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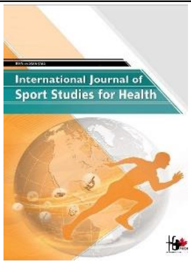

The Effects of Physical Activity on Key Variables That Influence the Characteristics of Children with Attention Deficit Hyperactivity Disorder

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A B S T R A C T

Objective: This study aims to explore the effects of physical activity on key variables that influence the characteristics of children with ADHD, employing an optimized framework to yield more accurate results.

Methods and Materials: This semi-experimental study utilized a pre-test. Post-test design with a control group. Eighteen male participants, aged 8 to 12 years and diagnosed with ADHD, were randomly assigned to either an experimental group or a control group. The experimental group engaged in a 12-session exercise protocol, consisting of 40 minutes of physical activity at 60% intensity. Evaluations were conducted using pre-test and post-test measures, including the Continuous Performance Test (CPT) (Razold et al., 1956), Wechsler Memory Scale (Bluber, 1939), Child Anxiety Questionnaire (Spence, 2003), Quality of Life Questionnaire for Children (Warni, 2003), and Conners Parent Rating Scale (Conners, 1960). Data were analyzed using SPSS version 19 with repeated measures ANOVA, establishing a significance level of $P<0.05$

Findings: The ANOVA results revealed significant effects in several areas: impulsivity was significant on the Conners Parent Rating Scale ($p=0.049$); in terms of quality of life, social functioning ($p=0.032$) and psychological well-being ($p=0.012$) showed notable improvements; regarding attention assessments, response errors in image recognition were significant ($p=0.039$); and in the Wechsler tests, digit span ($p=0.0001$), associative learning ($p=0.047$), and visual memory ($p=0.03$) demonstrated significant outcomes.

Conclusion: The findings indicate limited changes in behavioral indices and minimal shifts in cognitive measures. Therefore, while physical activity may serve as a potential avenue for symptom improvement, caution is advised in its application. Given the inconsistencies in the current literature, further comprehensive studies are necessary to better understand these dynamics.

Keywords: *Psychological indicators, attention, memory, Attention Deficit Hyperactivity Disorder (ADHD)*

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1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent neurobehavioral disorders, characterized by a persistent pattern of inattention, hyperactivity, and impulsivity typically observed in school-aged children (1). Approximately 3% to 7% of children are affected by ADHD, with a higher prevalence in boys compared to girls (2). This disorder arises from a combination of genetic and environmental factors, resulting in minor deficits in the brain regions associated with attention and focus. Key characteristics of ADHD include inattention, excessive physical activity, emotional instability, lack of mental effort in completing tasks, and difficulty concentrating. These symptoms often coexist with other disorders such as behavioral issues, oppositional defiant disorder, learning disabilities, and anxiety (3). In simpler terms, behavioral disorders manifest through persistent impulsive or emotional behaviors that disrupt educational processes and impair cognitive functioning in children. Learning disabilities are primarily linked to executive function deficits affecting memory, attention, planning, and organizational skills, indicating the presence of challenges in these areas. The hallmark symptoms of ADHD typically emerge during preschool years and may persist into adulthood in 15% to 20% of cases. Adults with ADHD often do not exhibit hyperactivity but may experience restlessness, impulsive actions, and difficulties with attention and concentration. Failure to address or treat ADHD timely can lead to academic challenges, social skill deficits, and strained parent-child relationships (4).

