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# The Effect of Cognitive-Motor Training on Physical Literacy and Cognitive Function of Children with ADHD

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## Abstract

**Introduction:** Understanding the key factors that influence physical literacy (PL) and cognitive function in children with ADHD is crucial.

**Objective:** This research seeks to explore how cognitive-motor training (CMT) influence both the PL and cognitive abilities of children diagnosed with ADHD.

**Methods:** A quasi-experimental design featuring a pretest-posttest framework with a control group was implemented in this research. The study involved 54 male children aged 7 to 10 years; all diagnosed with ADHD. Participants were split into two equal groups. The intervention group participated in a CMT for eight weeks, attending three sessions per week. To assess the research variables, the Canadian Assessment of Physical Literacy Development, the Numerical Span Subscale of the Revised Wechsler Intelligence Scale for Children, and the Corsi Block-Tapping Task were utilized, with data analysis conducted using ANCOVA.

**Results:** Body mass index (BMI) in both groups was similar, again showing no significant differences ( $P>0.05$ ). The analysis performed at the end of the intervention period showed significant differences across all groups for the evaluated parameters, including both PL and cognitive function dimensions ( $P<0.001$ ). These findings suggest that CMT successfully enhanced PL and cognitive function in male children diagnosed with ADHD.

**Conclusion:** By intentionally merging physical exercises with cognitive tasks, there is potential for children with ADHD to experience improvements in both their PL and cognitive functions, which are often areas of difficulty for them. Nonetheless, further research is essential to explore this intersection more thoroughly.

**Keywords:** ADHD, Cognitive Behavioral Therapy, Physical Fitness, Executive Function, Child

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## 1. Introduction

ADHD, or attention deficit hyperactivity disorder, is a common childhood condition that has attracted considerable attention from both psychologists and psychiatrists (1). This neurodevelopmental disorder is defined by three primary characteristics: inattention, hyperactivity, and impulsivity (2). ADHD is among the most prevalent neurobehavioral disorders affecting children worldwide, influencing a significant number of individuals (3). Those diagnosed with ADHD often encounter difficulties in maintaining focus on details, which can lead to carelessness in academic work, job duties, or daily activities (4). This inconsistency in task execution frequently results in hasty and unconsidered performance. Individuals with ADHD may find it particularly challenging to maintain attention during games and assignments, hindering their ability to concentrate and complete tasks effectively (5).

It is essential to consider a crucial aspect in this area: the distinct physical challenges encountered by children with ADHD compared to their peers (6). These children demonstrate markedly lower motor skills than their typically developing counterparts, with

their abilities often lagging behind what is expected for their age and cognitive level (7), and face obstacles in various motor areas (8). Furthermore, children with ADHD often experience delays in reaching motor development milestones, difficulties in planning and executing movements, and challenges in maintaining balance and controlling their body weight (9). The development of motor skills in children with ADHD exhibits distinct characteristics that can influence their psychomotor growth and movement coordination. Conversely, the presence of varied and underdeveloped motor abilities may also impact the physical literacy (PL) (10).

PL refers to the combination of motivation, confidence, physical abilities, knowledge, and understanding that enables individuals to value and commit to lifelong participation in physical activity (PA) (11). The interconnected domains of physical competence, motivation, and self-confidence play a vital role in fostering participation in PA during childhood and into adulthood (12). This concept serves as a framework for promoting sustained involvement in PA throughout life (13). PL emphasizes the interplay of emotional, physical, and cognitive components that



are crucial for fostering lifelong engagement in p PA (14). The affective domain holds particular importance as it includes key factors such as confidence, motivation, enjoyment, commitment, autonomy, self-esteem, and perceived physical competence. These elements are essential for fostering sustained participation in PA, as they significantly influence individuals' willingness to engage and persist in such pursuits (15).

An important area of investigation is the physical and cognitive difficulties encountered by children with ADHD when compared to their neurotypical counterparts (16). Research shows that individuals with ADHD often experience difficulties with executive functions and working memory (16,17). Executive function encompasses a range of advanced cognitive and metacognitive abilities (18-20).

