

Effects of High-Intensity Interval Training on Executive Function, Academic Performance, and Health-Related Physical Fitness in Overweight Adolescents: A Randomized Controlled Trial

Negar Arazshi

Assistant Professor, Department of Sport Science ,Ct.C., Islamic Azad University ,Tehran, Iran. Email: negar.arazshi@iau.ac.ir

Article Info	Abstract
Article type: Research Article Article history: Received 05 February 2026 Received in revised form 18 April 2026 Accepted 03 May 2026 Available online 29 June 2026 Keywords: Adolescent, Exercise, Executive Function, Obesity, Physical Fitness.	Introduction: Overweight and obesity during adolescence are associated with impaired physical fitness, reduced cognitive functioning, and poorer academic outcomes. High-intensity interval training (HIIT) has gained recognition as a time-efficient physical activity protocol capable of simultaneously enhancing both physical fitness and cognitive function. Objective: To investigate the effects of a 12-week HIIT program on executive function (EF), academic performance (AP), and health-related physical fitness (HRPF) in overweight adolescents. Method: Sixty-eight overweight adolescents aged 12-15 years were randomly assigned to a HIIT group (n=34) or a control group (n=34). The HIIT group participated in supervised training sessions three times weekly for 12 weeks, while the control group maintained usual activities. Following attrition, 31 and 32 participants completed the intervention in the HIIT and control groups, respectively. Study variables were assessed using standard tools. Data were analyzed using mixed-design ANOVA. Results: Compared with the control group, participants assigned to the HIIT intervention achieved significantly greater gains in Stroop ($F = 16.42, p < 0.001, \eta^2 = 0.21$), Trail Making Test-B ($F = 18.75, p < 0.001, \eta^2 = 0.24$), Digit Span ($F = 14.91, p < 0.001, \eta^2 = 0.19$), GPA ($F = 10.28, p = 0.002, \eta^2 = 0.14$), shuttle run ($F = 22.84, p < 0.001, \eta^2 = 0.28$), and push-up ($F = 24.13, p < 0.001, \eta^2 = 0.29$). Conclusions: HIIT program effectively enhanced EF, AP, and HRPF in overweight adolescents, supporting HIIT as a practical intervention for promoting cognitive and physical health in youth. Cite this Article: Arazshi, N. (2026). Effects of High-Intensity Interval Training on Executive Function, Academic Performance, and Health-Related Physical Fitness in Overweight Adolescents: A Randomized Controlled Trial. <i>Physical Activity in Children</i>, 3(1), 91-98. https://doi.org/10.22034/pach.2026.586893.1092

1. Introduction

Global trends indicate a substantial surge in youth obesity rates, marking it as an urgent public health imperative (1). This excess adiposity is clinically significant, as it frequently predicts poor health outcomes, ranging from reduced physical performance to early-onset cardiometabolic dysfunction and an increased likelihood of chronic disease manifestation throughout the lifespan (2). In addition to these physical consequences, increasing evidence indicates that excess body weight may adversely affect brain health and cognitive development during a critical period of neurological maturation (3,4). Given that adolescence is characterized by rapid structural and functional brain development alongside increasing educational demands, identifying interventions capable of simultaneously improving physical health and cognitive functioning has become an important public health and educational priority.

Executive function (EF) comprises a cluster of high-level neurocognitive processes necessary for managing goal-oriented behaviors, adjusting to fluctuating situational demands, and executing complex mental

operations (5,6). These processes serve as foundational elements for effective problem-solving, self-regulation, and scholastic achievement (7). Consequently, established literature links diminished EF capacity to significant challenges in academic performance, including decreased classroom participation and suboptimal educational progression (8,9). Importantly, overweight and obesity have been linked to impairments in EF, although the underlying mechanisms remain incompletely understood. Proposed pathways include chronic low-grade inflammation, insulin resistance, altered neuroplasticity, cerebrovascular dysfunction, and reduced cerebral perfusion, but these mechanisms have not been directly confirmed in intervention studies (10,11). Consequently, interventions that can improve EF in overweight adolescents may also have important implications for educational performance and long-term health.

Physical activity (PA) has emerged as a promising non-pharmacological approach for improving both cognitive and physical health outcomes in youth (12,13). A growing body of literature indicates that PA can enhance EF through multiple physiological and neurobiological pathways, including increased



cerebral perfusion, elevated concentrations of neurotrophic factors, enhanced synaptic plasticity, and improved neural connectivity (7,14). Although these biological mechanisms are biologically plausible and supported by experimental research, most exercise intervention studies have inferred rather than directly measured these processes. In addition to its cognitive benefits, PA contributes to improvements in body composition, cardiovascular health, muscular fitness, and overall well-being (15). Beyond these physiological adaptations, participation in structured exercise programs may also improve classroom engagement, self-discipline, motivation, mood, sleep quality, and psychosocial well-being, all of which could indirectly contribute to better academic performance (AP). These findings have prompted researchers and practitioners to explore exercise interventions for conducting in school-aged populations.

Accordingly, high-intensity interval training (HIIT) has received increasing attention in recent years. HIIT typically involves repeated bouts of vigorous exercise interspersed with brief periods of recovery and offers a time-efficient alternative to traditional continuous exercise programs (16,17). Evidence suggests that HIIT can elicit substantial improvements in cardiorespiratory fitness, muscular endurance, metabolic health, and body composition in youth (18–20). Recent randomized controlled trials and systematic reviews have also reported improvements in selected aspects of EF following HIIT interventions, although findings remain heterogeneous across different cognitive domains and participant populations. Furthermore, emerging studies indicate that high-intensity exercise may produce favorable effects on cognitive performance, particularly EF, through proposed adaptations within the central nervous system (7,21). However, because most previous studies have not directly assessed these neurophysiological mechanisms, causal explanations should be interpreted cautiously. The relatively short duration of HIIT sessions may also enhance adherence and practicality within school and community settings, making this training modality particularly attractive for adolescent populations (22). Its time-efficient nature further facilitates integration into school schedules, where limited curricular time often represents a barrier to implementing regular PA programs.

