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Research Article

Exploring the Effects of High-Intensity Interval Training on Cardiovascular Fitness Among Senior High School Athletes in Ghana

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Abstract

This study investigated the effect of high-intensity interval training (HIIT) on cardiovascular fitness (CF) among senior high school athletes in Ghana, using VO_2max as the primary outcome measure, and compared it with a steady-state cardio program (SSCP). A total of 42 student-athletes were randomly assigned to either the HIIT or SSCP group. A mixed-design ANOVA revealed a significant group effect on VO_2max, F (1, 40) = 12.77, p = .001, η^2 = .24, indicating greater improvement in the HIIT group. An independent samples t-test showed that post-test VO_2max scores were significantly higher for the HIIT group than for the SSCP group, t (40) = *7.70, p < .001,* 95% CI [1.05, 1.80], with a mean difference of 1.43. Multiple regression analysis further showed that group membership significantly predicted post-test VO_2max scores, B = 1.43, t (40) = 9.75, p < .001, η^2 = .71, controlling for 70.9 % of the variance. The findings support the conclusion that HIIT is more effective than SSCP in improving cardiovascular fitness among senior high school athletes in Ghana. This finding suggests that HIIT may be a time-efficient and impactful training strategy for student-athletes seeking to improve aerobic capacity and overall cardiovascular performance. The study provides practical implications for coaches, physical education instructors, and sports performance professionals by demonstrating that shorter, more intense training sessions can yield superior fitness gains compared to traditional steady-state methods. These results support the integration of HIIT into school-based athletic conditioning programmes, especially in contexts where training time, resources, and facilities are limited. Further research is recommended to examine long-term adaptations, sport-specific performance outcomes, and the applicability of HIIT across different age groups and athletic populations in Ghana.

Keywords

High-intensity Interval Training, VO_2max, Cardiovascular Fitness, Aerobic Fitness, Student Athletes, Ghana

1. Introduction

1.1. Background to the Study

Cardiovascular fitness, also known as aerobic fitness, plays a central role in promoting health and overall well-being [1, 2]. It refers to the efficiency of the heart, lungs, and blood vessels in delivering oxygen to working muscles during sustained physical activity and is influenced by several physiological factors such as heart rate, cardiac output, stroke volume, and

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maximal oxygen consumption [3]. Key indicators of cardiovascular fitness include VO_2max, resting heart rate, and blood pressure. High levels of cardiovascular fitness are associated with a reduced risk of cardiovascular disease, improved metabolic health, and better quality of life [4, 5].

In pursuit of optimal cardiovascular performance among athletes, various training methods have been developed and refined by exercise physiologists and coaches across elite sport environments. These include High-Intensity Interval Training (HIIT), initially formalized by researchers such as Professor Véronique Billat in France; Sprint Interval Training (SIT), advanced through laboratory work by Burgomaster and Gibala at McMaster University in Canada; and Fartlek training, which originated in Sweden and was developed by Gösta Holmér for cross-country runners. These methods have been widely documented to enhance VO_2max and aerobic capacity in different athletic populations [6-8]. However, HIIT has emerged as one of the most efficient and increasingly studied approaches for improving cardiovascular performance [9].

HIIT consists of repeated bouts of short, vigorous activity performed at a high workload (often exceeding 90% of VO_2max), interspersed with rest or low-intensity periods [7]. his training model differs from traditional steady-state aerobic exercise in that it allows for significant physiological adaptations in a shorter timeframe. HIIT has gained global attention for its time efficiency and ability to improve cardiovascular health, particularly among individuals with limited training time [9-11].

Research shows that HIIT can improve VO_2max, lower resting heart rate, and reduce blood pressure in both athletic and general populations [14, 13]. These improvements are particularly beneficial for athletes who require short bursts of intense effort followed by rest, such as sprinters and relay runners [15]. Additionally, studies confirm that HIIT induces rapid cardiovascular changes, making it a suitable method even for younger athletes with limited training time [17, 16].