PA stands out as one of the most straightforward and cost-effective approaches to addressing physical issues and preserving cognitive abilities in children with ADHD. Recent evidence underscores the role of exercise training in reducing risks associated with imbalance, motor disabilities, and cognitive decline among the ADHD population (21,22). Research has consistently highlighted the positive impact of exercise therapy on enhancing motor functions, particularly fundamental motor skills (23,24). Furthermore, recent studies have established a clear link between regular PA and improved cognitive function in children with ADHD, with one study specifically demonstrating its benefits for cognitive function in children with ADHD (25-28).

The advancement of science across various disciplines has led to the development of innovative training methods aimed at enhancing the motor and cognitive abilities of older adults, one notable approach being combined cognitive-motor training (CMT) (29). This type of intervention merges cognitive tasks with physical rehabilitation exercises, such as integrating strength and balance training with cognitive challenges or engaging in dual-task activities. Successfully managing to perform two tasks simultaneously, without compromising the quality of either, indicates effective attention division (30). A defining characteristic of CMT is their emphasis on integrated cognitive and motor components, which prioritize dual or multiple task training over more traditional, attention-intensive forms of exercise, such as Tai Chi (29). Research showed that CMT enhances the development of brain structures and functional networks associated with executive functions (30,31). Moreover, CMT has proven to be especially beneficial for children with low self-efficacy in PA or a lack of motivation to engage in exercise (30,32). By incorporating strategies such as goal setting, problem solving, and creative thinking, these interventions help children gain a deeper understanding of their bodily functions and enhance their enjoyment of PA (30,32). As a result, this heightened motivation can contribute to improved performance and outcomes in sports and various forms of exercise.

Given the beneficial effects of CMT, it is essential to explore their influence on children diagnosed with ADHD. Furthermore, recognizing the significance of PL and cognitive function in both child and public health, and noting the absence of research addressing the impact of CMT on the PL and cognitive abilities of children with ADHD, this study aims to investigate how

such interventions affect these areas in this specific population.

## 2. Methods

### 2.1. Participants

This research utilized a semi-experimental design with practical applications, incorporating a pre-test and post-test design alongside a control group. The study targeted male children diagnosed with ADHD, specifically those aged 7 to 10 years, recruited from various special schools. After a thorough screening process, 54 children were selected as participants, divided equally into the intervention control groups. Random assignment was implemented through a simple random sampling technique. This method guaranteed that each participant had an equal chance of being placed in either group, thereby reducing the likelihood of biases and confounding variables. A power analysis performed with G\*Power revealed that a sample size of 15 participants per group was required, utilizing an alpha level of 0.05, a power of 0.95 and a size effect of 0.80. In this study, a total of 30 participants were initially assigned to each group; however, three individuals from each group were unable to complete the protocol and were subsequently excluded from the research. As a result, the final number of participants in each group was 27. Prior to the study's commencement, both participants and their parents were briefed on the research objectives and methodologies. Discussions were held regarding the challenges associated with motor-cognitive functions in children with ADHD, emphasizing the importance of parental involvement in managing these issues, and written consent was obtained from the parents. Subsequently, each child underwent a health assessment by a qualified physician, receiving a health certificate and medical clearance for PA. Inclusion criteria for the study required participants to be diagnosed with ADHD, free from injuries or illnesses, and without restrictions on CMT. Those who did not meet these criteria were excluded from participation.

### 2.2. Measurements

#### 2.2.1. Physical Literacy

PL was evaluated through the Canadian Assessment of Physical Literacy Development (CAPL-2) (33). Participants receive scores for each domain, culminating in an overall PL score. Each test within the domains is assigned a score, contributing to a maximum total of 100 points. These scores are determined based on scoring tables that are tailored to the participant's gender and age, as outlined in the evaluation guide titled "Manual for Test Administration: Canadian Assessment of Physical Literacy." The findings of this study revealed a high reliability for the questionnaire, evidenced by a Cronbach's alpha coefficient of 0.92.