Extensive research has been conducted on the neuropsychological and physiological aspects of ADHD. For instance, a study conducted in 2012 demonstrated that physical exercise could temporarily alleviate symptoms of inattention while also impacting fundamental physiological mechanisms that potentially alter brain development pathways (5). These findings have led to various therapeutic recommendations: the first strategy involves the use of stimulant medications as the primary validated approach for managing ADHD symptoms. Although these medications effectively reduce hyperactivity symptoms, about 30% of children do not respond to them and may experience side effects such as insomnia, decreased appetite, growth retardation, and headaches (6). The second strategy encompasses a psychological-physical spectrum that includes mindfulness practices aimed at helping individuals regain lost focus on the present moment and neurofeedback techniques that enable individuals to modify their brain wave activity. Additionally, physical activities like yoga—which incorporate breathing exercises—are expected to enhance concentration, promote mental and physical relaxation, and reduce stress levels. Furthermore, engaging in physical exercise has emerged as a novel therapeutic approach aimed at improving brain function for children with ADHD. Studies examining the relationship between physical activity and performance outcomes for individuals with attention deficits suggest that this approach is simple, devoid of adverse effects, and cost-effective (7, 8). For example, one study proposed that physical interventions could lead to positive changes in behavioral structures and cognitive performance among children with ADHD, potentially resulting in reduced impulsivity and anxiety while enhancing attention spans (4). Recent systematic reviews have indicated that physical activity can improve response variability, response speed adaptation, alertness, and impulse control among these individuals (9, 10). However, contradictory studies have reported either no significant impact among various factors or limited effects within credible studies on physical activity or specific impacts based on different types of physical engagement (11-13).

While many findings indicate that physical activity serves as a catalyst for enhancing motor skills and coordination among children with ADHD, it is reasonable to expect variability in how exercise influences specific symptoms or brain systems due to the complex nature of ADHD. Given the extensive research on the impact of physical activity on alleviating symptoms of ADHD, the precise mechanisms through which varying intensities exert their effects remain inadequately understood. The meticulous execution of research protocols may significantly influence outcomes in this context. Therefore, considering the interplay between exercise and the multifaceted performance outcomes associated with attention deficits necessitates careful attention to parameters such as duration and intensity during research phases to mitigate complexities in performance results and enhance overall effectiveness. In this study, the researcher aimed to meticulously implement all research phases with a focus on identifying specific training intensities that yield distinct results. Consequently, this investigation sought to delve deeper into this topic while addressing existing limitations.

2. Methods and Materials

2.1 Study Design and Participants

This semi-experimental study was conducted with two groups, experimental and control, utilizing a pre-test and post-test design. The sample consisted of 18 children aged 8 to 12 years diagnosed with ADHD from Quchan. The selection of children with ADHD was carried out randomly, with official permission obtained from the Education Department of Quchan, ensuring that participants were matched in terms of age, gender, and grade level. The inclusion criteria included: a diagnosis of ADHD based on the Continuous Performance Test (CPT) (Razold et al., 1956) (14), the Wechsler Memory Scale (15), which was administered by a qualified psychologist; as well as the Child Anxiety Questionnaire (16), the Quality of Life Questionnaire for Children (17), and the Conners Parent Rating Scale (18), which were completed by the researcher in collaboration with parents and children. Additionally, none of these children were on any medication at the time of the study. During a meeting held at the school with the presence of parents and children, information regarding the research was presented. Parents expressed their support for the study and provided written consent for their children's participation. The students also verbally agreed to participate in the research during interviews.

Another key objective that received special attention in this study was establishing a specific intensity level for exercise; it appeared that performing activities at a designated intensity level (approximately 55% to 65% of maximum heart rate) could yield favorable outcomes within the specified duration. To maintain exercise intensity, following consultations with sports science experts, heart rate measurements were taken at intervals—initially every five minutes and then every ten minutes—to ensure accuracy in monitoring heart rates; it was essential that children were instructed on how to measure their heart rates correctly and occasionally coaches randomly checked their pulse rates (both measures were implemented).

2.2 Measures

2.2.1 Continuous Performance Test (CPT)

This test is utilized to assess attention and impulsivity, requiring sustained attention during a continuous task while inhibiting impulsive responses. This test was designed by Rosvold et al. in 1956 (14). Participants must focus on a relatively simple visual stimulus set and respond upon seeing a target stimulus. The test includes three variables: response error rate, omission errors, and reaction time. The reliability coefficients for various sections of the test, assessed over a 20-day interval with 43 male elementary students, ranged from 0.59 to 0.93; these coefficients demonstrated significant correlations at $p < 0.001$ levels. Validity was established through criterion validity by comparing normative groups against those diagnosed with ADHD, revealing significant differences in performance between the two groups (according to results from Dr. Hadianfard and colleagues' study indicating that the Persian version of CPT has appropriate validity and reliability). Their study showed that reliability coefficients for different sections ranged from 52% to 93%. Validity was assessed through criterion validation comparing normative samples (30 male elementary students) with those diagnosed with ADHD (25 male elementary students), revealing statistically significant differences across various sections consistent with findings from previous studies conducted in other countries (19).

