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Effect of Multimodal Therapy Incorporating High-Intensity Interval Training on Physical Fitness and Attention Skills in School-Going Children with ADHD

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Abstract:

Background: Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder associated with deficits in attention, executive function, and physical fitness. Multimodal therapy is recommended for its management, with physical activity, particularly High-Intensity Interval Training (HIIT), emerging as a promising adjunct intervention. Aim: To evaluate the effect of a multimodal intervention incorporating HIIT on physical fitness and attention skills in school-going children with ADHD. Methods: A pre–post quasi-experimental study with a non-randomized controlled design was conducted among 20 children with ADHD (7–12 years), divided into intervention (n=10) and control (n=10) groups. The intervention group received an 8-week HIIT-based program (3 sessions/week), while the control group continued routine activities. Outcome measures included physical fitness (PACER, push-up, sit-and-reach tests) and cognitive function (CPT-3, Stroop test, BRIEF-2). Data were analysed using paired and independent t-tests with significance set at $p \leq 0.05$. Results: The intervention group showed significant improvements in physical fitness (PACER, push-up, sit-and-reach; $p \leq 0.001$) and cognitive outcomes (CPT, Stroop, BRIEF-2; $p \leq 0.006$), whereas the control group showed no significant changes ($p > 0.05$). Between-group analysis revealed significant differences in PACER ($p = 0.044$), push-up ($p = 0.015$), and Stroop scores ($p = 0.031$). Conclusion: Multimodal therapy incorporating HIIT significantly improves physical fitness and selected cognitive functions in children with ADHD. It is a feasible, cost-effective, and engaging intervention that can complement conventional ADHD management in school settings.

Key Words : **ADHD, High-Intensity Interval Training (HIIT), Multimodal Therapy, Physical Fitness.**

1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental condition characterized by ongoing challenges with attention, impulse control, and activity regulation that are inconsistent with a child's age. According to the DSM-5, ADHD can present as predominantly inattentive, predominantly hyperactive-impulsive, or a combination of both, with symptoms emerging before 12 years of age and affecting multiple settings such as home and school[1]. Globally, approximately 5–7% of school-aged children are estimated to have ADHD, but in countries like India, awareness gaps and social stigma often result in under diagnosis.[1] ADHD frequently continues into adolescence and adulthood, with symptom severity fluctuating over time. Neurodevelopmental differences, including delayed maturation of the prefrontal cortex, basal ganglia, cerebellum, and dopaminergic pathways, contribute to difficulties in attention and executive function.[2] Beyond cognitive and behavioral challenges, children with ADHD may experience motor impairments, poor coordination, and balance difficulties, which can increase the risk of developmental coordination issues. Reduced physical activity, excessive screen time, irregular sleep, and suboptimal nutrition can further compromise fitness and exacerbate ADHD-related symptoms.[3]

While stimulant medications such as methylphenidate and amphetamines remain the standard first-line treatment, around 20–30% of children either do not respond adequately or experience side effects, highlighting the need for supplementary interventions.[4] Multimodal therapy, which combines pharmacological, behavioral, cognitive, and educational strategies, is widely recommended by organizations such as the American Academy of Pediatrics and NICE. Physical activity is increasingly recognized as a valuable component of multimodal therapy because it can enhance neurotransmitter function, support attention and executive skills, and improve cerebral blood flow, while being non-invasive, cost-effective, and safe.[5]

High-Intensity Interval Training (HIIT) is a structured exercise approach involving short periods of vigorous activity interspersed with brief recovery intervals, typically performed at 80–95% of maximum heart rate. Its engaging, dynamic nature makes it particularly suitable for children with ADHD, who often struggle with prolonged tasks.[6] HIIT has been shown to improve cardiovascular fitness, muscular strength, and insulin sensitivity, and it may also enhance neuroplasticity through increased levels of brain-derived neurotrophic factor (BDNF) and catecholamines, supporting improvements in attention, working memory, and cognitive flexibility. Compared to continuous moderate exercise, HIIT's stimulating format helps maintain motivation and participation in children with ADHD.[7]

Although previous studies have examined the effects of exercise interventions on ADHD symptoms, research specifically evaluating multimodal therapy incorporating HIIT on both physical fitness and attention skills in school- aged children is limited. The current study aims to address this gap by assessing the feasibility and effectiveness of an 8-week HIIT-based multimodal intervention in this population.

2. Materials and Methods

2.1 Study Design:
Pre–post quasi-experimental study with a non-randomized controlled trial design.

2.2 Study Setting:
Conducted in various school premises of Noida, Delhi NCR, India (2025–2026).

2.3 Study Participants:
School-going children diagnosed with ADHD, aged 7–12 years.

2.4 Ethical Clearance:
Ethical approval was obtained from the concerned authority, and informed consent was taken from parents/guardians.