Despite the growing interest in HIIT, several important gaps remain in the literature. First, much of the existing research has focused primarily on physical health outcomes, while comparatively fewer studies have examined cognitive and educational outcomes. Second, studies investigating EF often assess only one cognitive domain, limiting understanding of the broader cognitive effects of exercise interventions. Third, evidence regarding the influence of HIIT on AP remains inconsistent, with some studies reporting positive effects and others finding minimal or no improvements. These inconsistencies may be attributable to differences in exercise duration and intensity, assessment methods, and variability in school-related factors that also influence academic achievement. Furthermore, improvements in AP following exercise may not solely reflect enhanced EF but may also arise from increased classroom attendance, greater motivation, improved mood, enhanced self-esteem, better sleep quality, or increased

teacher engagement during the intervention period. Moreover, relatively few randomized controlled trials have simultaneously evaluated EF, AP, and health-related physical fitness (HRPF) within the same cohort of overweight adolescents.

To our knowledge, relatively few randomized controlled trials have comprehensively examined the effects of a school-based HIIT program on EF, AP, and multiple components of HRPF within the same sample of overweight adolescents. Addressing these outcomes simultaneously may provide more comprehensive evidence regarding the educational and health-related value of HIIT interventions in this population. Therefore, the purpose of the current study was to investigate the effects of a 12-week HIIT program on EF, AP, and HRPF in overweight adolescents.

2. Methods

2.1. Study Design

This study employed a parallel-group randomized controlled trial design.

2.2. Participants

Participants were recruited from local middle schools, and 86 adolescents were screened for eligibility. After excluding 18 individuals who did not meet the inclusion criteria, 68 eligible participants were randomly allocated to the HIIT group ($n = 34$) or the control group ($n = 34$). Eligibility criteria included being 12–15 years of age, having overweight status ($\text{BMI} \geq 85\text{th percentile}$), being medically fit for vigorous PA, and having no regular participation in structured exercise during the previous six months. Exclusion criteria comprised neurological, cognitive, psychiatric, or musculoskeletal conditions, use of medications affecting cognitive or physical performance, and failure to complete the intervention or outcome assessments. Sample size estimation using G*Power (Version 3.1; $f = 0.25$, $\alpha = 0.05$, power = 0.80) indicated that at least 52 participants were required; therefore, 68 adolescents were enrolled to accommodate potential attrition. Randomization was performed using a computer-generated sequence by an independent researcher, with allocation concealed in sealed opaque envelopes until baseline testing was completed. During follow-up, three participants in the HIIT group and two in the control group withdrew for personal reasons, leaving 31 and 32 participants, respectively, for the final analyses. The participant flow is presented in the CONSORT diagram (Figure 1).

2.3. Intervention

2.3.1. High-Intensity Interval Training Intervention

Participants assigned to the HIIT group completed a supervised 12-week exercise program conducted three times per week on non-consecutive days. Each training session lasted approximately 35–40 minutes and was administered by certified exercise specialists. Each session consisted of three phases: 1) warm-up, in which, participants completed a standardized 10-minute warm-up comprising light jogging, dynamic stretching exercises, and movement preparation drills; 2) HIIT protocol, in which, the main training phase consisted of repeated bouts of vigorous exercise interspersed with active recovery periods. Participants performed 10 intervals of 1 minute of high-intensity exercise at 85–

95% of age-predicted maximal heart rate (HR_{max}), followed by 1 minute of active recovery involving walking or low-intensity movement. The exercise modalities included shuttle runs, bodyweight squats, jumping jacks, high-knee running, mountain climbers, and burpees, organized in a circuit format. Training intensity was monitored using heart-rate monitors and periodically verified using ratings of perceived exertion (RPE) according to the Borg 6–20 scale. Participants were encouraged to maintain an RPE between 15 and 18 during work intervals; and 3) cool-down, in which, participants completed a 5-minute cool-down consisting of walking and static stretching exercises targeting the major muscle groups. Attendance was recorded at every session, and participants were required to attend at least 80% of the sessions to be included in the final analysis. To maximize intervention adherence, exercise sessions were delivered in small supervised groups and incorporated regular verbal encouragement, progressive variation in exercise circuits, and individualized feedback from instructors. Attendance records demonstrated excellent compliance, with participants who completed the intervention attending a mean of $91.6 \pm 5.4\%$ of scheduled training sessions. No exercise-related injuries or adverse events requiring medical attention were reported during the intervention period.

2.3.2. Control Group

Participants assigned to the control group continued their regular school activities and physical education curriculum throughout the study period. They were instructed not to initiate any new structured exercise programs during the intervention. No additional exercise sessions were provided to the control group.

2.4. Measurements

2.4.1. Anthropometric Measurements

Height and body weight were assessed using a portable stadiometer (0.1 cm) and a calibrated digital scale (0.1 kg), respectively. Body mass index (BMI) was calculated as $\text{weight (kg)} / \text{height}^2 \text{ (m}^2\text{)}$. Waist circumference was measured midway between the lowest rib and the iliac crest with a non-elastic tape to the nearest 0.1 cm. All anthropometric measurements were performed twice, and the average of the two measurements was used for analysis.

2.4.2. Executive Function Assessment

EF was evaluated in a quiet classroom by trained assessors blinded to group allocation using standardized neuropsychological tests. Inhibitory control was assessed with the Stroop Color-Word Test, with response time and accuracy recorded across congruent and incongruent conditions. Cognitive flexibility was measured using the Trail Making Test Part B, in which participants alternated between numbers and letters; shorter completion times reflected better performance. Working memory was assessed with the Digit Span Test, including both forward and backward recall tasks, and performance

was determined by the total number of correctly recalled sequences.

