

# The effect of long-term high-intensity workouts improving physical fitness in adolescent males

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## Abstract

**Background and Study Aim** The combination of a sedentary lifestyle with low physical activity contributes to reduced quality of life and can be a cause of death. Changing a sedentary lifestyle habit, such as increasing physical activity, is a form of prevention against the emergence of health problems. This study aimed to investigate the impact of long-term high-intensity workouts on enhancing physical fitness in adolescent males.

**Material and Methods** The study included 25 male adolescents aged 19-23 years who were university students residing in Malang. The participants were randomly assigned to one of two groups: K1 (control group; n = 12) or K2 (high-intensity workout group; n = 13). The high-intensity workout intervention was administered three times per week for eight weeks. Physical fitness components, including VO<sub>2</sub>max, speed, agility, strength, and flexibility, were measured twice: before and after the intervention. The data were analyzed via an independent samples t-test with a 5% significance level.

**Results** Significant improvements in VO<sub>2</sub>max, strength, speed, and agility were observed in the high-intensity workout group (K2), while no significant changes occurred in the control group (K1). Mean  $\Delta$ VO<sub>2</sub>max between K1 and K2 (0.13±0.56 to 4.49±1.18 mL/kg/min, p=0.001),  $\Delta$ speed (-0.02±0.05 to -0.21±0.15 s, p=0.001),  $\Delta$ agility (0.03±0.21 to -0.56±0.26 s, p=0.001),  $\Delta$ strength (1.50±2.02 to 8.85±1.82 kg, p=0.001), and  $\Delta$ flexibility (0.98±2.16 to 1.82±0.66 cm, p=0.219).

**Conclusions** This study revealed evidence of the effect of high-intensity workout interventions on improving physical fitness components but not on flexibility improvement, likely due to the strength- and endurance-focused nature of the training program.

**Keywords:** high-intensity workout, healthy lifestyle, adolescent males, physical fitness.

## Introduction

Sedentary lifestyles and the rapid pace of urbanization are primary contributors to the increasing prevalence of physical inactivity [1]. This decline in physical activity is a major public health concern, as it significantly affects overall well-being and increases the risk of various chronic diseases. The World Health Organization (WHO) defines a sedentary lifestyle as any waking behavior characterized by an energy expenditure of  $\leq$  1.5 METs (metabolic equivalents) while sitting or lying down [2]. This lifestyle has been identified as a leading cause of reduced quality of life and increased mortality rates [3]. Park et al. [4] reported that a sedentary lifestyle is associated with numerous adverse health outcomes, including a higher risk of mortality, cardiovascular disease, cancer, metabolic disorders, osteoporosis, and cognitive decline. Furthermore, prolonged sedentary behavior has been linked to an increased likelihood of developing type

2 diabetes and reduced bone density [5]. Globally, physical inactivity is responsible for approximately 6% of all deaths [6], with up to 81% of individuals failing to meet the WHO's recommended physical activity levels [7]. This inactivity is particularly concerning because it accelerates physiological aging and contributes to muscle deterioration [8]. However, research indicates that shifting from inactivity to regular physical activity could prevent up to 5.3 million deaths annually [9].

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure. The WHO recommends that adults engage in at least 150 minutes of moderate-intensity physical exercise per week or 75 minutes of high-intensity exercise, with each session lasting between 20 and 60 minutes [2]. Similarly, the American College of Sports Medicine (ACSM) suggests resistance training with 8 to 12 repetitions for each major muscle group at an intensity ranging from 40% to 80% of one repetition maximum (RM), depending on the individual's fitness level [10]. A rest period of two

to three minutes between sets is recommended for adequate recovery [11]. Among various training methods, circuit training has gained popularity due to its efficiency in improving multiple fitness components simultaneously [12]. High-intensity circuit training, in particular, has been recognized as a safe and effective approach for enhancing physical fitness [13]. This form of training engages both the cardiorespiratory and musculoskeletal systems, making it a comprehensive workout strategy. Previous studies have demonstrated that circuit training improves key health parameters, including cardiorespiratory endurance, muscular strength, and body composition [14].

Among adolescents, physical inactivity is especially concerning. This period is crucial for musculoskeletal development and metabolic health, emphasizing the importance of establishing active habits early in life [15]. While extensive research supports the benefits of regular exercise, there remains a gap in the literature regarding the long-term effects of structured high-intensity workouts on adolescent males' physical fitness. Most existing studies focus on general physical activity or moderate-intensity exercise, leaving uncertainties about the physiological adaptations induced by prolonged high-intensity training in this demographic.