#### 2.2.2. Cognitive Function

**Verbal Working Memory:** The Numerical Span Subscale of the Revised Wechsler Intelligence Scale for Children was used to measure working memory (34). It serves as a measure of short-term memory and attention through its direct digit span component. In

contrast, the reverse digit span subscale plays a crucial role in evaluating verbal working memory. This subscale not only demands attention and encoding but also requires the individual to retain information briefly, manipulate it, and subsequently articulate the results. During the reverse digit span assessment, the sequence of numbers presented increases from two to eight in each row, with the participant tasked with recalling the numbers in reverse order. The questionnaire demonstrated a high level of reliability, evidenced by a Cronbach's alpha coefficient of 0.94.

**Visual-Spatial Working Memory:** Corsi Block-Tapping Task was used to measure visual-spatial working memory (35). It assesses a specific aspect of working memory through a computerized adaptation of the Pulsating Blocks subtest, originally created by Corsi in 1971 to evaluate spatial memory with limited verbal input. The test involves remembering a visual-spatial pattern along with a series of movements, necessitating the retention of both the observed movements and the transitions between squares. While this test has been extensively utilized in neuropsychological studies to gauge spatial working memory, there is a scarcity of information regarding its validity and reliability. The questionnaire demonstrated a high level of reliability, evidenced by a Cronbach's alpha coefficient of 0.96.

2.3. Procedure

The research commenced with crucial cooperation from the Education Department, leading to the acquisition of necessary permissions to proceed. Following this, a briefing session was conducted to inform students and their parents about the research goals, methods, and the execution of the intervention. Subsequently, written consent was gathered from the parents. Following this, the experimental group engaged in a CMT protocol over a period of eight weeks. The intervention consisted of three weekly sessions, each lasting 60 minutes, which included a 10-minute warm-up, a 40-minute training segment, and a 10-minute cool-down. The training program featured games designed to enhance fundamental skills, where participants simultaneously performed cognitive tasks

alongside motor activities. The selected games encompassed rolling for preparation, various jumping exercises, maintaining a basket filled with balls while moving, children's basketball, kicking, soccer, and ball-saving activities to develop manual skills, as well as self-balancing and figurine play for strength enhancement. To further stimulate cognitive performance, participants were instructed to engage in tasks such as counting in sequence or reverse, identifying balls of specific colors, jumping on designated colors, or reciting a series of sentences in order, thereby integrating cognitive and motor exercises throughout each session. Participants underwent assessments of PL and cognitive function both one day prior to the intervention (pretest) and following its completion (posttest). Those in the control group did not receive any additional interventions.

2.4. Statistical Analysis

In this study, the research variables were established by calculating the mean and standard deviation (SD). The normality of the data distribution was assessed using the Kolmogorov-Smirnov test, with all results showing P values greater than 0.05. Additionally, analysis of covariance (ANCOVA) was used to investigate the differences between the two groups from pretest to posttest. A significance threshold of 0.05 was applied to all analyses, and data analysis was carried out using SPSS version 27.

3. Results

3.1. Demographic Data

The mean ages for the intervention and control groups were  $8.66 \pm 0.38$  years and  $8.70 \pm 0.35$  years, respectively, with no statistically significant differences observed ( $P > 0.05$ ). Additionally, initial assessments revealed that BMI in both groups was comparable, again showing no significant differences ( $P > 0.05$ ) (Table 1).

Table 1. Comparison of the Demographic Data across Groups.

| Variable    | Intervention     | Control          | Comparison |
|-------------|------------------|------------------|------------|
| Age (years) | $8.66 \pm 0.38$  | $8.70 \pm 0.35$  | $P=0.932$  |
| Height (m)  | $1.31 \pm 0.03$  | $1.30 \pm 0.04$  | $P=0.982$  |
| Weight (kg) | $25.50 \pm 3.86$ | $25.72 \pm 3.69$ | $P=0.879$  |
| BMI         | $14.90 \pm 1.48$ | $15.20 \pm 1.63$ | $P=0.960$  |

