numerous genetic variants, each exerting a relatively small individual effect. In addition, rare

genetic variants, including insertions and deletions, may also contribute to the heritability of ADHD [7].

Early genetic studies primarily focused on candidate genes associated with monoaminergic neurotransmission, particularly genes involved in dopaminergic pathways, which play a fundamental role in regulating attention and behavior. However, many of these findings were not replicated in subsequent genome-wide association studies (GWAS), largely because of the limited sample sizes of earlier investigations. Advances in genomic research have led to the identification of several genes associated with ADHD susceptibility, including GFOD1 (glucose-fructose oxidoreductase domain-containing protein 1) and CDH13 (*cadherin 13*) [8].

Current knowledge regarding the biological function of GFOD1 remains limited. Although its precise role has not yet been fully elucidated, studies have confirmed its expression in the frontal cortex of the brain [9]. Considerably more evidence is available for CDH13, which encodes a cell adhesion protein involved in neuronal development and synaptic plasticity. Animal studies have demonstrated that deletion of CDH13 results in impaired attention and increased locomotor activity. Furthermore, variants of this gene have been associated not only with ADHD but also with schizophrenia, major depressive disorder, autism spectrum disorder, and bipolar disorder [10].

3. The Impact of Sleep Disorders on ADHD Symptoms in Children

The relationship between sleep disorders and the symptoms of attention-deficit/hyperactivity disorder (ADHD) has been extensively investigated for many years. It is estimated that sleep problems affect up to 55% of children diagnosed with ADHD. Despite the growing body of evidence, the exact nature of the relationship between sleep disturbances and ADHD remains unclear and continues to be a subject of scientific debate [11].

Current evidence suggests that the relationship between ADHD and sleep disorders is bidirectional. On the one hand, ADHD symptoms may contribute to the development of sleep disorders, including obstructive sleep apnea, restless legs syndrome, circadian rhythm sleep disorders, and insomnia. On the other hand, sleep disturbances may exacerbate attention deficits, increase impulsivity, and impair behavioral control, thereby mimicking or aggravating the clinical manifestations of ADHD.

It should also be emphasized that sleep disorders are not exclusive to children with ADHD. They frequently coexist with obesity and various psychiatric disorders, including major depressive disorder, bipolar disorder, and anxiety disorders. Therefore, appropriate differential diagnosis and effective management of comorbid conditions are essential for the accurate assessment of sleep disturbances and the development of an appropriate treatment strategy [12].

4. ADHD and the Prevalence of Comorbid Disorders

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders, with onset typically occurring during early childhood. Numerous studies have demonstrated that psychiatric and neurodevelopmental comorbidities are highly prevalent among individuals with ADHD. It is estimated that between 60% and 100% of children with ADHD meet the diagnostic criteria for at least one comorbid disorder, many of which may persist into adulthood.

Studies conducted in the United States have shown that approximately 42% of children with autism spectrum disorder (ASD) also meet the diagnostic criteria for ADHD, whereas the prevalence of ADHD among children with learning disabilities (LD) is approximately 17%. Collectively, these findings indicate that approximately 59% of the studied population presented with one of these comorbid neurodevelopmental conditions. A similarly high prevalence has been reported for the coexistence of ADHD and Tourette syndrome, affecting approximately 55% of patients [13].

Anxiety disorders represent another common group of comorbid conditions, affecting approximately 25–50% of individuals with ADHD. Depressive disorders are also frequently observed, with reported prevalence rates ranging from 18.6% to 53.3%.

The presence of comorbid disorders has a substantial impact on the clinical course of ADHD. Comorbidities may complicate the diagnostic process, worsen prognosis, and increase the complexity of therapeutic management. Consequently, patients with ADHD and coexisting psychiatric or neurodevelopmental disorders often require comprehensive, multidisciplinary treatment that combines pharmacotherapy with appropriately tailored psychological and psychosocial interventions [14].

