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Navigating the Effects of Aerobic Exercise in Treating Patients with ADHD

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Abstract

Background: Attention Deficit Hyperactivity Disorder (ADHD) is a prevalent condition affecting millions of children and adolescents worldwide, causing challenges related to attention, organization, and impulse control. Disturbances in dopamine and norepinephrine pathways characterizethis disorder, leading to diminished neurotransmitter levels, particularly in the dorsolateral prefrontal cortex. Despite the existence of treatments like methylphenidate, their efficacy is often accompanied by undesirable side effects.

Methods: The objective of this study is to minimize the necessary effective dose of pharmacologic treatments through the incorporation of adjuvant therapies, specifically aerobic exercise. Combining aerobic exercise with medication has shown promising outcomes, resulting in asignificant reduction in total ADHD scores and a decline in perseverative errors.

Results: Brain imaging revealed noteworthy changes associated with this combined approach. There was heightened activity in the right frontal cortex, indicating improved problem-solving skills. Additionally, significant activity was observed in the left parietal lobe, contributing to enhancements in math, writing, and language skills.

Conclusions: The study demonstrates the substantial potential of aerobic exercise as an adjuvant therapy for managing ADHD symptoms andenhancing cognition. This approach opens new avenues for the future of ADHD treatment, suggesting a more holistic and potentially side-effect-reducing strategy.

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) affects approximately 2-10% of children globally and often persists into adolescence. Its primary symptoms are inattention, hyperactivity, difficulty in organization, and impulsive behavior. Symptoms of ADHD are believed to be linked to reduced functionality in the dorsolateral prefrontal cortex (DLPFC), a brain region that governs motor, cognitive, and emotional responses as well as the regulation of arousal neurotransmitters. This leads us to the question; Can aerobicexercise be used to minimize the therapeutic dose of stimulants in treating ADHD.

At its core, ADHD involves disruptions in the neurotransmitter pathways of dopamine and norepinephrine. Dopamine plays its rolewhen it comes to prioritizing tasks and focusing, hence disruptions can lead to deficit in focus and an overall lack of structure.Norepinephrine on the other hand is responsible for attention, arousal, and most importantly, impulse control. The persistent deficitin neurotransmitter levels stems from the actions of the dopamine transport protein and the norepinephrine reuptake protein. These proteins work by extracting their respective molecules from the synaptic cleft back into the presynaptic neuron causing a shortage inthe quantity for the D2 and α receptors.

Studies conducted using fMRI technology have suggested that patients with ADHD tend to have a reduced blood flow to the certainregions of the brain of which prevailing is the prefrontal cortex. Additionally, an overall size reduction within the frontal lobe has alsobeen observed. There are numerous existing pharmacologic as well as nonpharmacologic methods of treating ADHD.Methylphenidate, commonly known as ritalin, is a CNS stimulant which exerts its effect by inhibiting the uptake transport proteins for norepinephrine and dopamine, effectively increasing their concentrations within the synaptic cleft. Results are observed in thepatient as they are able to focus better and become less impulsive due to the rise in dopamine and norepinephrine respectively.

Numerous studies indicate that pharmacotherapies for Attention Deficit Hyperactivity Disorder (ADHD), such as dextroamphetamine, methylphenidate, and atomoxetine, are both cost-effective and commonly prescribed by healthcare providers. However, 10-30% of children with ADHD do not respond adequately to methylphenidate, and the drug's side effects can range from mild to severe, with rare instances of being life-threatening.

Need for Adjunctive Therapies

· Enhancing Stimulant Efficacy: There is a need for additional therapies to boost the effectiveness of stimulants and reduce the required dosage.

· Cognitive Behavioral Therapy (CBT): Research has shown that combining CBT with medication effectively improves ADHD symptoms.

· Psychotherapy for Self-Esteem: Psychotherapy aimed at enhancing self-esteem has been demonstrated to significantly alleviate symptoms and related issues in children with ADHD.

A study was conducted[1] in which 2 groups were formed. One undergoing only CBT treatment, and another undergoing CBT treatmentalong with ADHD medication. Baseline tests showed that the group on medication yielded higher scores in organizing and scored higher on the metacognition index than the group undergoing only CBT.