High-intensity circuit training has been shown to enhance muscle strength, muscle mass, and bone density. However, the optimal exercise dose required to maximize physical fitness adaptations remains underexplored. Therefore, this study aims to investigate the effects of long-term high-intensity workouts on improving physical fitness in adolescent males.

## Materials and Methods

### *Participants*

A total of 25 adolescent males meeting the following criteria were selected for participation: aged 19–22 years, normal body mass index, normal blood pressure, normal heart rate, normal body temperature, and normal oxygen saturation. All selected respondents were confirmed to have no history of chronic diseases (including diabetes mellitus, heart disease, hypertension, or respiratory problems). Additionally, selected respondents were also confirmed not to have consumed alcohol, smoked, or had a history of consuming alcohol or tobacco in the last five years, and not to have taken medication regularly. The selection of participants was carried out using a consecutive sampling technique, and the division into groups was carried out randomly. The participants were randomly assigned to one of two groups: K1 (control group;  $n = 12$ ) or K2 (high-intensity workout group;  $n = 13$ ). All procedures conducted in this study were approved by the Research Ethics Commission of Universitas

Negeri Malang (KEP UM) (No.4.07.2/UN32.14.2.8/LT/2024).

### *Study Design*

#### *High-intensity Workout Protocol*

The high-intensity workout regimen was conducted three times per week over ten weeks, for a total of 30 sessions. The workout consisted of six stations: jumping jacks, running in place, zig-zag running, squat thrusts, downline drifting, and dot-wave drill training. Each session lasted 25–30 minutes, with active rest intervals of 30–60 seconds between stations. Heart rate was monitored throughout the intervention via a Polar H10 Heart Rate Sensor. Details of the high-intensity workout protocol are presented in Table 1.

#### *Data collection procedure*

Data were collected by administering physical fitness tests at two time points: pre-intervention (0 weeks) and 24 hours after the intervention (10 weeks). The tests were conducted at the same time of day on both occasions. Maximal oxygen uptake ( $VO_{2max}$ ) was assessed via the multistage 20-meter shuttle run test (20 mMSFT) [16]. Strength was measured with a Back & Leg Dynamometer [17], whereas speed was evaluated using a 30-Meter Sprint Test [18]. Agility was assessed via the Shuttle Run Fitness Test [16], and flexibility was measured using the sit-and-reach flexibility test [19]. All instruments used in this research had been validated by several previous studies [16, 17, 18, 19].

#### *Statistical Analysis*

The data were analyzed using SPSS software version 20. The normality and homogeneity of the data were assessed using the Shapiro–Wilk test and Levene's test. All data that were normally distributed and had homogeneous variance were analyzed using paired samples t-tests and independent samples t-tests. A paired samples t-test was applied to evaluate differences in physical fitness within each group, whereas an independent samples t-test was used to compare differences between the groups. Meanwhile, data that were not normally distributed were analyzed using the Wilcoxon signed-rank test and the Mann-Whitney U test. Effect size evaluation was implemented using Cohen's  $d$ . Statistical significance was determined at a  $p$ -value of  $\leq 0.05$ .

## Results

Based on the study results, the analysis showed that the overall data on the characteristics of the research subjects in the two groups did not show any significant differences ( $p \geq 0.05$ ). Details of the analysis results can be seen in Table 2. Meanwhile, details of the analysis results for physical fitness components, including  $VO_{2max}$ , strength, speed, agility, and flexibility, can be seen in Figure 1 and Table 3.