5. Treatment of Attention-Deficit/Hyperactivity Disorder

The clinical manifestations of attention-deficit/hyperactivity disorder (ADHD) can be categorized into three core symptom domains: inattention, hyperactivity, and impulsivity. Inattention is primarily characterized by difficulties in sustaining attention and impaired selective attention, defined as the ability to focus on relevant stimuli while filtering out irrelevant information. Hyperactivity is manifested by excessive motor activity and difficulty remaining still, whereas impulsivity may adversely affect both interpersonal relationships and the performance of everyday activities.

Given the multidimensional nature of ADHD symptoms, therapeutic management should be comprehensive and individualized according to each patient's clinical needs. The cornerstone of treatment is appropriately selected pharmacotherapy, complemented by psychotherapeutic interventions. The primary objective of pharmacological treatment is to reduce symptom severity and improve patients' daily functioning. However, it should be emphasized that the beneficial effects of pharmacotherapy are generally maintained only during active treatment, and discontinuation of medication may result in the recurrence of ADHD symptoms [15].

Pharmacological agents used in the treatment of ADHD are broadly classified into two categories: stimulant and non-stimulant medications. First-line therapy consists of central nervous system stimulants, including methylphenidate, dextroamphetamine, lisdexamfetamine dimesylate, mixed amphetamine salts, and dexamethylphenidate. Non-stimulant medications are primarily prescribed when stimulant therapy is contraindicated, poorly tolerated, or fails to achieve adequate clinical efficacy. This group includes atomoxetine, clonidine, and guanfacine.

Pharmacotherapy is approved for children aged six years and older as well as for adults. In children younger than six years, non-pharmacological interventions, particularly cognitive behavioral therapy (CBT) delivered by appropriately trained healthcare professionals, are generally recommended as the initial therapeutic approach.

5.1. Stimulant Medications

Methylphenidate is the most commonly prescribed psychostimulant for the treatment of ADHD. It acts by inhibiting the reuptake of dopamine and norepinephrine, thereby increasing

the synaptic concentrations of these neurotransmitters. As a result, neuronal signaling is enhanced, particularly within the prefrontal cortex, which plays a crucial role in attention, executive functioning, and impulse control. The dorsolateral prefrontal cortex is primarily responsible for sustained attention, whereas the dorsal anterior cingulate cortex contributes to selective attention. In contrast, the orbitofrontal cortex is primarily involved in the regulation of impulsive behavior.

Treatment with methylphenidate has been shown to reduce hyperactivity and impulsivity while improving attention and concentration in children with ADHD. Numerous clinical studies have demonstrated its high therapeutic efficacy, accompanied by a relatively low incidence of adverse effects [16].

Another commonly used psychostimulant is dexamethylphenidate (d-MPH), the pharmacologically active d-enantiomer of methylphenidate. It was approved for clinical use by the U.S. Food and Drug Administration (FDA) in 2001. Similar to methylphenidate, dexamethylphenidate inhibits the reuptake of dopamine and norepinephrine. However, owing to its stereochemical properties, it exhibits greater pharmacological potency and higher selectivity. Clinical studies have also demonstrated more rapid absorption and a longer duration of action. Therapeutically, dexamethylphenidate reduces hyperactivity and impulsivity while improving attention and concentration in patients with ADHD [17].

Lisdexamfetamine dimesylate (LDX) is a prodrug of dextroamphetamine belonging to the amphetamine class of stimulants. Similar to other psychostimulants, it inhibits the reuptake of dopamine and norepinephrine; however, it additionally promotes the release of these neurotransmitters from presynaptic vesicles. This dual mechanism distinguishes lisdexamfetamine from other stimulant medications used in ADHD treatment.

Lisdexamfetamine itself is pharmacologically inactive and undergoes enzymatic hydrolysis primarily within erythrocytes, where it is converted into its active metabolite, dextroamphetamine. Owing to its pharmacokinetic profile, lisdexamfetamine exhibits a lower potential for inducing euphoria and a reduced risk of misuse compared with other psychostimulants. These properties are attributed to its gradual conversion into the active compound and its stable therapeutic effect throughout the day. The duration of action may extend up to 12 hours. Clinical use of lisdexamfetamine effectively reduces the core symptoms

of ADHD, including impaired attention, hyperactivity, and impulsivity. The medication is approved for use in children aged six years and older [18].