Observing the results, it was found that in both groups there was a notable improvement in both Attention Deficit Hyperactivity Disorder (ADHD) symptoms and emotional well-being. However, contrary to the expected outcome, there was an equivalent improvement in core symptoms and emotional symptoms in both groups

In conclusion, the findings suggest that a 12-week group Cognitive Behavioral Therapy (CBT) intervention effectively addressed core ADHD symptoms, anxiety, depression, daily functioning, and social interactions in adults with ADHD, regardless of whether medication was concurrently administered or not.

Benefits of Exercise for ADHD

The use of exercise as an adjunct therapy for Attention Deficit Hyperactivity Disorder (ADHD) has shown promising benefits for clinical, cognitive, and academic outcomes.

Positive Outcomes of Exercise

· Clinical Benefits: Physical activity has demonstrated positive effects on clinical symptoms of ADHD.

· Cognitive Improvements: Research indicates that exercise enhances concentration and inhibitory control in cognitive tasks.

· Academic Performance: Regular exercise is linked to better scholastic achievement.

Key Research Findings

· Studies on Healthy Children: Research has found that exercise improves both concentration in cognitive tasks and inhibitory control in healthy children.

· Pontifex et al. Study

o Participants: The study included a healthy control group and a group of children with ADHD.

o Procedure: Children participated in a single 20-minute session of moderate-intensity aerobic exercise.

o Results:

§ Both groups exhibited improved response accuracy and stimulus-related processing.

§ Children with ADHD showed selective enhancements in regulatory processes compared to a similar session of seated reading.

A study with a similar objective was conducted to explore the impact of sports on attention symptoms, social competence, and cognitive functions in children with ADHD. The study spanned 6 weeks, comprising twelve 90-minute sessions of either education or sports therapy. However, its difference lies in the use of different tests to analyze the changes in the subjects and the absence of abrain activity test to pinpoint the different regions of the brain that were active. Yet the results showed an overall great improvementin cognitive functions and cooperativeness when compared to the education group. To note, there was a prominent and highlightedeffect of exercise on the social outcomes in children with ADHD.

METHODOLOGY

Thirty-five male adolescents aged 13-18 with Attention Deficit Hyperactivity Disorder and fifteen age-matched healthy controls were recruited for the study. All participants underwent evaluations using the Korean Kiddie Schedule for Affective Disorders and Schizophrenia, as well as a diagnostic interview following the criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV).

The inclusion criteria for the ADHD group were:
1. A formal ADHD diagnosis
2. No medication use for the past 6 months
3. An IQ of 80 or higher.

Exclusion criteria for this group included:
1. Presence of other axis I disorders
2. History of head trauma, including seizures
3. An IQ below 80
4. A history of substance abuse.

For the healthy control group, inclusion criteria were:
1. Age 13-18 years
2. An IQ of 80 or higher.
3. No psychiatric or medical illnesses

The exclusion criteria for the healthy control group aligned with those for the ADHD group. All adolescents diagnosed with ADHD underwent initial assessments and brain imaging before being evenly divided between the sports and education groups. Each participant commenced treatment with methylphenidate (Metadate CD™) at a daily dose of 10 mg.Based on the response, the dosage wasincreased between 10-40 mg/d for the first 4 weeks and then kept stable for the remaining 2. After 6 weeks, the clinical symptomsand cognitive functions were assessed using the Dupaul rating scale and the Wisconsin Card Sorting (WCS) Test. Due to severalreasons, the final testing was evaluated using only 30 out of the 35 initial subjects.

Exercise

The sports team comprised a psychiatrist, two sports psychologists, and four teaching assistants specializing in sports psychology.The exercise regimen consisted of three weekly sessions lasting 90 minutes each, structured as follows: 10 minutes for stretching and warm-up, followed by 60 minutes of aerobic exercise, and concluding with 10 minutes for feedback and cool-down. Aerobic activities included zigzag running, jumping rope, and basketball drills, with the aim of reaching a target heart rate corresponding to 60% of the maximum intensity. Target heart rate (THR) was calculated using the following: Target Heart Rate = (Heart Rate max –HeartRater rest) × %intensity desired + Heart Rate rest.