2.2.2 Wechsler Memory Scale

Developed by David Wechsler in 1939 (15), this scale consists of two sections: verbal scale and performance scale, each measuring seven domains through a total of 60 questions. The performance scale assesses tasks such as completing unfinished pictures, block design tasks, arranging pictures to tell a story, coding tasks, and puzzle construction among others. The Wechsler Intelligence Scale is currently one of the most widely used standardized tests globally for measuring IQ; it is an individual test administered by an examiner to specific subjects (participants). Razavieh and Shahim (2008) validated this scale in Iran, which has been utilized to determine the validity of this research (20). Form A serves as an objective measure for assessing memory based on ten years of research focused on immediate recall memory tasks; administering this test typically takes approximately 51 minutes and encompasses seven sub-tests: personal awareness regarding daily matters; orientation concerning time and place; mental control; logical memory; forward. backward digit span recall; visual memory; and associative learning (21).

2.2.3 Child Anxiety Questionnaire

The Spence Children's Anxiety Scale was developed by Spence et al. in 2001 and revised in 2003 (16). This questionnaire consists of 45 items, including 38 scored items and six positively phrased items that are not scored, along with one open-ended question that children answer descriptively. It is designed for children aged 8 to 15 years and includes subscales for panic disorder, separation anxiety, fear of physical harm, social phobia, obsessive-compulsive disorder, and general anxiety. Psychometric evaluations have shown positive results for this scale; all subscales exhibit moderate to good internal consistency (Cronbach's alpha over 0.70). Reliability between informants includes correlations between data obtained from mothers and fathers exceeding 0.60 and test-retest reliability (over a period of 12 months) above 0.60. Factor analysis results indicate that symptom clustering aligns with lists of psychological disorders; furthermore, all subscales have shown significant positive correlations with internalizing problems as measured by the Child Behavior Checklist. The Cronbach's alpha calculated in domestic studies by Zargami et al. (2015) for this questionnaire was reported above 0.70 (22).

2.2.4 *Quality of Life Questionnaire for Children aged 8-12 years*

This scale was developed by Varni et al. in 2003 (17). The original English version of PedsQL is a 23-item tool that measures children's quality of life across four subscales: physical functioning (8 items), emotional functioning (5 items), social functioning (5 items), and school functioning (5 items). There are two forms: a self-report form for children and a parent-report form used for the same children. This tool has suitable psychometric properties for assessing quality of life across various populations. Respondents indicate how often they experience each item on a five-point Likert scale (never, rarely, sometimes, often, always). The total PedsQL score is derived from the mean score across all responses to the 23 items; additionally, individual scores are calculated based on each subscale independently. Higher scores indicate better quality of life among children. This tool was translated using methods established by Sperber with input from several experienced researchers. Internal consistency of PedsQL among children was evaluated using Cronbach's alpha; test-retest reliability over two weeks was calculated using intraclass correlation coefficients which exceeded 0.75—considered acceptable for short-term reliability (23).