Table 2 outlines the mean and SD for PL—encompassing dimensions such as daily behavior, physical competence, motivation and confidence, and knowledge and understanding—as well as cognitive function, specifically focusing on verbal and visual-spatial working memory, in the pretest and posttest. The data reveal that the mean PL scores were 59.6 for the intervention group and 59.9 for the control group, indicating a medium level of PL among children diagnosed with ADHD. Additionally, statistical analysis showed no significant differences between the two groups in the pretest ( $P=0.580$ ). Regarding verbal working memory, the intervention group had a mean score of 2.75, while the control group scored 2.69, both reflecting a low level of verbal working memory in this population, with no significant differences noted in

the pretest ( $P=0.534$ ). For visual-spatial working memory, mean scores were 13.46 for the intervention group and 13.56 for the control group, again demonstrating a low level of performance, with no significant differences observed in the pretest ( $P=0.793$ ). These findings indicate that both groups displayed similar baseline conditions concerning the evaluated variables.

**Table 2.** Comparison of Research Variables in the Pre-test.

|                                      | Intervention |              | Control      |             |
|--------------------------------------|--------------|--------------|--------------|-------------|
|                                      | Pre-test     | Post-test    | Pre-test     | Post-test   |
| <b>Physical Literacy (Total)</b>     | 59.6 ± 10.2  | 72.5 ± 12.6  | 59.9 ± 10.8  | 60.2 ± 10.9 |
| <b>Daily Behavior</b>                | 12.5 ± 3.5   | 15.2 ± 4.1   | 12.3 ± 3.2   | 12.4 ± 3.3  |
| <b>Physical Competence</b>           | 17.4 ± 5.3   | 20.7 ± 5.9   | 16.9 ± 4.8   | 17.0 ± 4.9  |
| <b>Motivation and Confidence</b>     | 23.7 ± 3.8   | 29.5 ± 4.5   | 23.9 ± 4.0   | 24.0 ± 4.1  |
| <b>Knowledge and Understanding</b>   | 6.2 ± 1.7    | 7.3 ± 2.0    | 6.5 ± 1.9    | 6.5 ± 1.8   |
| <b>Cognitive Function</b>            |              |              |              |             |
| <b>Verbal Working Memory</b>         | 2.75 ± 0.96  | 2.75 ± 0.96  | 2.69 ± 0.88  | 3.70 ± 0.88 |
| <b>Visual-Spatial Working Memory</b> | 13.46 ± 2.52 | 13.46 ± 2.52 | 13.56 ± 2.69 | 13.7 ± 2.71 |

Table 3 presents the concerning the impact of the intervention on the research variables. The analysis performed at the end of the intervention period showed significant differences across all groups for the

evaluated parameters, including both PL and cognitive function dimensions ( $P < 0.001$ ). These findings suggest that CMT successfully enhanced PL and cognitive function in male children diagnosed with ADHD.

**Table 3.** Comparison of Pre-test-Post-test.

|                                      | F-Value | P-Value | $\eta^2$ |
|--------------------------------------|---------|---------|----------|
| <b>Physical Literacy (Total)</b>     | 18.667  | <0.001  | 0.385    |
| <b>Daily Behavior</b>                | 6.968   | <0.001  | 0.010    |
| <b>Physical Competence</b>           | 8.442   | <0.001  | 0.013    |
| <b>Motivation and Confidence</b>     | 10.231  | <0.001  | 0.108    |
| <b>Knowledge and Understanding</b>   | 7.559   | <0.001  | 0.009    |
| <b>Cognitive function</b>            |         |         |          |
| <b>Verbal Working Memory</b>         | 8.109   | <0.001  | 0.011    |
| <b>Visual-Spatial Working Memory</b> | 12.529  | <0.001  | 0.129    |

#### 4. Discussion

The positive outcomes associated with CMT necessitate an examination of their effects on children with ADHD. Additionally, given the importance of PL and cognitive function for both individual and public health, and the lack of existing research on the impact of CMT in this demographic, this study sought to assess how such interventions influence these aspects in children with ADHD. The results indicate significant differences among all groups concerning the assessed parameters, which encompass both PL and cognitive function. These findings imply that CMT effectively improved PL and cognitive abilities in male children diagnosed with ADHD. This aligns with previous research that has underscored the various benefits of CMT for children (29-32).