2.4.3. Academic Performance Assessment

AP was evaluated using official school records obtained with parental and school authorization. Scores from mathematics, science, and language courses were collected at baseline and after the intervention period. In addition, overall grade point average (GPA) was calculated based on the academic grading system used by the participating schools.

2.4.4. Health-Related Physical Fitness Assessment

HRPF was assessed using standardized field-based tests. Cardiorespiratory fitness was measured by the 20-m shuttle run test, in which participants ran between two lines following progressively increasing audio-paced signals, and the completed stages were recorded. Muscular endurance was evaluated through the push-up and one-minute sit-up tests, with the maximum number of correctly performed repetitions used as the performance indicator. Speed and agility were assessed using the 4×10 m shuttle run test, with completion time recorded. Flexibility was determined by the sit-and-reach test, based on the maximum forward reach distance (cm) achieved in a seated position.

2.5. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (Version 27; IBM Corp., Armonk, NY, USA). Data distribution was evaluated through the Shapiro-Wilk test and visual examination of histograms. Descriptive data are reported as mean $\pm$ standard deviation (SD), and baseline group comparisons were conducted using independent-samples t-tests. Intervention effects were examined using a two-way mixed ANOVA, followed by Bonferroni-adjusted post hoc tests when significant interactions were observed. Findings are presented with mean differences, 95% confidence intervals (CIs), p-values, and effect sizes. Partial eta squared (η^2p) was reported for interaction effects, while Cohen's d was calculated to quantify within-group pre-post changes. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Participant Flow

Of the 86 adolescents screened, 18 were excluded due to ineligibility, leaving 68 participants who were randomly allocated to the HIIT ($n = 34$) or control ($n = 34$) groups. Five participants (HIIT: $n = 3$; Control: $n = 2$) discontinued the study because of personal reasons or incomplete post-intervention assessments. Therefore, 63 participants completed the trial and were included in the final analyses (retention rate: 92.6%). The HIIT group demonstrated excellent adherence, completing 33.8 ± 1.7 of 36 prescribed sessions (93.9%), with all participants meeting the predefined attendance threshold of 80%. No adverse events related to the intervention were observed (Figure 1).

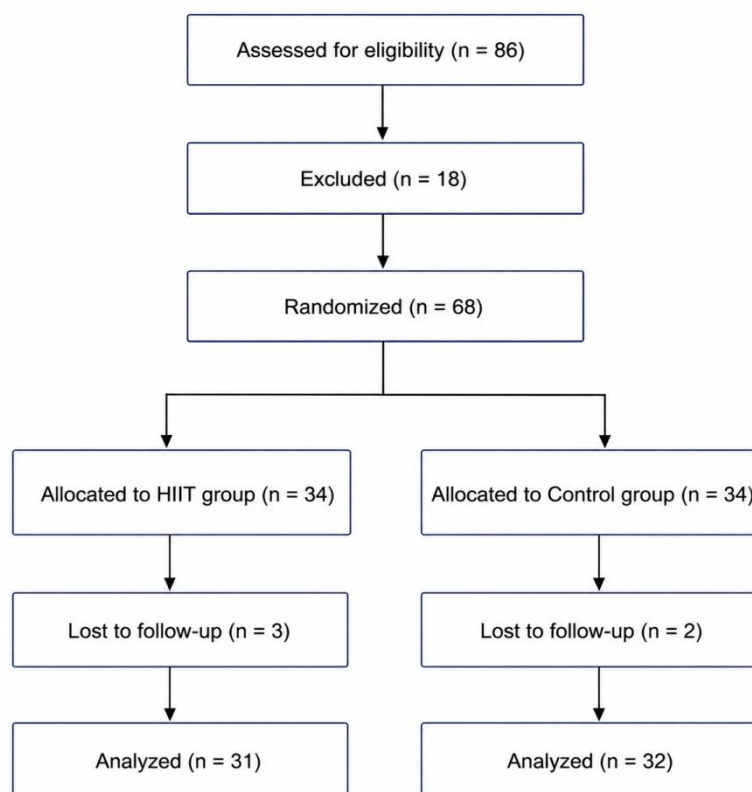


Figure 1. Participant Flow Diagram

3.2. Baseline Characteristics

No statistically significant between-group differences were observed at baseline for any variable

(all $p > 0.05$), indicating successful randomization and comparable groups before the intervention (Table 1).

Table 1. Baseline Characteristics of Participants.

Variable	HIIT (n = 31)	Control (n = 32)	p
Age (years)	13.4 ± 0.9	13.5 ± 0.8	0.68
Height (cm)	158.2 ± 7.5	157.6 ± 7.9	0.77
Weight (kg)	72.8 ± 8.7	73.4 ± 9.1	0.81
BMI (kg/m ²)	29.1 ± 2.8	29.4 ± 2.7	0.65
Waist Circumference (cm)	91.8 ± 6.4	92.5 ± 6.1	0.67
Stroop Score	42.3 ± 6.1	41.7 ± 5.8	0.70
Trail Making Test-B (s)	78.4 ± 12.7	79.1 ± 11.9	0.83
Digit Span Score	10.8 ± 2.1	10.6 ± 2.0	0.71
Mathematics Grade	14.2 ± 1.8	14.0 ± 1.7	0.66
Science Grade	14.4 ± 1.9	14.2 ± 1.8	0.68
Language Grade	14.8 ± 1.6	14.6 ± 1.7	0.64
GPA	14.5 ± 1.3	14.3 ± 1.4	0.59
20-m Shuttle Run (stages)	5.9 ± 1.2	5.8 ± 1.1	0.75
Push-ups (repetitions)	13.5 ± 4.1	13.2 ± 4.0	0.78
Sit-ups (repetitions)	24.7 ± 5.2	24.3 ± 5.4	0.79
4 × 10 m Shuttle run (s)	12.8 ± 0.9	12.9 ± 1.0	0.73
Sit-and-Reach (cm)	21.4 ± 4.8	21.1 ± 4.5	0.80

3.3. Executive Function Outcomes

Mixed-design ANOVA demonstrated significant group × time interactions for inhibitory control, cognitive flexibility, and working memory (all $p < 0.001$), with moderate-to-large interaction effect sizes

($\eta^2 = 0.19$ – 0.24). Compared with the control group, participants in the HIIT group demonstrated significantly greater improvements in EF components. Cohen's d values ranged from 0.72 to 0.96, indicating moderate-to-large intervention effects (Table 2 and Figure 2A).