2.2.5 *The Conners Parent Rating Scale (CPRS) for Childhood Behavior Problems*

It was developed by Conners in 1960 (18) and consists of 48 items and utilizes a four-point Likert scale for scoring, where responses range from 0 (not true at all, never, rarely) to 3 (very true, often, almost always). It includes subscales for conduct disorder, learning disabilities, psychosomatic disorders, impulsivity, anxiety, and hyperactivity symptoms. Out of the 48 items, 26 pertain specifically to ADHD, divided into two subscales: hyperactivity (16 items) and inattention (10 items). The score range for these 26 items related to ADHD is from 0 to 78. Conners and colleagues (1997) reported the reliability of this scale as 0.90. The validity of this questionnaire has been reported by the Cognitive Science Institute as 0.85 (24). In his research, Reilly (2011) reported a reliability coefficient of 0.89 based on Cronbach's alpha (25). In Iran, to determine the reliability coefficients of the Conners Parent Rating Scale for Childhood Behavior Problems, a sample of 360 male students from the first to fourth grades of elementary school in Sanandaj was used. Using Cronbach's alpha, Spearman-Brown split-half method, and Guttman split-half method, the overall reliability coefficients of the scale were found to be 0.91, 0.90, and 0.90 respectively. The reliability coefficients for the inattention subscale were 0.79, 0.76, and 0.75 respectively, while those for the hyperactivity subscale were 0.87, 0.84, and 0.83 respectively. Additionally, the aforementioned study utilized confirmatory factor analysis to assess the validity of the Conners Parent Rating Scale for Childhood Behavior Problems, which yielded positive results (26). Furthermore, in a study conducted by Shahabian et al. (2007), correlation coefficients between subscales and total scores were calculated as evidence of validity. These coefficients ranged from 0.76 for the anxiety-shyness subscale to 0.90 for the conduct problems subscale and were significant across all subscales (27). In conducting the activities, participants were first warmed up by a physical education expert. Following a ten-minute warm-up that elevated heart rates, participants engaged in a structured activity for twenty minutes: they were divided into two groups where one group passed a ball among themselves while the other attempted to intercept it. This was followed by another twenty-minute activity called "create a mess," where one group set up cones while another group knocked them down. The selected activities in this study were validated by five motor behavior specialists who had experience working with children with attention deficits; the first activity focused on both fine and gross motor skills while the second emphasized attention and memory—specifically targeting issues faced by children with ADHD. However, it is crucial to note that the specific type of activity was not the primary criterion for this study; rather, efforts were made to select games that would be more suitable for hyperactive children. The main objective was to achieve and maintain an optimal heart rate intensity between 55% and 65% of maximum heart rate over twelve weeks to observe the effects of physical activity at this intensity level on these children (given that participants were hyperactive children). To achieve this heart rate range through play and competition was prioritized. Additionally, exercises were conducted over a twelve-week period to maximize their impact on the experimental group (28). Previous studies on hyperactive children have examined the effects of both fine and gross motor skills on attention (29), the influence of exercise type on working memory and attention (30), as well as enjoyable ball games (31), which were utilized in this study as well. Notably, during the experimental group's activities, the control group did not engage in any physical activity.

2.3 Data Analysis

Data analysis was performed using SPSS version 19; after assessing normality with the Kolmogorov-Smirnov test and confirming data normality, repeated measures ANOVA was employed with a significance level set at $p < 0.05$.

3. Results

Table 1 provides a comprehensive summary of the statistical outcomes from the study, highlighting the effects of physical activity on various measures related to behavioral problems, anxiety, attention, memory, and quality of life in children with ADHD. The table details the results of the repeated measures ANOVA, including p-values for Levene's tests, physical activity effects, and group differences, along with partial eta squared values to indicate the magnitude of observed effects.

Table 1. Behavioral Problems, Anxiety, Attention, Life Quality and Children's Memory in Both Experimental and Control Groups