1.2. Problem Statement

Despite its growing popularity and robust evidence base, most HIIT research has been conducted in high-income countries such as Canada, Australia, and the United States [17-19]. Recent reviews have highlighted this research imbalance and emphasized the need for more studies in low- and middle-income contexts [20]. A notable gap remains in understanding the application of HIIT among adolescent athletes in sub-Saharan Africa, including Ghana. In Ghanaian schools, athletic training is largely dominated by traditional endurance-based approaches such as long-distance running and moderate-intensity aerobic exercise. This trend reflects limited access to structured, evidence-informed conditioning protocols that are more commonly implemented in higher-resource environments [20].

Observations at Wamanafo Senior High Technical School (WSHTS) located in the Dormaa East District of the Bono Region in Ghana indicated that many student-athletes rely primarily on low to moderate-intensity running for training. While this method offers general aerobic benefits, it may not be the most effective approach for improving cardiovascular fitness, as it lacks the intensity needed to elicit optimal physiological adaptations such as increased VO_2max and improved cardiac efficiency [7, 21].

While global literature supports HIIT as a powerful training tool, the evidence is inconsistent due to varying protocols, intensities, and work-to-rest ratios used in different studies [24, 23]. Furthermore, little is known about its long-term effects and safety in younger populations. These uncertainties make it crucial to investigate how HIIT performs in specific populations under real-life training conditions.

To date, there is limited evidence regarding the use and impact of HIIT among high school athletes in Ghana. As a physical education teacher, and upon consultation with colleague physical education teachers who doubled as sports coaches, the researcher observed that HIIT is barely used during preparation for inter-school sports competitions in Ghana.

1.3. Purpose of the Study

This study, therefore, seeks to address this knowledge gap by examining the effects of HIIT on cardiovascular fitness among student-athletes at WSHTS. By comparing HIIT with traditional training methods, this study aims to provide relevant insights for coaches, physical education teachers, and sports scientists to enhance training strategies in school settings.

1.4. The specific objectives of the study are to:

1) Investigate the effect of high-intensity interval training (HIIT) on cardiovascular fitness levels in adolescent athletes.
2) Compare the effectiveness of HIIT and traditional steady-state cardio in improving cardiovascular fitness indicators, such as VO_2max, resting heart rate, and blood pressure.

1.5. Research Questions

1) How does HIIT affect cardiovascular fitness levels in athletes?
2) How does the effectiveness of HIIT in improving cardiovascular fitness compare to that of steady-state cardio?

1.6. Hypothesis

It was hypothesized that HIIT would significantly improve cardiovascular fitness compared to a control group engaging in traditional steady-state cardio.

1.7. Significance of the Study

Ultimately, findings of this research may help highlight HIIT as a practical, time-efficient option for improving cardiovascular fitness, particularly in resource-constrained environments. Findings may also contribute to the broader conversation about evidence-based training practices in youth sports, grounded in the realities of local contexts.

2. Materials and Methods

2.1. Study Design

A randomized controlled trial (RCT) design was used in this study [24]. The RCT is a scientific experiment used in healthcare and social sciences to evaluate the effectiveness of an intervention [24]. The use of RCT in this study involved randomly assigning participants to an intervention group and a control group with an aim to minimize bias and confounding factors, allowing the researcher to isolate the effect of the intervention on the outcome by blinding and allocation concealment. A researcher who was not involved in the experimental process randomly assigned participants to either the experimental group (HIIT) or the control group (MICT), using a computer-generated algorithm to ensure equal probability of assignment.

Both groups underwent their respective training programs over four weeks at WSHTS, located in the Dormaa East District of the Bono Region, Ghana. Health-related variables such as resting heart rate, blood pressure, and VO2 max were measured before and after the intervention for between-group and within-group comparisons. Weekly checks were also done to observe progressive responses. Participants were asked to maintain their normal diet and routine activities throughout the study to minimize potential confounding effects, as changes in diet or additional physical activity could independently influence cardiovascular fitness outcomes. This approach ensures that observed changes in VO_2max, heart rate, and blood pressure can be attributed primarily to the HIIT intervention, thereby enhancing the internal validity of the study [13].