Table 2. Executive Function Outcomes Before and After the Intervention.

Variable	Group	Pre-Test	Post-Test	Mean Change	F (Group × Time)	p	Partial η^2
Stroop Test	HIIT	42.3 ± 6.1	50.1 ± 5.7	+7.8	16.42	<0.001	0.21
	Control	41.7 ± 5.8	42.8 ± 5.9	+1.1			
Trail Making Test-B (s)	HIIT	78.4 ± 12.7	66.2 ± 10.8	-12.2	18.75	<0.001	0.24
	Control	79.1 ± 11.9	77.5 ± 11.4	-1.6			
Digit Span	HIIT	10.8 ± 2.1	13.4 ± 2.0	+2.6	14.91	<0.001	0.19
	Control	10.6 ± 2.0	11.0 ± 2.1	+0.4			

3.4. Academic Performance Outcomes

Significant group $\times$ time interactions were observed for mathematics, science, language, and overall GPA (all $p \leq 0.011$), with η^2 values ranging from 0.10 to 0.14. Participants assigned to the HIIT group demonstrated greater improvements across all academic indicators than those in the control group.

Mean improvements consistently favored the intervention group, with moderate Cohen's d values (0.55–0.79), and 95% confidence intervals supported the statistical significance of these differences (Table 3 and Figure 2B).

Table 3. Academic Performance Outcomes Before and After the Intervention.

Variable	Group	Pre-Test	Post-Test	Mean Change	F (Group $\times$ Time)	p	Partial η^2
Mathematics	HIIT	14.2 $\pm$ 1.8	16.1 $\pm$ 1.6	+1.9	9.33	0.003	0.13
	Control	14.0 $\pm$ 1.7	14.4 $\pm$ 1.8	+0.4			
Science	HIIT	14.4 $\pm$ 1.9	16.0 $\pm$ 1.7	+1.6	8.21	0.005	0.12
	Control	14.2 $\pm$ 1.8	14.6 $\pm$ 1.8	+0.4			
Language	HIIT	14.8 $\pm$ 1.6	16.0 $\pm$ 1.5	+1.2	6.71	0.011	0.10
	Control	14.6 $\pm$ 1.7	14.9 $\pm$ 1.6	+0.3			
GPA	HIIT	14.5 $\pm$ 1.3	16.0 $\pm$ 1.2	+1.5	10.28	0.002	0.14
	Control	14.3 $\pm$ 1.4	14.7 $\pm$ 1.3	+0.4			

3.5. Health-Related Physical Fitness Outcomes

Significant group $\times$ time interactions were identified for all fitness variables (all $p < 0.001$), with large interaction effect sizes (partial $\eta^2 = 0.22$ –0.31). Compared with controls, adolescents who completed the HIIT program exhibited significantly greater improvements in cardiorespiratory fitness, upper- and abdominal-muscular endurance, agility, and flexibility.

The magnitude of the intervention effects was large (Cohen's $d = 0.88$ –1.29), and all primary outcome estimates were accompanied by 95% confidence intervals indicating clinically meaningful improvements in favor of the HIIT group (Table 4 and Figure 2C).

Table 4. Health-Related Physical Fitness Outcomes Before and After the Intervention.

Variable	Group	Pre-Test	Post-Test	Mean Change	F (Group $\times$ Time)	p	Partial η^2
20-m Shuttle Run	HIIT	5.9 $\pm$ 1.2	8.1 $\pm$ 1.4	+2.2	22.84	<0.001	0.28
	Control	5.8 $\pm$ 1.1	6.1 $\pm$ 1.1	+0.3			
Push-ups	HIIT	13.5 $\pm$ 4.1	21.2 $\pm$ 4.5	+7.7	24.13	<0.001	0.29
	Control	13.2 $\pm$ 4.0	14.4 $\pm$ 4.2	+1.2			
Sit-Ups	HIIT	24.7 $\pm$ 5.2	33.6 $\pm$ 5.5	+8.9	26.07	<0.001	0.31
	Control	24.3 $\pm$ 5.4	25.7 $\pm$ 5.3	+1.4			
4 $\times$ 10 m Shuttle Run (s)	HIIT	12.8 $\pm$ 0.9	11.9 $\pm$ 0.8	-0.9	19.42	<0.001	0.24
	Control	12.9 $\pm$ 1.0	12.7 $\pm$ 0.9	-0.2			
Sit-and-Reach (cm)	HIIT	21.4 $\pm$ 4.8	26.8 $\pm$ 4.9	+5.4	17.16	<0.001	0.22
	Control	21.1 $\pm$ 4.5	22.0 $\pm$ 4.6	+0.9			