Scale	Variables	Levene's test p-value	Physical activity effects		Group effects	
			F	Sig. (Partial Eta Squared)	F	Sig. (Partial Eta Squared)
CPRS_48	Conduct problem	Pretest = 0.564 Posttest = 0.424	30.46	0.134 (0.135)	8.089	0.012* (0.336)
	Learning problem	Pretest = 0.165 Posttest = 0.801	1.373	0.258 (0.079)	0.003	0.959 (0.001)
	Psychosomatic	Pretest = 0.259 Posttest = 0.634	0.46	0.507 (0.028)	0.305	0.588 (0.019)
	Impulsive-Hyperactive	Pretest = 0.344 Posttest = 0.810	4.537	0.049* (0.221)	8.638	0.01* (0.351)
	Anxiety	Pretest = 0.054 Posttest = 0.482	1.067	0.317 (0.063)	1.33	0.265 (0.077)
SCAS	Panic disorder – Agoraphobia	Pretest = 0.149 Posttest = 0.325	0.181	0.676 (0.011)	1.011	0.33 (0.059)
	Separation anxiety	Pretest = 0.671 Posttest = 0.53	1.112	0.307 (0.065)	0.087	0.772 (0.005)
	Personal injury fears	Pretest = 0.921 Posttest = 0.069	0.571	0.461 (0.034)	2.942	0.106 (0.155)
	Social phobia	Pretest = 0.690 Posttest = 0.854	0.539	0.437 (0.033)	4.715	0.0001* (0.84)
	Obsessive- compulsive disorder	Pretest = 0.232 Posttest = 0.387	21.716	0.119 (0.145)	5.268	0.036* (0.248)
	Generalized anxiety	Pretest = 0.470 Posttest = 0.266	2.734	0.118 (0.146)	2.182	0.159 (0.120)
	Total number	Pretest = 0.600 Posttest = 0.370	0.548	0.47 (0.033)	2.816	0.113 (0.15)
CPT test	Digit commission errors	Pretest = 0.502 Posttest = 0.095	4.243	0.057 (0.22)	1.475	0.243 (0.09)
	Digit omission errors	Pretest = 0.194 Posttest = 0.268	1.215	0.288 (0.075)	0.568	0.463 (0.037)
	Digit correct detection	Pretest = 0.617	4.17	0.059	1.655	0.216

		Posttest = 0.754		(0.218)		(0.1)
	Digit reaction time	Pretest = 0.20	0.572	0.461	6.66	0.021*
		Posttest = 0462		(0.037)		(0.307)
	picture omission errors	Pretest = 0.136	1.024	0.327	0.121	0.733
		Posttest = 0.388		(0.06)		(0.008)
	picture correct detection	Pretest = 0.15	2.285	0.15	3.625	0.075
		Posttest = 0.40		(0.125)		(0.185)
	Picture reactin time	Pretest = 0.051	0.003	0.959	2.014	0.175
		Posttest = 0.858		(0.001)		(0.112)
	Picture commission errors	Pretest = 0.119	5.07	0.039*	3.175	0.094
		Posttest = 0.640		(0.241)		(0.166)
PedsQL	Physical functioning	Pretest = 0.236	0.007	0.936	0.009	0.926
		Posttest = 0.323		(0.001)		(0.001)
	Emotional functioning	Pretest = 0.799	2.236	0.154	1.872	0.190
		Posttest = 0.132		(0.123)		(0.105)
	Social functioning	Pretest = 0.365	5.537	0.032*	1.633	0.22
		Posttest = 0.211		(0.257)		(0.093)
	School functioning	Pretest = 0.603	3.184	0.093	0.154	0.7
		Posttest = 0.942		(0.166)		(0.01)
	Total score	Pretest = 0.185	2.972	0.104	1.002	0.332
		Posttest = 0.108		(0.157)		(0.059)
Wechsler memory scale	Personal and current information	Pretest = 0.300	2.327	0.147	16.694	0.001
		Posttest = 0.121		(0.127)		(0.511)
	Orientation	Pretest = 0.406	0.001	0.99	11.636	0.004*
		Posttest = 0.051		(0.001)		(0.421)
	Mental control	Pretest = 0.144	0.617	0.444	7.731	0.013*
		Posttest = 0.289		(0.037)		(0.326)
	Logical memory	Pretest = 0.073	0.116	0.738	2.11	0.166
		Posttest = 0.546		(0.007)		(0.117)
	Digit span	Pretest = 0.794	76.22	0.0001*	12.55	0.003*
		Posttest = 0.266		(0.827)		(0.44)
	Associate learning	Pretest = 0.120	4.622	0.047*	3.855	0.067
		Posttest = 0.400		(0.224)		(0.194)
	Visual reproduction	Pretest = 0.389	5.661	0.03*	3.706	0.072
		Posttest = 0.875		(0.261)		(0.188)