Education

Educational sessions only lasted 50 minutes and were placed as a control for the sports group. These sessions followed the same system as a previously conducted experiment on education and sports therapy. The program consisted of twelve sessions covering a range of topics:

1. Introductions and establishing self-awareness
2. Understanding and distinguishing between positive and negative behaviors
3. Self-reflection and behavior review
4. Comparing personal behavior with that of others
5. Exploring family dynamics and interactions
6. Techniques for building and maintaining friendships (covered over two sessions)
7. Strategies for improving focus and attention
8. Managing hyperactivity
9. Anger management techniques
10. Insightful discussions with guest speakers who have successfully overcome ADHD
11. Recap and summary of key points discussed in previous sessions

Throughout the program, each session was overseen by both a psychiatrist and a social worker, ensuring comprehensive support and guidance for all participants.

Brain Activity

Brain activity was recorded using an fMRI in response to a modified version of the WCSTest. Two versions of the WCSTest werepresented to ADHD subjects. During the scanning procedure, adolescents diagnosed with ADHD viewed a black screen displaying four cards at the top and a stimulus card at the center of the bottom edge. Their task was to match the stimulus card with one of the four reference cards using a keypad within a time frame of 4000 milliseconds for each stimulus presentation. After each response, a 500 ms feedback screen was presented indicating whether the selected choice was correct or incorrect. During the intervals between card presentations, the participants were instructed to press the keypad buttons randomly.

In an alternative version, participants engaged in a task lasting 450 seconds, divided into five 90-second segments. Each segment consisted of three sub-segments: a white cross on a black background (BG), a neutral control (N), and the task (T), which involved the WCSTest. These segments were presented in a randomized order using the IFIS-SA™ during a single scanning session.

RESULTS

Following the completion of baseline assessments, no notable demographic distinctions were observed among individuals diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). group and the healthy comparison group. Following this, its also important to note that:

1. The K-ARS scores, along with preservative responses and errors, were notably higher in the ADHD group compared to the healthy control group.
2. Moreover, individuals in the ADHD group displayed lower IQ scores than those in the healthy control group.
3. Despite these differences, there were no discernible variations in any parameter between the group receiving educational intervention for ADHD and the one engaged in sports-based intervention for Attention Deficit Hyperactivity Disorder.

At baseline, adolescents with Attention Deficit Hyperactivity Disorder (ADHD) exhibited altered activation patterns in various brain regions compared to their healthy counterparts during WCS Test stimulation:

1. Decreased activation in:
   - Right occipital lobe
   - Both middle temporal gyri
   - Right cerebellum
   - Right frontal lobe
   - Both parietal lobes

2. Increased activation in:
   - Right temporal lobe (limbic lobe)

(Difference After 6 Weeks)

Using a rapid review methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement, this study synchronized current resources available on research engines - PubMed, ResearchGate, and Google Scholar. The aim was to evaluate the effect of aerobic exercise on brain function and structure in patients suffering from Parkinson’s disease. The findings substantiated the hypothesis that aerobic exercise possesses potential neuroprotective properties in the context of Parkinson’s disease. However, it's crucial to acknowledge that maintaining a consistent exercise regimen may pose challenges for specific Parkinson's disease patients. Nonetheless, the cumulative evidence underscores that the benefits derived from aerobic exercise far surpass the challenges associated with adherence.

· Utilized rapid review methodology following PRISMA guidelines
· Synchronized resources from PubMed, ResearchGate, and Google Scholar
· Evaluated the impact of aerobic exercise on Parkinson's disease
· Confirmed potential neuroprotective properties of aerobic exercise
· Highlighted challenges associated with maintaining an exercise regimen for Parkinson's patients
· Emphasized the benefits outweighing the challenges of aerobic exercise

The average β value in the frontal lobe increased in both groups, showing a notably sharper rise in the sports-Attention Deficit Hyperactivity Disorder group. This surge correlated with improved problem-solving skills and task organization among the participants. Moreover, the mean β value in the left parietal lobe exhibited a significantly more substantial increase in the sports- Attention Deficit Hyperactivity Disorder group compared to the edu-ADHD group. This enhancement, linked to the left parietal lobe's role in coordinatingbody movements, translated into enhanced mathematical abilities, writing proficiency, and sentence construction. In contrast, the mean β value for the right temporal lobe, responsible for processing non-verbal information, decreased in the sports group while remaining steady in the edu group. This decline in right limbic lobe activity, associated with emotional expression, empathy, andemotionally-driven problem-solving, deviated from the expected impact of the sports intervention.