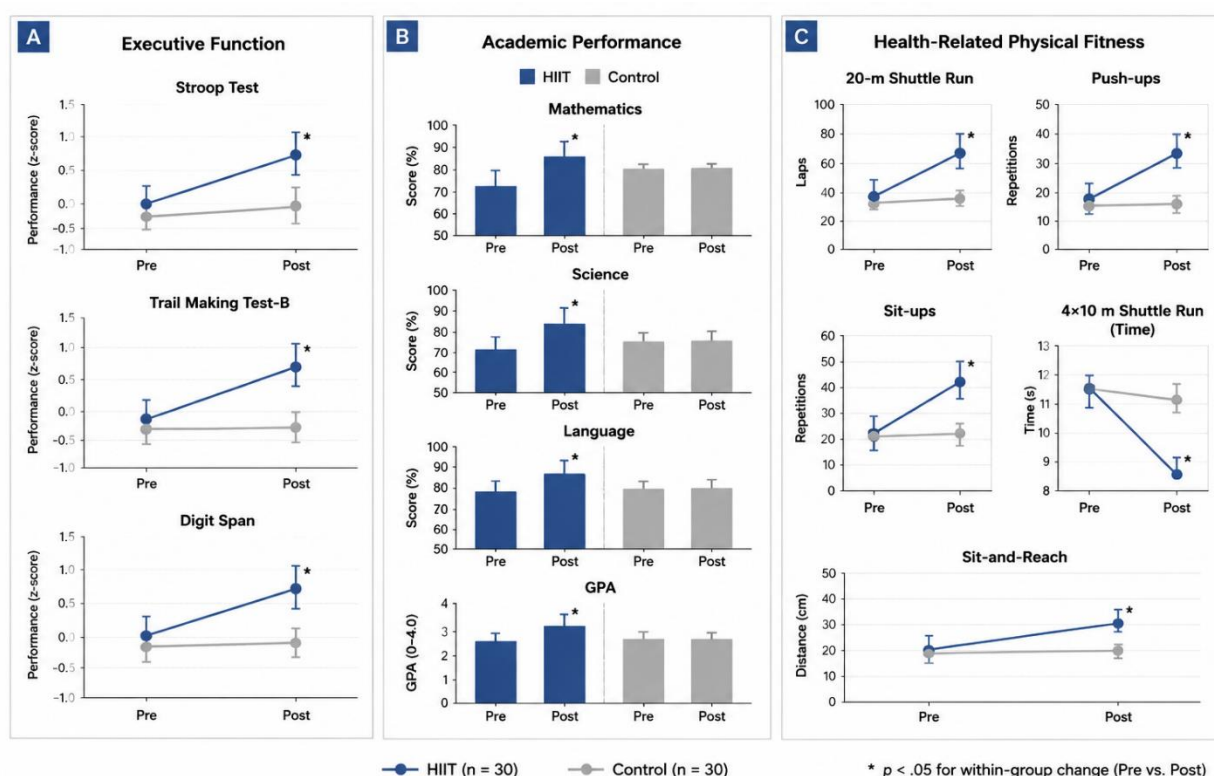


Figure 2. Changes in Executive Function, Academic Performance, and Health-Related Physical Fitness Following Intervention.

4. Discussion

The present study investigated the effects of a 12-week HIIT program on EF, AP, and HRPF in overweight adolescents. The principal finding was that participants in the HIIT group demonstrated significantly greater short-term improvements in EF, academic achievement, and HRPF than those in the control group. These findings support the growing evidence that school-compatible HIIT programs can simultaneously improve multiple domains of adolescent health and performance.

One of the most important findings of the present study was the improvement in EF following the HIIT intervention. These findings are consistent with previous randomized trials and recent systematic reviews showing that HIIT and other vigorous exercise interventions can enhance EF in youth, particularly among individuals with overweight or low baseline fitness (26–30). The magnitude of improvement observed in the present study is comparable with that reported in previous school-based HIIT interventions, suggesting that relatively brief but vigorous exercise programs may provide meaningful cognitive benefits.

Several physiological mechanisms have been proposed to explain these improvements. Previous research suggests that HIIT may increase cerebral blood flow, stimulate the release of brain-derived neurotrophic factor (BDNF), enhance synaptic plasticity, and improve metabolic regulation (7,15,31). Collectively, these adaptations could facilitate more efficient functioning of prefrontal cortical networks responsible for executive control. Because no neurophysiological or biochemical markers were measured, these explanations should be regarded as plausible hypotheses rather than direct evidence from the current trial.

The HIIT intervention also resulted in significant improvements in AP, including mathematics, science, language grades, and overall GPA. These findings extend previous research reporting positive, although sometimes inconsistent, effects of PA on educational outcomes (32–35). While improvements in EF may have contributed to better AP by enhancing attention, working memory, and self-regulation during classroom learning, alternative explanations should also be considered. For example, participation in regular supervised exercise may improve school attendance, classroom engagement, motivation, mood, sleep quality, and self-confidence, all of which can positively influence academic achievement independently of cognitive changes. Furthermore, natural academic progression during a school semester and teacher-related grading practices may also have contributed to improvements, although the randomized controlled design and greater gains observed in the HIIT group suggest that the intervention played an important role.

The present findings further demonstrated substantial improvements in HRPF, including cardiorespiratory fitness, muscular endurance, agility, and flexibility. These results are highly consistent with previous HIIT studies conducted in overweight and healthy adolescents, which have consistently reported improvements in aerobic capacity and muscular fitness following relatively short training programs (18–22). The large improvements in cardiorespiratory

fitness observed in the present study are particularly relevant because low aerobic fitness is an established predictor of future cardiometabolic risk (36). Similarly, improvements in muscular endurance, agility, and flexibility likely reflect the multidirectional and whole-body nature of the exercise protocol used during the intervention. Although improved HRPF may partially explain the observed cognitive and academic benefits, causal relationships among these outcomes cannot be established from the present data. Previous studies have reported positive associations between cardiorespiratory fitness and EF in youth (37), but further longitudinal studies incorporating mediation analyses are needed to determine whether improvements in fitness directly contribute to cognitive enhancement.

The present findings have several practical implications. First, the high attendance rate observed during the intervention demonstrates that supervised HIIT is feasible and well accepted by overweight adolescents. Second, because each training session required only approximately 35–40 minutes, HIIT could be incorporated into school physical education classes, extracurricular health programs, or after-school initiatives without major disruption to academic schedules. Third, the simultaneous improvements observed across cognitive, academic, and physical domains suggest that structured exercise programs may complement, rather than compete with, educational objectives. These findings support current recommendations encouraging schools to integrate regular vigorous PA into comprehensive health-promotion strategies.