**Table 1.** Details of the High-Intensity Workout Protocol

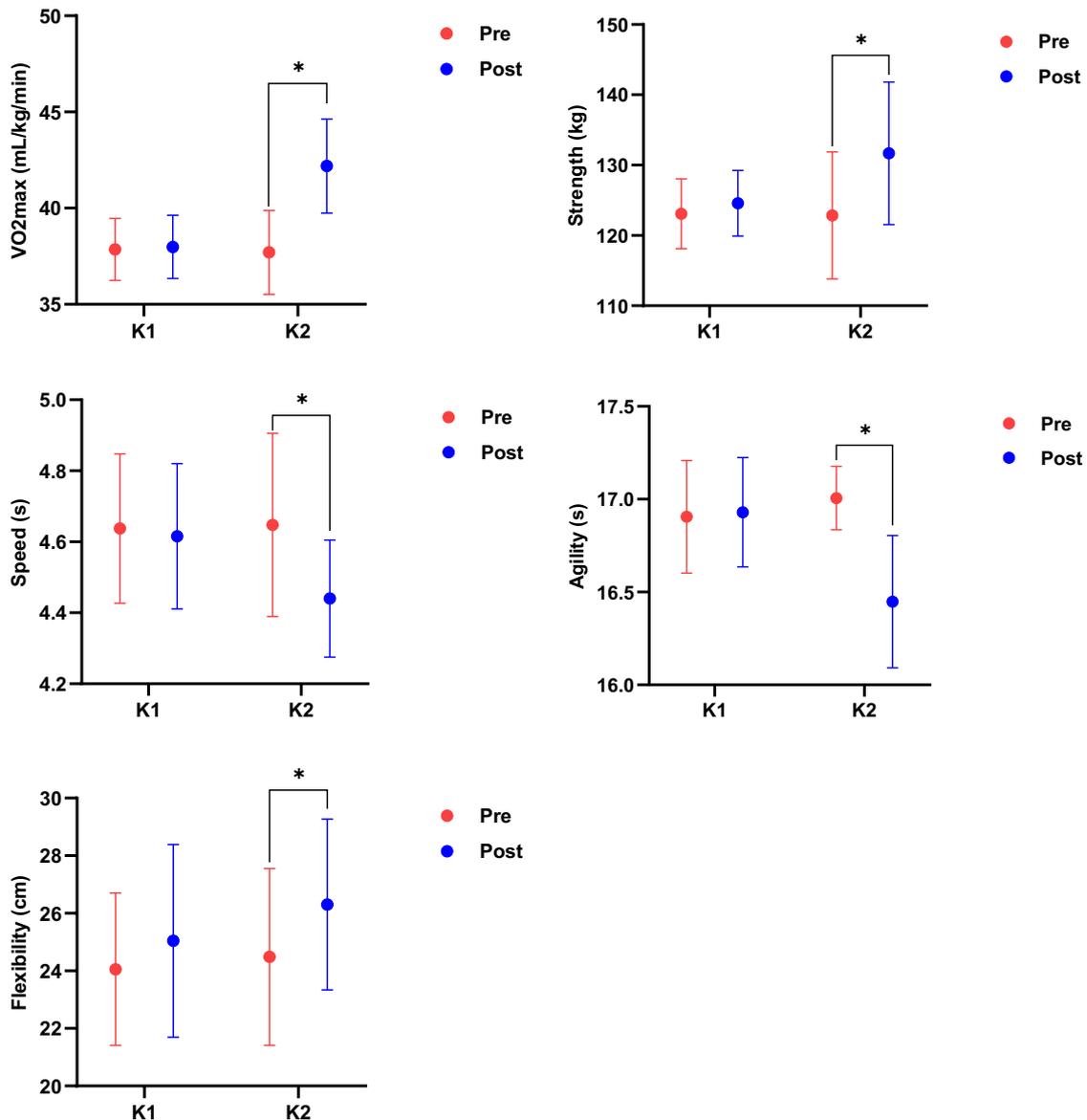
Group	Frequency	Intensity	Duration	Type of Exercises	Warm-up	Cooldown
High-intensity workout training						
Week 1–2	3 times per week for 10 weeks	Work-rest ratio 1:1	4 sets with active rest intervals of 60 seconds between stations and a rest period of 3 minutes between sets	Circuit training (jumping jacks, running in place, zig-zag running, squat thrusts, downline drifting, and dot-wave drill training)	Dynamic stretching for 5 minutes	Running at low intensity (50% HRmax) for 5 minutes
Week 3–4	3 times per week for 10 weeks	Work-rest ratio 1:0.5	4 sets with active rest intervals of 30 seconds between stations and a rest period of 2 minutes between sets	Circuit training (jumping jacks, running in place, zig-zag running, squat thrusts, downline drifting, and dot-wave drill training)	Dynamic stretching for 5 minutes	Running at low intensity (50% HRmax) for 5 minutes
Week 5–6	3 times per week for 10 weeks	Work-rest ratio 1:1	5 sets with active rest intervals of 60 seconds between stations and a rest period of 3 minutes between sets	Circuit training (jumping jacks, running in place, zig-zag running, squat thrusts, downline drifting, and dot-wave drill training)	Dynamic stretching for 5 minutes	Running at low intensity (50% HRmax) for 5 minutes
Week 7–8	3 times per week for 10 weeks	Work-rest ratio 1:0.5	5 sets with active rest intervals of 30 seconds between stations and a rest period of 2 minutes between sets	Circuit training (jumping jacks, running in place, zig-zag running, squat thrusts, downline drifting, and dot-wave drill training)	Dynamic stretching for 5 minutes	Running at low intensity (50% HRmax) for 5 minutes
Week 9–10	3 times per week for 10 weeks	Work-rest ratio 1:1	6 sets with active rest intervals of 30 seconds between stations and a rest period of 2 minutes between sets	Circuit training (jumping jacks, running in place, zig-zag running, squat thrusts, downline drifting, and dot-wave drill training)	Dynamic stretching for 5 minutes	Running at low intensity (50% HRmax) for 5 minutes
Control	10 weeks without training intervention					