In summary, stimulant medications remain the first-line pharmacological treatment for ADHD. Although individual agents differ in their pharmacokinetic properties, they share a common mechanism of action involving modulation of dopaminergic and noradrenergic neurotransmission, resulting in comparable clinical efficacy. In cases of inadequate therapeutic response or unacceptable adverse effects, switching to another stimulant or initiating treatment with a non-stimulant medication may be considered.

One potential adverse effect of methylphenidate therapy is the development or exacerbation of tic disorders. In such cases, atomoxetine may represent an appropriate therapeutic alternative. For patients in whom tic disorders constitute the predominant clinical problem alongside ADHD, clonidine may be particularly beneficial.

Regular monitoring is recommended throughout stimulant treatment to ensure both efficacy and safety. In pediatric patients, body weight and height should be assessed periodically because prolonged stimulant therapy may influence growth velocity. Blood pressure and heart rate should also be monitored routinely, whereas electrocardiography (ECG) is recommended only when clinically indicated. In addition, regular reassessment of the need for continued pharmacotherapy is advised, including consideration of carefully supervised treatment interruptions when clinically appropriate, typically on an annual basis.

5.2. Non-Stimulant Medications

Non-stimulant medications are considered second-line pharmacological treatment for ADHD. They are primarily recommended for patients in whom stimulant therapy is contraindicated, poorly tolerated, or fails to achieve satisfactory therapeutic outcomes. Although non-stimulant agents generally demonstrate slightly lower efficacy than stimulant medications, they represent a valuable therapeutic alternative in many clinical situations.

One of the most commonly prescribed non-stimulant medications is atomoxetine. It is a selective norepinephrine reuptake inhibitor (NRI) that exerts its therapeutic effect by blocking the norepinephrine transporter (NET), thereby inhibiting the reuptake of norepinephrine from the synaptic cleft. As a result, norepinephrine concentrations increase within the central nervous system. Atomoxetine also indirectly enhances dopaminergic neurotransmission. In the

prefrontal cortex, the norepinephrine transporter is responsible for the reuptake of both norepinephrine and dopamine. Consequently, inhibition of NET increases the concentration of both neurotransmitters in this brain region. Importantly, atomoxetine does not substantially increase dopamine levels within the striatum, thereby minimizing activation of the brain reward system and reducing the potential for abuse. Its therapeutic effects are therefore primarily mediated through the prefrontal cortex, a region responsible for attention, executive functioning, and impulse control [19].

The initial therapeutic effects of atomoxetine are typically observed approximately two weeks after treatment initiation, whereas maximal clinical efficacy is usually achieved after about six weeks. Atomoxetine is approved for use in children aged six years and older, as well as in adults. Compared with psychostimulants, it carries a very low risk of abuse and dependence because it does not increase dopamine concentrations within the mesolimbic reward pathway. Treatment with atomoxetine has been shown to improve attention and concentration, reduce hyperactivity and impulsivity, and consequently enhance patients' functioning at school, in the workplace, and in everyday social life.

Another group of non-stimulant medications comprises α_2 -adrenergic receptor agonists, including guanfacine and clonidine. These agents reduce the release of norepinephrine from presynaptic nerve terminals and modulate noradrenergic neurotransmission. Clonidine is less selective because it binds to all three α_2 -adrenergic receptor subtypes (α_{2A} , α_{2B} , and α_{2C}), enabling it to exert effects within both the prefrontal cortex and the brainstem. In contrast, guanfacine demonstrates high selectivity for α_{2A} -adrenergic receptors, resulting in more targeted modulation of prefrontal cortical activity.

The therapeutic effects of both medications develop gradually and generally become clinically apparent after approximately six weeks of treatment. α_2 -Adrenergic receptor agonists are particularly effective in patients with ADHD accompanied by tic disorders. Clonidine also interacts with imidazoline receptors, which may contribute to reductions in blood pressure. Therefore, treatment discontinuation should be gradual to avoid rebound hypertension. Clinical studies have demonstrated that both clonidine and guanfacine effectively reduce hyperactivity and impulsivity while improving attention and concentration in patients with ADHD [20].