The present study has several strengths. The randomized controlled design reduced selection bias and strengthened internal validity. Outcome assessors followed standardized testing procedures, and the intervention demonstrated excellent participant adherence, supporting intervention fidelity. In addition, EF, academic achievement, and HRPF were evaluated simultaneously, providing a comprehensive assessment of intervention effects.

Several limitations should also be noted. First, the intervention lasted only 12 weeks, and no follow-up assessments were conducted; therefore, the durability of the observed improvements cannot be determined. Second, participants were recruited from a limited geographical area, which may restrict generalizability to broader adolescent populations. Third, AP was assessed using school grades, which may be influenced by teacher evaluation practices and other educational factors. Fourth, neurobiological and psychosocial mechanisms potentially underlying the observed cognitive improvements were not measured directly. Finally, although the findings support construct validity of the intervention effects, they should not be interpreted as evidence of long-term educational or health outcomes.

Future randomized controlled trials should incorporate longer intervention periods, post-intervention follow-up assessments, larger multicenter samples, and objective neurophysiological or biomarker measures to clarify the mechanisms responsible for exercise-induced cognitive adaptations. Investigating mediating variables such as BDNF, inflammatory markers, sleep quality, motivation, and psychological well-being would further improve

understanding of how HIIT influences academic and cognitive performance in adolescents.

4.1. Conclusions

A 12-week HIIT program produced significant short-term improvements in EF, AP, and HRPF in overweight adolescents compared with a control condition. These findings suggest that HIIT represents a feasible and time-efficient intervention for promoting multiple aspects of adolescent health. Because no long-term follow-up was performed, the sustainability of these improvements remains uncertain. Nevertheless, the present findings support the inclusion of appropriately supervised HIIT programs within school-based physical education and health-promotion initiatives as a practical strategy to enhance both HRPF and cognitive functioning in overweight adolescents.

Authors' Contribution: The author was involved in all major stages of the research, including study conceptualization, methodological design, participant recruitment, implementation of the HIIT intervention, data collection, statistical analysis, interpretation of the findings, and preparation and revision of the manuscript.

Funding Support: No external financial support was received for the conduct of this research, including from governmental, commercial, or private funding sources.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: The author declares that no generative artificial intelligence or AI-assisted technology was used in the preparation, writing, editing, or revision of this manuscript. The author takes full responsibility for the accuracy, originality, integrity, and overall content of the published work.

Ethical Considerations: Ethical approval for this study was obtained from the relevant institutional ethics committee (Ethics Code: IR.IAU.SARI.REC.1404.344). The research was conducted in accordance with the principles of the Declaration of Helsinki, and written informed consent was obtained from the parents or legal guardians of all participating adolescents before their enrollment in the study. The adolescents received age-appropriate information about the study procedures, and their voluntary participation was respected.

Data Availability: The data generated and analyzed during the current study are available from the corresponding author upon reasonable request, subject to applicable ethical, privacy, and confidentiality requirements.

Acknowledgments: The author gratefully acknowledges all adolescents who participated in the study, as well as their parents or legal guardians and the school personnel who supported the implementation of the research.

Conflicts of Interest: The author declares that there are no financial, personal, or professional conflicts of interest associated with this study.