These findings confirm that both groups had similar physiological profiles at baseline, ensuring that any observed improvements in physical fitness resulted from the intervention rather than pre-existing differences (Table 2).

There were significant differences between pre- and post-intervention values in the high-intensity workout group (K2) for VO<sub>2</sub>max (p = 0.001; effect size (ES): 1.937), strength (p = 0.001; ES: 0.922), speed (p = 0.001; ES: 0.958), agility (p = 0.001; ES: 1.997), and flexibility (p = 0.001; ES: 0.603)

(Figure 1). Meanwhile, in the control group (K1), no significant differences were observed in VO<sub>2</sub>max, strength, speed, agility, or flexibility between pre- and post-intervention measurements (all p ≥ 0.05) (Figure 1).

The results indicate that the high-intensity workout group (K2) experienced significant improvements in all measured physical fitness components, including VO<sub>2</sub>max, strength, speed, agility, and flexibility, following the intervention (Table 3). In contrast, no significant changes were



**Figure 1.** Pre- and post-intervention physical fitness assessment for each group. Significant difference in pre ( $p \leq 0.001$ ). Data are presented as means  $\pm$  SDs. The p-value was evaluated using a paired samples t-test.

observed in the control group (K1). These findings suggest that structured high-intensity training is an effective approach for enhancing multiple aspects of physical performance in adolescent males.

## Discussion

This study aimed to evaluate the impact of long-term high-intensity workouts on physical fitness in adolescent males. The primary finding was that this intervention significantly improved VO<sub>2</sub>max, strength, speed, and agility, although it did not enhance flexibility. These results align with previous research demonstrating the efficacy of high-intensity exercise in enhancing overall fitness levels [20]. Lee et al. [21] reported that high-intensity circuit training effectively improves multiple fitness components by simultaneously engaging the cardiovascular and musculoskeletal systems.

The improvement in VO<sub>2</sub>max observed in this study can be attributed to cardiovascular adaptations, including increased stroke volume, enhanced capillary density, and improved oxygen utilization by skeletal muscles. High-intensity workouts induce repeated cardiovascular stress, which stimulates myocardial hypertrophy and increases cardiac efficiency, leading to improved oxygen delivery during exercise [22]. Similarly, the observed strength and speed improvements are likely driven by neuromuscular adaptations, such as greater motor unit recruitment, enhanced intramuscular coordination, and increased muscle fiber activation, contributing to higher force production and improved movement efficiency [23]. The improvements in agility may be associated with enhanced neuromuscular control and proprioceptive adaptation, which are crucial for rapid directional

**Table 2.** General characteristics of the study subjects

Parameters	Group	n	Mean	Std. Deviation	p-value
Age (years)	K <sub>1</sub>	12	21.42	1.45	0.762
	K <sub>2</sub>	13	21.23	1.59	
Height (m)	K <sub>1</sub>	12	1.74	0.06	0.758
	K <sub>2</sub>	13	1.75	0.04	
Body weight (kg)	K <sub>1</sub>	12	63.67	4.31	0.846
	K <sub>2</sub>	13	64.00	4.14	
Body Mass Index (kg/m <sup>2</sup> )	K <sub>1</sub>	12	20.98	0.65	0.867
	K <sub>2</sub>	13	20.93	0.81	
Systolic blood pressure (mmHg)	K <sub>1</sub>	12	117.08	3.61	0.715
	K <sub>2</sub>	13	117.62	3.59	
Diastolic blood pressure (mmHg)	K <sub>1</sub>	12	75.33	3.12	0.940
	K <sub>2</sub>	13	75.23	3.61	
Heart rate (bpm)	K <sub>1</sub>	12	62.92	2.75	0.722
	K <sub>2</sub>	13	63.39	3.71	
Body temperature (°C)	K <sub>1</sub>	12	36.68	0.39	0.819
	K <sub>2</sub>	13	36.72	0.48	
Oxygen saturation (%)	K <sub>1</sub>	12	97.67	1.07	0.793
	K <sub>2</sub>	13	97.54	1.33	

K<sub>1</sub>: Control group; K<sub>2</sub>: High-intensity workout group. The p-value was evaluated using an independent samples t-test.

changes and acceleration.