On the Conners Parent Rating Scale (CPRS), which assesses a range of behavioral problems, the study revealed that physical activity did not significantly impact conduct problems, as indicated by a p-value of 0.134. Despite the lack of significance in the pre-to-post intervention analysis for physical activity effects, there were notable group differences, with a p-value of 0.012, suggesting some improvement in conduct problems attributable to the physical activity intervention. Similarly, for learning problems, neither the intervention nor the group effects showed statistical significance, with p-values of 0.258 and 0.959, respectively. This result indicates that the exercise protocol had minimal influence on these specific behavioral indicators.

Psychosomatic symptoms were another area evaluated, and no significant differences were found in the effects of physical activity (p = 0.507) or between groups (p = 0.588). However, a more notable finding was observed in impulsive-hyperactive behavior. The intervention showed a statistically significant effect, with a p-value of 0.049, and group differences were also significant (p = 0.01), reflecting a reduction in impulsive-hyperactive symptoms in the experimental group.

The study also explored anxiety variables using the Spence Children’s Anxiety Scale (SCAS), covering various subscales such as panic disorder, separation anxiety, personal injury fears, social phobia, obsessive-compulsive disorder, and generalized anxiety. Across most anxiety metrics, physical activity did not yield statistically significant results. Specifically, panic disorder-agoraphobia (p = 0.676), separation anxiety (p = 0.307), and personal injury fears (p = 0.461) showed no significant changes. In terms of social phobia, while there was a significant group effect (p = 0.0001), physical activity effects did not reach significance. A significant group effect was also found for obsessive-compulsive disorder (p = 0.036), but no significant impact was observed for generalized anxiety, which had a p-value of 0.118 for physical activity effects and 0.159 for group differences.

The Continuous Performance Test (CPT) was utilized to evaluate attention, measuring variables such as commission and omission errors and reaction times. The findings showed no significant differences in digit commission errors (p = 0.057) or digit omission errors (p = 0.288), suggesting that physical activity did not substantially alter these attention indicators. Additionally, correct digit detection and digit reaction time did not reveal significant effects (p = 0.059 and p = 0.461, respectively), except for a significant group effect in digit reaction time (p = 0.021). Picture omission errors, picture correct detection, and picture reaction time similarly did not yield significant results for physical activity effects. However, a notable finding emerged in picture commission errors, with physical activity effects showing significance (p = 0.039).

Assessing the Quality of Life (PedsQL) in children, the study examined physical, emotional, social, and school functioning. The physical activity effects on physical functioning (p = 0.936) and emotional functioning (p = 0.154) were not significant, and similar results were found for school functioning (p = 0.093). Nonetheless, the social functioning domain showed significant improvement with a p-value of 0.032, indicating that social aspects of the children's quality of life benefited from the intervention.

In examining cognitive performance through the Wechsler Memory Scale, the study found significant effects in several areas. While measures like personal and current information did not reach statistical significance (p = 0.147), there was a highly significant effect for digit span (p = 0.0001), emphasizing substantial improvements in short-term memory due to the intervention. The results for orientation were not significant for physical activity (p = 0.99), yet a significant group difference was observed (p = 0.004). Improvements in mental control were significant for group differences (p = 0.013) but not for the intervention itself (p = 0.444). Logical memory did not show significant changes, while associative learning displayed a meaningful impact (p = 0.047), indicating enhanced learning capacity following the intervention. Visual reproduction also showed significant improvements (p = 0.03), highlighting gains in visual memory performance.