References

- Prem Kumar AE, Lakshminarayanan K. Prevalence of Overweight and Obesity and Their Associated Factors Among Adolescent Children in an Urban School in Tamil Nadu. *Cureus*. 2026;18(2):e103933. [PubMed ID: 41737825]. [PubMed Central ID: PMC12926614] doi:10.7759/cureus.103933.
- Lewandowska A, Rudzki G, Lewandowski T, Bartosiewicz A, Próchnicki M, Strykowska-Góra A, Laskowska B, Sierpińska M, Rudzki S, Pavlov S. Overweight and obesity among adolescents: health-conscious behaviours, acceptance, and the health behaviours of their parents. *BMC Public Health*. 2025;25(1):418. [PubMed ID: 39894844]. [PubMed Central ID: PMC11789381] doi:10.1186/s12889-025-21591-0.
- Panda A, Parida J, Jena S, Behera SS, Pradhan A, Patra PK, Pati S, Kaur H, Acharya SK. Prevalence and associated risk factors of overweight and obesity among adolescent population of India: a scoping review. *BMC Nutr*. 2025;11(1):10. [PubMed ID: 40474315]. [PubMed Central ID: PMC12139068] doi:10.1186/s40795-025-01088-0.
- Tekchandani N, Mukherjee A, Farook F, Varghese H, Aikoroje P. Understanding How Childhood Obesity Influences Educational Outcomes: A Literature Review. *Cureus*. 2026;18(1):e101691. [PubMed ID: 41700254]. [PubMed Central ID: PMC12906851] doi:10.7759/cureus.101691.
- Napolitano N, Rojas-Barahona CA, Gaete J, Araya R. A comparison of three executive function interventions on direct and far transfer in Chilean school children: a cluster-randomized controlled protocol. *BMC Psychol*. 2025;13(1):730. [PubMed ID: 40615866]. [PubMed Central ID: PMC12228356] doi:10.1186/s40359-025-03075-3.
- Carvalho S. Executive dysfunction as a transdiagnostic mechanism of psychopathology: a neurocognitive framework for diagnosis and intervention. *Front Hum Neurosci*. 2026;20:1778271. [PubMed ID: 42003986]. [PubMed Central ID: PMC13083063] doi:10.3389/fnhum.2026.1778271.
- Guzmán-Muñoz E, Concha-Cisternas Y, Jofré-Saldía E, Castillo-Paredes A, Molina-Márquez I, Yáñez-Sepúlveda R. Physical Activity and Its Effects on Executive Functions and Brain Outcomes in Children: A Narrative Review. *Brain Sci*. 2025;15(11):1238. [PubMed ID: 41300244]. [PubMed Central ID: PMC12651547] doi:10.3390/brainsci1511238.
- Spiegel JA, Goodrich JM, Morris BM, Osborne CM, Lonigan CJ. Relations between executive functions and academic outcomes in elementary school children: A meta-analysis. *Psychol Bull*. 2021;147(4):329-351. [PubMed ID: 34166004]. [PubMed Central ID: PMC8238326] doi:10.1037/bul0000322.
- Rakesh D, Lee PA, Gaikwad A, McLaughlin KA. Annual Research Review: Associations of socioeconomic status with cognitive function, language ability, and academic achievement in youth: a systematic review of mechanisms and protective factors. *J Child Psychol Psychiatry*. 2025;66(4):417-439. [PubMed ID: 39625804]. [PubMed Central ID: PMC11920614] doi:10.1111/jcpp.14082.
- Liu K, Liu S, Wang D, Qiao H. Obesity-induced cognitive impairment: Underlying mechanisms and therapeutic prospects. *Metabol Open*. 2026;29:100444. [PubMed ID: 41625558]. [PubMed Central ID: PMC12859810] doi:10.1016/j.metop.2026.100444.
- Salas-Venegas V, Flores-Torres RP, Rodríguez-Cortés YM, Rodríguez-Retana D, Ramírez-Carreto RJ, Concepción-Carrillo LE, Pérez-Flores LJ, Alarcón-Aguilar A, López-Díazguerrero NE, Gómez-González B, Chavarría A, Königsberg M. The Obese Brain: Mechanisms of Systemic and Local Inflammation, and Interventions to Reverse the Cognitive Deficit. *Front Integr Neurosci*. 2022;16:798995. [PubMed ID: 35422689]. [PubMed Central ID: PMC9002268] doi:10.3389/fnint.2022.798995.
- Unterguggenberger S. Physical Activity, Cognitive Health and Learning in Youth: A Narrative Umbrella Review. *Int J Environ Res Public Health*. 2025;23(1):11. [PubMed ID: 41595805]. [PubMed Central ID: PMC12841123] doi:10.3390/ijerph23010011.
- Machado S, Paes F, Lima JL. Exercise as a Promising Non-Pharmacological Intervention for ADHD. *Rev Neurol*. 2025;80(11):48058. [PubMed ID: 41504201]. [PubMed Central ID: PMC12781223] doi:10.31083/RN48058.
- Tao Y, Zhang Y, Qian H, Cao Z. Long term effects of physical activity types on executive functions in school aged children. *Sci Rep*. 2025;15(1):30303. [PubMed ID: 40830545]. [PubMed Central ID: PMC12365328] doi:10.1038/s41598-025-09674-9.
- Romero Garavito A, Díaz Martínez V, Juárez Cortés E, Negrete Díaz JV, Montilla Rodríguez LM. Impact of physical exercise on the regulation of brain-derived neurotrophic factor in people with neurodegenerative diseases. *Front Neurol*. 2025;15:1505879. [PubMed ID: 39935805]. [PubMed Central ID: PMC11810746] doi:10.3389/fneur.2024.1505879.
- Poon ET, Li HY, Gibala MJ, Wong SH, Ho RS. High-intensity interval training and cardiorespiratory fitness in adults: An umbrella review of systematic reviews and meta-analyses. *Scand J Med Sci Sports*. 2024;34(5):e14652. [PubMed ID: 38760916]. doi:10.1111/sms.14652.
- Atakan MM, Li Y, Koşar ŞN, Turnagöl HH, Yan X. Evidence-Based Effects of High-Intensity Interval Training on Exercise Capacity and Health: A Review with Historical Perspective. *Int J Environ Res*