Bupropion is not considered a standard medication for the treatment of ADHD. However, several studies have evaluated its off-label use in selected patient populations. Although primarily indicated for the treatment of depressive disorders, bupropion may also be prescribed for certain individuals with ADHD. It belongs to the class of norepinephrine-dopamine reuptake inhibitors (NDRIs), acting through inhibition of the transporters responsible for the reuptake of these neurotransmitters. Studies have shown that bupropion exerts minimal effects on serotonergic neurotransmission, which may explain its lower incidence of gastrointestinal adverse effects compared with selective serotonin reuptake inhibitors (SSRIs) and tricyclic antidepressants (TCAs).

Compared with stimulant medications, bupropion exerts a weaker effect on dopaminergic neurotransmission, and its therapeutic benefits, including improvements in cognitive performance and attention, typically become evident only after several weeks of treatment. Nevertheless, it is associated with a substantially lower potential for abuse and dependence than conventional psychostimulants [21].

5.3. Psychotherapy as a Treatment Modality for Attention-Deficit/Hyperactivity Disorder

Psychotherapy represents an essential component of ADHD management in both children and adolescents as well as adults. Cognitive behavioral therapy (CBT) is the most widely used psychotherapeutic approach for this disorder. CBT is based on the premise that thoughts, emotions, and behaviors are closely interconnected. By modifying maladaptive patterns of thinking, patients can achieve meaningful changes in both their emotional responses and behavioral patterns. Cognitive behavioral therapy enables patients to identify dysfunctional cognitive schemas and develop more adaptive coping strategies. An integral component of CBT involves structured exercises focused on planning, time management, and task organization between therapy sessions. Consequently, patients acquire practical skills that improve emotional regulation, organization of daily responsibilities, and readiness to function effectively in educational and occupational settings. The major advantages of CBT include its structured format, relatively short duration, and well-established efficacy supported by extensive scientific evidence [22].

In children and adolescents, cognitive behavioral therapy is frequently combined with parent training programs. Psychoeducation for parents and caregivers constitutes a fundamental component of treatment, as it enhances understanding of ADHD and equips families with

effective strategies for supporting children in their daily lives. Psychotherapeutic interventions have been shown to improve behavioral regulation, social functioning, emotional well-being, and academic performance in children with ADHD [23].

In summary, ADHD is a chronic neurodevelopmental disorder whose symptoms can be effectively managed through appropriately individualized treatment. Successful management requires a holistic approach that considers both the patient's clinical needs and their psychosocial environment. Stimulant medications remain the first-line pharmacological treatment for most patients; however, the greatest therapeutic benefits are achieved by combining pharmacotherapy with psychotherapy [24]. In children, treatment is primarily based on cognitive behavioral therapy supported by parent psychoeducation, whereas pharmacotherapy is generally initiated after the age of six years in accordance with current clinical guidelines [25]. Early diagnosis and timely initiation of appropriate treatment substantially improve patients' long-term functioning and overall quality of life.

6. Prognosis of Patients with Attention-Deficit/Hyperactivity Disorder

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder whose symptoms persist into adulthood in a substantial proportion of affected individuals. It is estimated that approximately 50–65% of patients diagnosed with ADHD during childhood continue to experience clinically significant symptoms later in life. Although hyperactivity typically decreases with age, difficulties related to attention, organization, and planning frequently persist into adulthood. These findings indicate that ADHD is not exclusively a childhood disorder but rather a lifelong condition that may affect functioning across multiple stages of life.

Untreated ADHD is associated with an increased risk of academic underachievement, occupational difficulties, and impaired interpersonal relationships. Individuals with ADHD are more likely to experience poorer educational outcomes, difficulty maintaining employment, and challenges in social functioning. Numerous studies have also demonstrated an increased prevalence of psychiatric comorbidities, particularly major depressive disorder, anxiety disorders, and substance use disorders. Furthermore, impulsivity and impaired behavioral regulation may contribute to risk-taking behaviors and a reduced quality of life.