2.5 Sample Size:
A study by Sun F et al.[17] in 2024 observed that mean of pre-test and post-test was 7.15 and 3.65 respectively. Standard deviation of pre and post-test was 0.812 and 0.489 respectively of Group A similarly the mean of pre-test and post-test was 7.4 and 4.35 respectively as well as standard deviation of pre-test and post-test was 0.753 and 0.745 respectively of Group B. Taking those values as reference, the minimum required sample with 80% power of study and 5% level of significance is 20 subjects. So, our sample size will be taken is 20, 10 in each group. **N= 20**, calculated through sample size formula i.e, $\mathbf{N \geq 2(standard\ deviation)^2 \times (z\alpha+z\beta)^2 / (mean\ difference)^2}$

2.6 Sampling Technique:
Convenience sampling.

2.7 Selection Criteria:
Inclusion: Children with ADHD, aged 7–12 years, both genders, medically stable, and able to follow instructions.
Exclusion: Comorbid neurodevelopmental disorders, recent medication changes, or conditions contraindicating exercise.

2.8 Procedure & outcome measures:
Participants were divided into control (routine activities) and experimental groups. The experimental group received an 8-week HIIT-based intervention (3 sessions/week, 30–35 minutes), including warm-up, HIIT cycles with cognitive tasks, and cool-down.
Physical fitness (PACER, push-up, sit-and-reach tests) and cognitive function (CPT-3, Stroop test, BRIEF-2), assessed at baseline and post-intervention.

2.9 Data Analysis:
Performed using SPSS v26.0. Mean and standard deviation were calculated; paired t-test and independent t-test were used, with significance set at $p \leq 0.05$.

3. Results

This section presents the findings from pre- and post-intervention assessments of both groups to evaluate the effectiveness

of the 8-week multimodal HIIT program on physical fitness and cognitive function in children with ADHD. Data are expressed as mean ± standard deviation, and appropriate statistical tests were applied.

3.1 Baseline Characteristics (Table no. 1) :

Both groups were comparable at baseline in terms of age, gender distribution, ADHD subtype, and medication status, indicating homogeneity prior to intervention.

Table no. 1

	Intervention Group (n=10)	**Control Group (n=10)**
Age (years)	9.1 ± 1.3	8.9 ± 1.2
Gender (Male: Female)	7:3	6:4
ADHD Subtype (Combined %)	70%	60%
On Medication (%)	40%	50%

3.2 Within-Group Comparison:

In the intervention group, significant improvements were observed in physical fitness measures including PACER score ($p = 0.001$), push-up test ($p = 0.001$), and sit-and-reach test ($p = 0.000$). (Table no. 2, Fig. 1)

Similarly, cognitive outcomes showed significant improvement with reduced CPT omission errors ($p = 0.002$), and better Stroop ($p = 0.001$) and BRIEF-2 scores ($p = 0.006$). (Table no. 3, Fig. 2)

In contrast, the control group showed no statistically significant changes in either physical fitness ($p > 0.05$) or cognitive measures ($p > 0.05$).

Table no. 2

Variable	**Group**	**Pre (Mean ± SD)**	**Post (Mean ± SD)**	**N**	**t-value**	**p-value**
PACER Score	Intervention	26.5 ± 7.94	30.0 ± 6.78	10	4.671	0.001*
	Control	27.8 ± 4.6	28.2 ± 4.3	10	4.012	0.082
Push-Up Test	Intervention	10.1 ± 2.6	13.9 ± 2.8	10	5.229	0.001*
	Control	9.8 ± 2.5	10.1 ± 2.7	10	3.479	0.075
Sit-and-Reach (cm)	Intervention	17.4 ± 3.1	21.2 ± 3.6	10	4.535	0.000*
	Control	17.0 ± 3.4	17.4 ± 3.2	10	6.172	0.072

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Table no. 3

Variable	Group	Pre (Mean ± SD)	Post (Mean ± SD)	t-value	p-value
CPT – Omission Errors	Intervention	12.4 ± 2.8	9.3 ± 2.5	3.197	0.002*
	Control	12.8 ± 3.1	12.5 ± 2.9	3.197	0.653
Stroop Test Scores	Intervention	41.7 ± 5.2	36.1 ± 4.7	5.653	0.001*
	Control	42.0 ± 5.0	41.5 ± 4.8	5.653	0.912
BRIEF-2 Score	Intervention	68.5 ± 6.1	60.4 ± 5.8	8.184	0.006*
	Control	67.9 ± 6.3	67.1 ± 6.1	8.184	0.749