- Public Health. 2021;18(13):7201. [PubMed ID: 34281138]. [PubMed Central ID: PMC8294064] doi: 10.3390/ijerph18137201.
18. Stankovic M, Čaprić I, Pezelj L, Biševac E, Mekić R, Zečirović A, Salihagić Z, Ajdinović A, Jelaska I. High-Intensity Interval Training (HIIT): Impact of Duration on Body Composition, Cardiometabolic Health, and Aerobic Capacity in Adolescent Women. *Metabolites*. 2025;15(9):623. [PubMed ID: 41003007]. [PubMed Central ID: PMC12472050] doi: 10.3390/metabo15090623.
 19. Deng Y, Wang X. Effect of high-intensity interval training on cardiorespiratory in children and adolescents with overweight or obesity: a meta-analysis of randomized controlled trials. *Front Public Health*. 2024;12:1269508. [PubMed ID: 38344230]. [PubMed Central ID: PMC10853929] doi: 10.3389/fpubh.2024.1269508.
 20. Poon ET, Sum WM, Lubans D, Wong SH, Ho RS. High-intensity interval training for improving cardiometabolic health in children and adolescents: An umbrella review of systematic reviews. *J Sports Sci*. 2024;42(23):2199-2215. [PubMed ID: 39560429]. doi: 10.1080/02640414.2024.2425910.
 21. Kapur S, Joshi GM. Acute and chronic effects of exercise intensity on cognitive functions of fastball athletes. *Cogn Neurodyn*. 2024;18(5):2289-2298. [PubMed ID: 39555261]. [PubMed Central ID: PMC11564466] doi: 10.1007/s11571-024-10083-3.
 22. Mitić P, Jovanović R, Stojiljković N, Trajković N, Olanescu M, Suciu A, Popa D, Peris M. Implementing High-Intensity Interval Training in Physical Education: Effects on Adolescents' Exercise Motivation. *Behav Sci (Basel)*. 2025;15(4):501. [PubMed ID: 40282122]. [PubMed Central ID: PMC12024064] doi: 10.3390/bs15040501.
 23. Periañez JA, Lubrini G, García-Gutiérrez A, Ríos-Lago M. Construct Validity of the Stroop Color-Word Test: Influence of Speed of Visual Search, Verbal Fluency, Working Memory, Cognitive Flexibility, and Conflict Monitoring. *Arch Clin Neuropsychol*. 2021;36(1):99-111. [PubMed ID: 32514527]. doi: 10.1093/arclin/aaaa034.
 24. Lähde N, Basnyat P, Raitanen J, Kämppi L, Lehtimäki K, Rosti-Otajärvi E, Peltola J. Complex executive functions assessed by the trail making test (TMT) part B improve more than those assessed by the TMT part A or digit span backward task during vagus nerve stimulation in patients with drug-resistant epilepsy. *Front Psychiatry*. 2024;15:1349201. [PubMed ID: 38419904]. [PubMed Central ID: PMC10899669] doi: 10.3389/fpsy.2024.1349201.
 25. Egeland J, Lund O, Raudeberg R. Measuring working memory span with WAIS-IV: Digit sequence is the superior span test. *Appl Neuropsychol Adult*. 2026;33(1):65-72. [PubMed ID: 39829251]. doi: 10.1080/23279095.2024.2330998.
 26. Liu L, Xin X, Zhang Y. The effects of physical exercise on cognitive function in adolescents: a systematic review and meta-analysis. *Front Psychol*. 2025;16:1556721. [PubMed ID: 40792082]. [PubMed Central ID: PMC12337486] doi: 10.3389/fpsyg.2025.1556721.
 27. Carcelén-Fraile MDC, Montánchez-Torres ML, Cecic-Mladinic D. Exercise Interventions and Attentional Performance in Children and Adolescents: Evidence from Randomized Controlled Trials. *Sports (Basel)*. 2026;14(4):139. [PubMed ID: 42043071]. [PubMed Central ID: PMC13120170] doi: 10.3390/sports14040139.
 28. Schoenfeld J, Kaiser M, Rieger B, Haller B, Halle M, Siegrist M. Effect of lifestyle interventions on cognitive function, physical fitness and activity over 2 years in primary school children: results from the fit4future intervention programme. *BMJ Open Sport Exerc Med*. 2025;11(1):e002277. [PubMed ID: 39963177]. [PubMed Central ID: PMC11831296] doi: 10.1136/bmjsem-2024-002277.
 29. Ma J, Liu X, Pan T, Ji L, Zhang W. Developmental Changes in the Structure of Executive Function from Early To Late Adolescence. *J Youth Adolesc*. 2026;55(4):982-997. [PubMed ID: 41342995]. [PubMed Central ID: PMC13076501] doi: 10.1007/s10964-025-02293-7.
 30. Ben Ezzdine L, Dhahbi W, Dergaa I, Ceylan HI, Guelmami N, Ben Saad H, Chamari K, Stefanica V, El Omri A. Physical activity and neuroplasticity in neurodegenerative disorders: a comprehensive review of exercise interventions, cognitive training, and AI applications. *Front Neurosci*. 2025;19:1502417. [PubMed ID: 40092068]. [PubMed Central ID: PMC11906675] doi: 10.3389/fnins.2025.1502417.
 31. Wang Z, Jia J. Enhancing the understanding between exercise and brain health: A new tool of oxygen imaging. *J Sport Health Sci*. 2024;13(6):751-752. [PubMed ID: 38768657]. [PubMed Central ID: PMC11336363] doi: 10.1016/j.jshs.2024.05.008.
 32. Niebaum JC, Munakata Y. Why doesn't executive function training improve academic achievement? Rethinking individual differences, relevance, and engagement from a contextual framework. *J Cogn Dev*. 2023;24(2):241-259. [PubMed ID: 37457760]. [PubMed Central ID: PMC10348702] doi: 10.1080/15248372.2022.2160723.
 33. Le Diagon S, Jacquel M, Van der Henst JB, Prado J. Individual differences in executive functions and theory of mind mediate the relation between academic skills from kindergarten to 5th grade. *PLoS One*. 2025;20(6):e0324547. [PubMed ID: 40455817]. [PubMed Central ID: PMC12129330] doi: 10.1371/journal.pone.0324547.
 34. Han X, Li H, Xiao C, Wang W, Gao K, Yan S, Niu L. Physical activity enhances college students' mental health through social adaptability and exercise behavior chain mediation. *Sci Rep*. 2025;15(1):21127. [PubMed ID: 40594661]. [PubMed Central ID: PMC12214962] doi: 10.1038/s41598-025-07791-z.
 35. Mahindru A, Patil P, Agrawal V. Role of Physical Activity on Mental Health and Well-Being: A Review. *Cureus*. 2023;15(1):e33475. [PubMed ID: 36756008]. [PubMed Central ID: PMC9902068] doi: 10.7759/cureus.33475.
 36. Men J, Yu Z, An W, Wang P, Hou X, Zhang Y, Wu S, Zhu G, Wang P, Cui C, Zhang Y, Wang J, Ding J, Wang Y. Effects of exercise on cardiorespiratory fitness in children and adolescents with overweight and obesity: a systematic review and meta-analysis of 72 randomized controlled trials. *BMC Public Health*. 2025;25(1):3899. [PubMed ID: 41219861]. [PubMed Central ID: PMC12607143] doi: 10.1186/s12889-025-25254-y.
 37. Rico-González M, Martín-Moya R, Giles-Girela FJ, Ardigo LP, González-Fernández FT. The Effects of Cardiopulmonary Fitness on Executive Functioning or Academic Performance in Students from Early Childhood to Adolescence? A Systematic Review. *J Funct Morphol Kinesiol*. 2025;10(3):254. [PubMed ID: 40700190]. [PubMed Central ID: PMC12286005] doi: 10.3390/jfmk10030254.