Appropriately tailored treatment substantially improves the prognosis of individuals with ADHD. The most favorable outcomes are observed in patients who receive an early diagnosis and consistently adhere to the recommended therapeutic interventions. Effective treatment enhances academic, occupational, and social functioning, reduces impulsivity, and lowers the risk of developing additional psychiatric comorbidities. However, pharmacotherapy alone is generally insufficient to address all manifestations of ADHD. Consequently, current evidence supports combining medication with cognitive behavioral therapy (CBT), psychoeducation, and family support to achieve optimal long-term outcomes.

The clinical course of ADHD varies considerably among individuals and is influenced by several factors, including symptom severity, the presence of comorbid disorders, and the timing of treatment initiation. While some patients experience a marked reduction in symptoms with age, others require continued treatment throughout adulthood. Despite these challenges, many individuals with ADHD achieve successful educational attainment, stable employment, and satisfying interpersonal relationships, particularly when they receive an accurate diagnosis, comprehensive treatment, and appropriate psychosocial support [26].

7. The Impact of Physical Activity on Concentration in Individuals with Attention-Deficit/Hyperactivity Disorder

Pharmacotherapy and cognitive behavioral therapy constitute the foundation of ADHD management. However, a growing body of evidence highlights the important role of physical activity as an adjunct to standard treatment. Meta-analyses investigating the effects of physical activity on children with attention-deficit/hyperactivity disorder (ADHD) have demonstrated that regular exercise improves attention, executive functioning, and overall cognitive performance. The greatest benefits have been observed following aerobic exercise and activities requiring simultaneous motor and cognitive engagement [27].

One of the mechanisms underlying the beneficial effects of physical activity involves increased activity of the dopaminergic and noradrenergic neurotransmitter systems, which play essential roles in regulating attention, executive functions, and behavioral control. Consequently, regular physical exercise may reduce inattentive symptoms while improving daily functioning in individuals with ADHD [27].

The findings of subsequent clinical studies and meta-analyses consistently support the beneficial effects of regular physical activity on ADHD symptoms. Aerobic exercise and activities that combine physical movement with cognitive demands appear to produce the greatest therapeutic benefits. Regular participation in these forms of exercise has been associated with significant improvements in attention, cognitive performance, and behavioral regulation [28].

Beneficial effects of physical activity have been demonstrated in both children and adults with ADHD. Particularly favorable outcomes have been reported following aerobic activities such as running, cycling, and team sports. Regular exercise has also been shown to reduce hyperactivity and impulsivity while enhancing emotional well-being, social functioning, and cognitive performance, ultimately contributing to an improved quality of life [29].

It should be emphasized, however, that physical activity should not be regarded as a substitute for evidence-based ADHD treatment. Instead, it represents an effective complementary intervention that enhances the benefits of pharmacotherapy and cognitive behavioral therapy within a comprehensive treatment strategy.

8. Conclusions

Attention-deficit/hyperactivity disorder is a chronic neurodevelopmental disorder affecting both children and adults. Its core symptoms—including inattention, hyperactivity, and impulsivity—may substantially impair everyday, academic, occupational, and social functioning.

Current evidence indicates that optimal ADHD management requires a comprehensive and individualized treatment approach combining pharmacotherapy, cognitive behavioral therapy, and appropriately prescribed physical activity. Aerobic exercise and activities integrating physical and cognitive engagement appear to provide the greatest clinical benefits. Regular physical activity positively influences dopaminergic and noradrenergic neurotransmission, which plays a central role in attention regulation, executive functioning, and behavioral control. Consequently, it may contribute to reductions in hyperactivity and impulsivity while improving attention and concentration.

Furthermore, available evidence suggests that regular physical activity enhances cognitive performance, psychological well-being, and overall daily functioning in both children and

adults with ADHD. Therefore, physical activity should be considered an important component of comprehensive ADHD management, complementing conventional therapeutic interventions and contributing to improved long-term outcomes and quality of life.

Disclosures

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Conflict of Interest

The authors deny any conflict of interest.

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