2.2. Participants

Approval from the WSHTS headmaster was obtained for the recruitment of student-athletes for this study. Participants were competitive athletes aged 15 to 22 years from Wamanafo Senior High Technical School (WSHTS). Eligibility criteria included being in good health, having no cardiovascular or musculoskeletal conditions that would interfere with participation, and willingness to complete the entire training period.

Eligibility was confirmed using the Physical Activity Readiness Questionnaire (PAR-Q) and a medical history questionnaire, both standard tools for screening prior to physical activity [13]. A total of 44 volunteer athletes (22 males and 22 females) were purposively selected to ensure equal representation of both genders for balanced comparison. This purposive sampling approach was adopted to support equal representation in the intervention and control groups and to reduce potential gender bias in the analysis of cardiovascular fitness outcomes. Participants were then randomly assigned to the respective intervention groups using simple random techniques. All 44 volunteer athletes participated in the screening process after they were well briefed on the objective of the study, its expectations and given full consent to participate in the study. Parental consents for the participation of the athletes who were below 18 years of age were obtained.

During the four-week program, two participants from each group (HIIT and control) withdrew due to personal reasons, resulting in a final sample of 42 athletes, equally divided by sex. The 9% dropout rate remained within acceptable limits for exercise intervention research [20]. The final sample size aligns with prior HIIT studies involving adolescents [11, 25].

The study followed ethical principles that ensured voluntary participation and confidentiality. Any health conditions that posed risks with high-intensity activity were identified and addressed using the PAR-Q and medical history screening.

2.3. Training Protocol

The HIIT group trained three days per week for four weeks. The training was non-residential, as all participants continued with their regular school routines, which maintained ecological validity and reflected a realistic school-based training environment. Sessions were spaced 48 hours apart to minimize fatigue. The sessions were supervised by a sports science graduate and a physical education teacher experienced in HIIT delivery. The supervisors were purposefully selected to ensure the intervention was delivered with both scientific accuracy and pedagogical appropriateness. The sports science graduate provided expertise in exercise prescription, physiological monitoring, and adherence to training intensity, while the physical education teacher contributed practical experience in working with adolescent athletes and managing school-based sessions. This combination maximized participant safety, training effectiveness, and ecological validity.

2.3.1. Warm-up Procedures

Each session began with a 5-minute warm-up and ended with a 5-minute cool-down. The warm-up comprised light aerobic activities including jogging, dynamic stretching (e.g., leg swings, arm circles), and mobility drills targeting major joints to elevate heart rate, increase blood flow to working muscles, enhance joint range of motion, and prepare the neuromuscular system for high-intensity exercise.

2.3.2. HIIT Main Session

The HIIT group completed structured high-intensity interval sessions three times per week for four weeks. Each session consisted of whole-body movements performed at vigorous intensity, with prescribed work–rest intervals that progressively increased in volume and intensity across the four weeks. In Week 1, participants performed six movements for three repetitions each, with 15 seconds rest between repetitions. This progressed to eight movements in Week 2 with 12 seconds rest, eight movements for four repetitions in Week 3 with 10 seconds rest, and ten movements for four repetitions in Week 4 with 10 seconds' rest. Sessions were supervised to ensure proper technique, adherence to intensity, and safe execution of all movements.

2.3.3. Cool-Procedure

The cool-down involved slow jogging or walking, followed by static stretching of the major muscle groups (e.g., quadriceps, hamstrings, calves, shoulders), aiming to gradually reduce heart rate, facilitate metabolic recovery, improve flexibility, and minimize post-exercise muscle soreness.

2.3.4. Control Group Procedure

The control group performed steady-state cardiovascular exercises such as jogging and aerobic routines at a moderate intensity, three times weekly for four weeks. Each session lasted about 30 minutes. Although described as moderate, the intensity level was not quantified using objective metrics such as heart rate or RPE; however, it followed the usual training structure during non-competitive periods in schools.