Despite these positive effects, flexibility did not show significant changes, likely due to the nature of high-intensity workouts, which predominantly emphasize strength and power rather than joint range of motion. Unlike stretching-based training, high-intensity circuits do not prioritize prolonged muscle elongation, which is necessary to improve flexibility [24]. Future research should explore whether incorporating dynamic stretching or mobility exercises into high-intensity programs could lead to enhanced flexibility outcomes.

High-intensity exercise is widely recognized for its ability to improve physical fitness and overall health. When performed in group settings, high-intensity exercise can also provide social engagement opportunities for individuals with sedentary lifestyles. Participating in group workouts allows individuals to interact with others who share similar goals of improving fitness and health [25].

Allen et al. [26] demonstrated that high-intensity exercise conducted over a 9-week period effectively reduced waist circumference in sedentary individuals, which was attributed to increased adenosine triphosphate (ATP) consumption by skeletal muscles, leading to the activation of adenosine monophosphate-activated protein kinase (AMPK). AMPK plays a crucial role in mobilizing fat from adipose tissue, thereby reducing fat storage, particularly in the abdominal region [27]. Furthermore, a decrease in waist circumference

is often associated with improved flexibility, a key component of physical fitness.

High-intensity training is also known to increase VO<sub>2</sub>max levels. Research indicates that high-intensity exercise performed over a 5-week period can significantly increase VO<sub>2</sub>max [28], and sessions lasting 30 minutes have shown notable improvements in VO<sub>2</sub>max [29]. This effect is due to the activation of the sympathetic nervous system during high-intensity exercise, which regulates muscle contractions and neuromuscular efficiency [30]. Such activation leads to an increase in heart volume and efficiency, enhancing plasma volume and myocardial contractility, which in turn lowers resting heart rate (HR) [31]. Additionally, improved musculoskeletal efficiency allows for more effective oxygen utilization, contributing to increased VO<sub>2</sub>max and overall fitness [32].

High-intensity exercise can increase the production of free radicals and potentially cause muscle damage. Muscle damage may result from inflammation triggered by oxidative stress [33], which can lead to mitochondrial membrane damage and a decrease in mitochondrial biogenesis [34]. Recent studies have suggested that low-to moderate-intensity exercise can also induce oxidative stress, highlighting that both exercise volume and a weakened antioxidant defense system are key contributors to exercise-induced oxidative stress [35]. This finding contrasts with earlier research suggesting that high-intensity