4. Discussion and Conclusion

This study aimed to explore the effects of physical activity on key variables that influence the characteristics of children with ADHD, employing an optimized framework to yield more accurate results. Before discussion the mechanisms and reasons behind the results obtained in the aforementioned study, it is essential to acknowledge that previous research in this area has somewhat explored how physical activity impacts cognitive and behavioral variables associated with hyperactivity. Therefore, the primary objective of this study was to establish an optimal model for physical activity while imposing stricter limitations compared to earlier studies to achieve more precise outcomes. A key aspect to consider is the distinct characteristics of this research, which represent its strengths relative to similar studies. In examining the effects of physical activities on variables influencing individuals with ADHD, existing studies can be categorized into two types: acute physical activities (high intensity and short duration) and chronic activities (low intensity and long duration). This study aimed to address significant changes in the structure and limitations of prior research by isolating a substantial number of high-quality studies in these areas. Among these, acute physical activity studies are particularly noteworthy (9, 32-34), as are those focusing on chronic activities (35-38). The first distinguishing feature of this study is its use of a combined model that seeks to integrate both intensity and duration, thereby creating a suitable comparative framework for both categories of research. The second distinction lies in employing the most appropriate and precise available tools while conducting assessments across various domains such as sustained attention, anxiety, cognitive performance, and psychological characteristics. Most existing studies tend to concentrate on a limited range of affected variables. However, the most significant aspect that sets this study apart from others is the robust screening and initial diagnostic evaluation of children involved; all participants were carefully selected using diagnostic tools and had no history of medication use. This approach enhances the quality and clarity of the results compared to studies where stimulant medications often influence outcomes (39). The first concept examined in this study was cognitive performance. Over the years, a variety of tools have been utilized to assess cognitive performance structures in individuals with ADHD, including direct measurements from neurological systems such as electroencephalograms and neuroimaging techniques (9, 40). Additionally, functional imaging studies have proven significant in this context (37), alongside standardized tests like the Wechsler scales and Strops tests that have been analyzed (38, 41). Comparisons in this domain are generally made broadly;