CMT plays a crucial role in enhancing PL of children with ADHD by integrating a variety of fundamental movements and physical skills (30). Research shows that individuals with higher PL are more inclined to participate in PA, and this literacy can be cultivated at any age. The findings indicate that such interventions not only make the learning process enjoyable but also significantly improve PL (36). This improvement is reflected in various aspects of daily behavior, and a deeper understanding of PL model. Furthermore, human development is greatly shaped by environmental interactions, where physical competence and adequate daily activity levels are essential for advancing PL (37). Physical fitness comprises multiple components, such as movement skills and health-related fitness, and increased PA in children correlates with enhanced daily behavior and physical competence (33).

Children with ADHD often exhibit motor abilities that fall significantly short of what is typically expected for their age and cognitive development (6). These children frequently struggle with various aspects of motor skills, including gross and fine motor coordination, bilateral coordination, and may experience delays in achieving developmental milestones. They also encounter challenges in

movement planning, execution, balance, and postural control (7,8). Participation in PA can yield beneficial effects by diverting attention from anxiety-provoking situations. Moreover, engaging in regular PA is essential for strengthening the nervous and vestibular systems, which in turn enhances higher brain functions associated with motor skills and action integration. This nurturing environment can boost self-confidence and self-efficacy, potentially alleviating ADHD symptoms and improving motor skills, ultimately contributing to a greater level of PL (36,38).

Furthermore, engaging in CMT enhances positive responses and offers individuals a means to shift their focus away from anxiety-inducing situations (34). Furthermore, participation in CMT fortifies the deep nervous and vestibular systems while enhancing higher cognitive functions, such as motor skills and action integration. This foundation fosters increased self-confidence and a sense of self-efficacy, which can mitigate symptoms of ADHD and improve motor abilities (36,37). Additionally, CMT not only refine motor skills but also promote the development of social behaviors in children, essential for their adaptation to the surrounding environment and various social contexts, guiding them toward acceptable social norms. In addition, the impact of CMT on verbal working memory and visuospatial memory in children diagnosed with ADHD can be understood through the lens of recent theories that highlight the significance of attention and cognitive function impairments associated with this neuropsychological disorder. Children with ADHD often struggle with response inhibition, working memory, planning, and maintaining alertness (37-39). Engaging in physical exercise induces physiological changes, particularly by regulating the cardiovascular system and influencing the parasympathetic autonomic nervous system. This stimulation of the vagus nerve leads to a decrease in action potential within the heart's sinus atrial node, promoting relaxation of the nervous system (32,37). Consequently, these physiological benefits may alleviate attention deficits, thereby enhancing both verbal working memory and visuospatial memory in

affected children. These factors contribute to enhancing PL and cognitive performance of children with ADHD.

This study encountered several limitations that warrant consideration. Notably, the research focused solely on male children, which may restrict the generalizability of the results to females. To address this limitation, future studies should explore the effects of CMT on the cognitive functions of girls diagnosed with ADHD. Additionally, the lack of a follow-up assessment post-intervention hinders the ability to evaluate the long-term outcomes of CMT. Future research should incorporate follow-up evaluations over extended periods to gain a clearer understanding of these effects.

#### 4.1. Conclusion

In conclusion, it can be asserted that integrating sports and CMT serves as an effective complementary approach to mitigate certain cognitive disorders in children with ADHD while simultaneously enhancing their PL levels. Given that children inherently enjoy PA and are inclined to engage in them, they stand to gain significantly from such involvement. By intentionally merging physical exercises with cognitive tasks, there is potential for children with ADHD to experience improvements in both their PL and cognitive functions, which are often areas of difficulty for them. Nonetheless, further research is essential to explore this intersection more thoroughly.

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#### Footnotes

**Authors' Contribution:** This study was carried out solely by the corresponding author.

#### Conflicts of Interest

Non to declare.

**Data Availability:** The data that support the findings of this study are openly available upon request from the corresponding author.

**Ethical Approval:** The author confirms that all steps and requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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