**Table 3.** Results of the physical fitness analysis for each group

Parameters	Group	n	Mean±Std. Deviation	p-value	Effect Size
Pre-VO <sub>2</sub> max (mL/kg/min)	K <sub>1</sub>	12	37.86±1.61	0.838	0.083
	K <sub>2</sub>	13	37.70±2.19		
Post-VO <sub>2</sub> max (mL/kg/min)	K <sub>1</sub>	12	37.99±1.65	0.000	2.011
	K <sub>2</sub>	13	42.19±2.45 <sup>b</sup>		
Δ-VO <sub>2</sub> max (mL/kg/min)	K <sub>1</sub>	12	0.13±0.56	0.000	4.721
	K <sub>2</sub>	13	4.49±1.18 <sup>b</sup>		
Pre-Flexibility (cm)	K <sub>1</sub>	12	24.06±2.65	0.713	0.149
	K <sub>2</sub>	13	24.49±3.07		
Post-Flexibility (cm)	K <sub>1</sub>	12	25.04±3.35	0.329	0.401
	K <sub>2</sub>	13	26.31±2.97		
Δ-Flexibility (cm)	K <sub>1</sub>	12	0.98±2.16	0.219	0.525
	K <sub>2</sub>	13	1.82±0.66		
Pre-Strength (kg)	K <sub>1</sub>	12	123.08±4.98	0.935	0.031
	K <sub>2</sub>	13	122.85±9.03		
Post-Strength (kg)	K <sub>1</sub>	12	124.58±4.68	0.036	0.901
	K <sub>2</sub>	13	131.69±10.13 <sup>a</sup>		
Δ-Strength (kg)	K <sub>1</sub>	12	1.50±2.02	0.000	3.822
	K <sub>2</sub>	13	8.85±1.82 <sup>b</sup>		
Pre-Speed (s)	K <sub>1</sub>	12	4.64±0.21	0.915	0.042
	K <sub>2</sub>	13	4.65±0.26		
Post-Speed (s)	K <sub>1</sub>	12	4.62±0.21	0.028	0.942
	K <sub>2</sub>	13	4.44±0.17 <sup>a</sup>		
Δ-Speed (s)	K <sub>1</sub>	12	-0.02±0.05	0.001	1.699
	K <sub>2</sub>	13	-0.21±0.15 <sup>b</sup>		
Pre-Agility (s)	K <sub>1</sub>	12	16.91±0.30	0.323	0.411
	K <sub>2</sub>	13	17.01±0.17		
Post-Agility (s)	K <sub>1</sub>	12	16.93±0.29	0.001	1.468
	K <sub>2</sub>	13	16.45±0.36 <sup>b</sup>		
Δ-Agility (s)	K <sub>1</sub>	12	0.03±0.21	0.000	2.496
	K <sub>2</sub>	13	-0.56±0.26 <sup>b</sup>		

K<sub>1</sub>: Control group; K<sub>2</sub>: High-intensity workout group. <sup>a</sup>Significant difference in the control group ( $p \leq 0.05$ ).

<sup>b</sup>Significant difference in the control group ( $p \leq 0.001$ ). The p-value was evaluated using an independent samples t-test.

exercise might significantly reduce oxidative stress [36]. Other studies have demonstrated that regular exercise can enhance the body's antioxidant system, increase physiological resilience, and mitigate oxidative stress [37].

Our findings indicate that high-intensity training can reduce oxidative stress following exercise and enhance physical fitness, as evidenced by improvements in speed, agility, muscle strength, and VO<sub>2</sub>max. This effect is likely due to the adaptive nature of exercise, which stimulates muscle adaptation and increases antioxidant levels to counteract oxidative stress, thereby improving mitochondrial function [38].

This study has several limitations that should be

considered when interpreting the findings. First, the focus on adolescent males limits the generalizability of the results to other age groups and genders. Physiological responses to high-intensity training may differ due to hormonal fluctuations, muscle composition, and metabolic rates, which were not accounted for in this study. Future research should include a more diverse sample to determine whether similar adaptations occur across different populations.

Additionally, this study primarily assessed physical fitness components (strength, speed, agility, VO<sub>2</sub>max, and flexibility) without incorporating biomolecular parameters, which limits the understanding of the underlying

physiological mechanisms. High-intensity training induces hormonal, mitochondrial, and oxidative stress adaptations, which were not measured in this study. Future research should integrate biochemical markers, such as oxidative stress indicators and inflammatory cytokines, to provide a more comprehensive perspective on these physiological effects.

Another limitation is the lack of flexibility improvement, which may be due to the training regimen emphasizing strength and endurance over joint mobility. Incorporating dynamic stretching or mobility-focused exercises in future protocols may address this gap.

Moreover, external factors such as nutrition, recovery strategies, and prior fitness levels were not strictly controlled, potentially introducing variability in the results. Future studies should implement more rigorous controls on these variables to enhance the validity and applicability of the findings.

## Conclusions

The results of this study demonstrate that high-intensity workouts conducted over 10 weeks significantly improved key physical fitness components, including VO<sub>2</sub>max, strength, speed, and agility, compared to the control group. These

findings suggest that structured high-intensity training can be an effective strategy for enhancing athletic performance in adolescent males, making it a potential recommendation for sports training programs and school-based physical education curricula. However, no significant improvement in flexibility was observed in the high-intensity workout group compared to the control group. This outcome may be attributed to the nature of high-intensity exercises, which primarily target cardiovascular endurance and muscular strength rather than flexibility. Additionally, the training regimen used in this study did not incorporate specific flexibility-enhancing exercises, such as static or dynamic stretching routines. Future research should explore whether integrating flexibility-focused exercises into high-intensity training protocols could lead to more comprehensive fitness benefits.

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## Conflict of Interest

The authors declare that they have no conflicts of interest regarding this study.

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