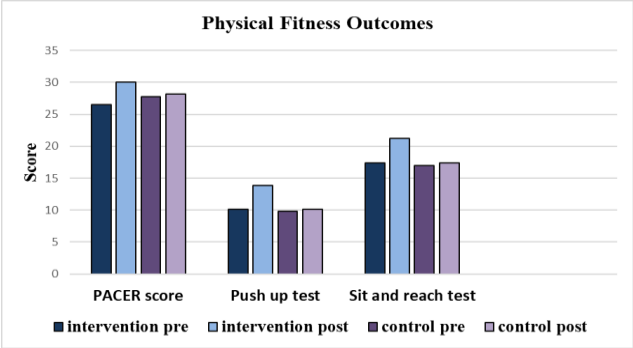

Fig. 1

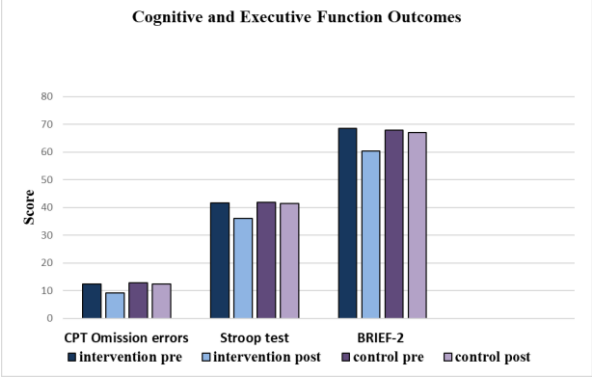

Fig. 2

3.3 Between-Group Comparison:

Between-group analysis revealed significant differences in PACER score ($p = 0.044$) and push-up test ($p = 0.015$), while sit-and-reach was not significant ($p = 0.098$). For cognitive outcomes, a significant improvement was observed only in Stroop test scores ($p = 0.031$), whereas CPT omission errors ($p = 0.268$) and BRIEF-2 scores ($p = 0.642$) were not statistically significant.

Table no. 4

Variable	Domain	F-value	t-value	df	p-value
PACER Score	Physical Fitness	0.252	2.101	18.37	0.044*
Push-Up Test	Physical Fitness	3.761	-1.982	16.99	0.015*
Sit-and-Reach Test	Physical Fitness	2.88	-1.172	15.59	0.098
CPT Omission Error	Cognitive	0.52	-1.284	23.54	0.268
Stroop Test	Cognitive	2.41	1.918	14.32	0.031*
BRIEF-2 Score	Cognitive	0.87	-1.065	18.48	0.642

So, the multimodal HIIT intervention resulted in significant improvements in physical fitness and selected cognitive functions, particularly attention and executive function, in the intervention group, while no significant changes were observed in the control group. (Table no. 4)

4. Discussion

This study investigated the effectiveness of a school-based multimodal HIIT program on both physical fitness and attention skills in children with ADHD. The results demonstrate that participation in an 8-week HIIT intervention significantly enhanced cardiovascular endurance, muscular strength, and flexibility. Cognitive measures related to attention and executive function also showed notable improvements, as evidenced by better performance on the Stroop test, CPT, and BRIEF-2 assessments within the intervention group.

The observed physical gains are likely due to the repeated high-intensity activity cycles, which stimulate cardiovascular and muscular adaptation. Improvements in cognitive performance may be attributed to enhanced cerebral blood flow, increased catecholamine activity, and elevated BDNF levels, which support attention, working memory, and inhibitory control. These mechanisms align with current understanding of how exercise influences brain function and cognitive outcomes in children.

Comparisons with previous studies suggest that multimodal interventions incorporating HIIT can effectively enhance both physical and cognitive domains in ADHD populations. For example, Meßler et al. (2018) reported similar improvements in fitness and social behavior following multimodal HIIT therapy, supporting the potential of HIIT as an engaging and beneficial component of ADHD management.

Despite the positive findings, certain limitations should be acknowledged. The study involved a relatively small sample size (n=20) and a non-randomized design, which may limit generalizability. Additionally, the assessment period was short-term, and long-term effects of the intervention were not examined. Future research should consider larger, randomized trials with longer follow-up periods and explore potential differences based on gender, ADHD subtype, or baseline fitness levels.

Overall, the results indicate that integrating HIIT into multimodal therapy is feasible, low-cost, and well-received in a school setting. Such interventions can complement existing behavioral and pharmacological treatments, providing an effective approach to improving both physical health and cognitive function in children with ADHD.

5. Conclusion

It is concluded that multimodal therapy incorporating HIIT is a promising adjunctive intervention for school-going children with ADHD as it leads to remarkable improvements in attention, executive functioning, and physical fitness, and is feasible to implement in educational settings. The intervention appears to be well-tolerated, engaging, and scalable, making it a viable addition to school health and inclusive education programs.

5.1 Limitation & Future suggestion

The present study had several limitations, including a small sample size, a narrow age range of participants, non-randomized group allocation, and assessment limited to the short term. Future research should focus on conducting larger, randomized controlled trials with more diverse populations to confirm and extend these findings. Additionally, examining potential gender-specific responses and exploring dose-response relationships of multimodal physical interventions may provide further insight into optimizing therapy for children with ADHD.

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