No notable alterations were observed in the β values for the right occipital lobe, left middle temporal lobe, right cerebellum, and right parietal lobe.

K-ARS Score & Perseverative Response

Limitations

The alteration in right prefrontal cortex activity among all adolescents with ADHD presented with a negative correlation with changes in both K-ARSscores and perseverative errors. Notably, there was no
significant correlation found between K-ARS scores, perseverative errors, and brain activity in other clusters with in the brain. The study had several limitations. Firstly, the relatively small number of participants and the brief duration of the exercise regimen might limit the generalizability of the results. Additionally, the differing time allocations between sports (90 minutes for 18 sessions) and education(50 minutes for 12 sessions) could have influenced the outcomes. Secondly, due to the combined use of methylphenidate, thepresent results do not distinctly illustrate the isolated effects of exercise on symptoms and brain activity. Lastly, the study onlyinvolved single assessments of clinical symptoms and cognitive functions in adolescents, potentially limiting the comprehensive understanding of the long-term impact.

DISCUSSION

Previous research[2] has demonstrated that Parkinson's disease, arising from dopamine deficiency, is impacted by exercise involving intricate movement patterns coupled with visual and spatial cognition. Dopamine modulation in the prefrontal cortex, striatum, and basal ganglia is implicated in this process. The heightened brain activity is believed to result from two primary mechanisms:
angiogenesis and dopamine release induced by hypoxia.

- Parkinson's disease, rooted in dopamine deficit, is affected by exercise incorporating complex movement patterns alongside visual and spatial cognition.
- Dopamine modulation in the prefrontal cortex, striatum, and basal ganglia plays a pivotal role in influencing the impact of exercise on Parkinson's disease.
- Increased brain activity attributed to exercise in Parkinson's disease is likely a result of angiogenesis and dopamine release induced by hypoxia.

Seifert and colleagues[3] discovered that three months of endurance training in overweight healthy males led to improved cerebral oxygenation and metabolism. Likewise, Colcombe et al.[4] conducted a study indicating a rise in global brain volume in healthy older adults (aged 60-79 years) following six months of aerobic exercise. These findings suggest that aerobic exercise enhances brain activity and boosts blood flow, largely due to angiogenesis. Angiogenesis[8] involves two main processes: sprouting and intussusception. Primordial capillary plexuses expand through both mechanisms, with ongoing growth and remodeling primarily driven by intussusception.

- Seifert et al.[3] observed enhanced cerebral oxygenation and metabolism in overweight healthy males after three months of endurance training.
- Colcombe et al.[4] reported an increase in global brain volume in healthy older adults (aged 60-79 years) following six months of aerobic exercise.
- Aerobic exercise is believed to augment brain activity and increase blood flow, primarily through angiogenesis.
- Angiogenesis[8] comprises sprouting and intussusception processes, with ongoing growth and remodeling predominantly driven by intussusception.

CONCLUSION

In summary, the study underscores the significant impact of aerobic exercise in augmenting the efficacy of methylphenidate in mitigating clinical symptoms and perseverative errors. Furthermore, it enhances brain activity within the right frontal cortex during the WCS Test stimulation compared to educational behavioral control. Although there was a noticeable inclination towards increased activity in the left parietal cortex, no significant alterations were noted in several other brain regions. These results underscore the potential of aerobic exercise as a valuable supplementary intervention for managing ADHD symptoms and enhancing cognitive function.

DECLARATION

Ethical Statement

The research conducted in this study received approval from the Institutional Review Board/Ethics Committee at Tbilisi State Medical University. All procedures involving human participants adhered to the ethical standards of Tbilisi State Medical University, the 1964 Helsinki Declaration, and its subsequent amendments or comparable ethical guidelines.

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Conflicts of Interest

The authors maintain that there are no conflicts of interest related to this research. Neither financial nor non-financial competing interests are present.

Data Availability

The data supporting the findings of this study are comprehensively presented within the article and its supplementary materials. For any additional data, interested parties may request access, and such requests will be considered.

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