however, this study specifically employed the Wechsler test, revealing relative improvements in subscales such as visual memory, digit memory, and associative learning due to physical activity. Based on the findings, engaging in physical activity at an intensity of approximately 55% to 65% for one hour resulted in relative improvements in cognitive variables measured by Wechsler tests, including visual memory, digit memory, and associative learning. Evaluating similar studies indicates a relative consistency between these findings and those focused on high-intensity physical activities involving treadmill use (9, 36, 42) or cycle ergometry (34), as well as those centered on moderate and low-intensity activities (39, 40). For instance, Chang et al. (2012) demonstrated improvements in cognitive structures through Wechsler and Stroop tests after examining different physical activity groups with varying intensities between 40-50% and 65-75% over 25 minutes (42). Another study by Pan et al. (2019) investigated moderate-intensity physical activity (table tennis) for 70 minutes, ultimately reporting enhancements in Stroop test responses alongside improved shifting patterns. In general, considering physiological and behavioral explanations for ADHD suggests multiple potential mechanisms through which physical activity may exert its effects. Conversely, reviewing studies focused on low-intensity activities lasting between 30-90 minutes—primarily aerobic exercises, water sports, yoga, and sports skills—reveals similar outcomes regarding cognitive concepts (37). For example, a study by Ziris Ziereis and Jansen (2015) found that engaging in one hour of physical activity over a twelve-week period led to improvements in spatial visual performance and working memory (38). Similarly, Chang et al. (2012) reported enhancements in frontal lobe activity following 60-minute sessions over eight weeks (42) while Choi et al. (2015) confirmed improvements in anterior lobe and right parietal lobe functions after 90-minute sessions across eighteen meetings; both studies supported cognitive performance improvements consistent with this research's findings (35). Based on existing research, physical activity induces changes within brain structures that correlate with attention control concepts. Although hyperactivity is a disorder with diverse origins and manifestations, several variables associated with physical activity show improvement. Dopamine is one such variable that appears significantly influential in disorders related to hyperactivity (43). Another critical factor is neurogenesis dependent on brain function which plays a primary role in neurotransmission within dopaminergic pathways; animal studies indicate that its function increases with stimulant medication administration (44). Additionally, physical activity enhances blood flow to the prefrontal cortex and anterior prefrontal regions, leading to improved utilization of catecholamine pathways—dysregulation of which is a significant contributor to disorders among hyperactive individuals. Enhancements in prefrontal cortex functioning and its connectivity with other brain regions also play a role in reducing anxiety and stress levels (45). Cholecystokinin tetrapeptide is another variable that directly influences anxiety levels; it is closely related to both physical activity levels and oxygen consumption during exercise (46). Studies indicate that physical activity can elevate dopamine levels as well as norepinephrine at synapses, subsequently improving catecholamine function—this increase is linked to enhanced memory retention and learning capabilities alongside cognitive variables (47). The next category of variables pertains to behavioral metrics associated with disorders evaluated through various tools such as extensive Conners questionnaires alongside psychological assessments yielding reported results (18). Based on findings from this study, no significant or specific changes were observed correlating with the level or type of physical activity applied. While numerous studies affirm that cognitive variables are influenced by physical activity—often supported by review literature—the behavioral concepts present a serious conflict regarding existing findings. Although overall results suggest a positive impact of physical activity on behavioral variables as well (48), for instance, findings from Paimir et al. (2015) indicated that while physical activity improves cognitive metrics like Stroop test performance, it does not affect behavioral metrics significantly; similarly, Flor et al. (2004) reported no effects from physical activity on any cognitive or behavioral measures among children based on parent questionnaires or classroom observations (34, 49). Conversely, Chan et al.'s study revealed that engaging in thirty minutes of physical activity could lead not only to enhanced processing performance but also positively influence behavioral metrics as well (32). The discrepancies observed across various studies—particularly concerning this research—can be attributed to broad factors such as tools used, intensity and duration of activities, types of activities involved, age groups studied, and even gender differences among samples. However, reviewing literature suggests that one critical factor influencing these outcomes may be the limitations imposed by stimulant medication use for treatment purposes. According to existing research in this area, medication remains the only approved therapeutic approach for ADHD management (39). Supporting this notion is a review by Suárez and Manzano (2018), which noted that among sixteen high-quality studies based on specified criteria for evaluation—many did not impose any restrictions concerning medication use; only a few reduced dosages or maintained them uniformly while others ceased medication administration twelve to twenty-four hours prior to testing; notably only one study included participants without a history of medication use as subjects (48). In conducting this study—and all previous research involving hyperactive children—certain concepts and limitations exist whose improvement could pave the way for future investigations yielding more effective results regarding these interventions. The first concept involves utilizing more standardized samples within this field; one limitation identified was sample size—given the broad spectrum of children with ADHD present today's society—a larger sample size would enhance generalizability across populations. Many past studies failed to standardize dosage or symptom intensity adequately; all samples utilized medication during exercise sessions despite efforts made herein to address this issue; however, due to limited participant numbers assessing multiple protocols simultaneously proved impractical. While this study endeavored to employ optimal tools concerning cognitive and behavioral structures effectively—it remains evident that further research addressing psychological aspects alongside motor skills for these children within contexts involving physical activity is warranted.

Based on the studies conducted in this area, research indicates a significant positive impact of physical activity on the indicators of ADHD. However, the findings of this study did not support these results. Specifically, the results showed that physical activity could have limited effects on cognitive indicators (such as digit span and associative memory) as measured by the Wechsler test. In contrast, no evidence was found regarding its influence on behavioral concepts, including anxiety levels, quality of life, or outcomes from the Conners test and Continuous Performance Test. Consequently, this study does not recommend physical training methods as a definitive alternative for addressing ADHD symptoms; rather, it views their effects as temporary and limited, serving only as a complement to existing pharmacological treatments for this population.

Authors' Contributions

M.K.A author played a crucial role in all aspects of the research process, including study design, oversight of data collection, and interpretation of results. M.N.R. significantly contributed to verifying the accuracy of data and findings. M.S. collaborated on data analysis and interpretation, while the A.F. provided substantial assistance in editing and revising both English and Persian content. Furthermore, the final version of this study was approved by all authors.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

Each family of the participants completed an informed consent form for participation in the study. They were also assured of the confidentiality of their information. This research has received ethical approval with code IR.SSRC.REC.1402.209 from the Ethics Committee of the Research Institute of Physical Education and Sports Sciences.

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