Table 1. *Training Regimen for the Study.*

WEEK	FREQUENCY	WARM-UP	MAIN SESSION	COOL-DOWN
Week 1 Introduction phase	3 sessions per week	5 minutes	6 movements x 3 repetitions each Rest: 15 seconds	5 minutes
Week 2 (Progression Phase)	3 sessions per week	5 minutes	8 movements x 3 repetitions each Rest: 12 seconds	5 minutes
Week 3 (Intensity Phase)	3 sessions per week	5 minutes	8 movements x 4 repetitions each Rest: 10 seconds	5 minutes
Week 4 (Peak Phase)	3 sessions per week	5 minutes	10 movements x 4 repetitions each Rest: 10 seconds	5 minutes

Source: Adapted from Savikj et al. (2019)

2.4. Measurements

Baseline measurements were taken at least three days before the intervention and repeated after the final session. Participants fasted for at least eight hours and refrained from vigorous physical activity for 48 hours before testing. Compliance was monitored through verbal confirmation and adherence checks by the supervising researchers, who reminded participants of the pre-test guidelines during scheduled briefings and the evening before assessments. Boarding school setting also allowed for closer observation and control of activity patterns. Tests were conducted between 8:00 a.m. and 10:00 a.m., following the same sequence for both pre- and post-tests. Weekly tests were also conducted among the HIIT group on the rest days following training.

2.4.1. Cardiorespiratory Fitness

Cardiorespiratory fitness was estimated using the Queen's College Step Test (QCST), a validated tool for estimating VO_2max [24, 22]. Participants stepped on a 41.25 cm high platform at 24 steps/min (males) or 22 steps/min (females), guided by a metronome. The rhythm "up-up-down-down" was maintained for 3 minutes. Heart rate was measured immediately after with a Polar Electro monitor and used to estimate VO_2max:

1) *Males:* VO_2max (ml/kg/min) = $111.33 - (0.42 \times HR)$
2) *Females:* VO_2max (ml/kg/min) = $65.81 - (0.1847 \times HR)$

Cadence consistency was aided by the metronome, but there was no direct mechanism to ensure strict adherence to rhythm beyond observation.

2.4.2. Resting Heart Rate and Blood Pressure

These were recorded in the morning after 5 minutes of rest. Heart rate was taken using a validated Polar monitor, and blood pressure was measured using a calibrated sphygmomanometer, following standardized guidelines [11]. Two readings, taken two minutes apart, were averaged for analysis.

Table 2. Pre and Post-Test Readings of Cardiovascular Measures by Group.

Group	Time	Measure	Reading 1	Reading 2	Average
HIIT	Pre-test	Resting Heart Rate (bpm)	84.0	83.0	83.5
	Pre-test	Systolic BP (mmHg)	130.0	128.2	129.1
	Pre-test	Diastolic BP (mmHg)	85.4	84.0	84.7
	Post-test	Resting Heart Rate (bpm)	68.9	67.3	68.1
	Post-test	Systolic BP (mmHg)	112.9	111.1	112.0
	Post-test	Diastolic BP (mmHg)	73.0	71.6	72.3
Control	Pre-test	Resting Heart Rate (bpm)	85.2	84.5	84.8
	Pre-test	Systolic BP (mmHg)	132.5	131.0	131.8
	Pre-test	Diastolic BP (mmHg)	86.3	85.0	85.7
	Post-test	Resting Heart Rate (bpm)	83.0	82.0	82.5
	Post-test	Systolic BP (mmHg)	130.0	128.5	129.2
	Post-test	Diastolic BP (mmHg)	84.0	82.5	83.2

Note: Two readings were taken two minutes apart for each cardiovascular variable and averaged for analysis. BP = Blood Pressure; bpm = beats per minute.

2.5. Data Analysis

All analyses were performed using International Business Machines Corporation (IBM) Statistical Package for the Social Sciences (SPSS) Statistics for Windows, Version 26.0. An independent samples t-test assessed baseline differences. A one-way repeated measures ANOVA with Bonferroni post-hoc tests evaluated changes across weeks. To assess the overall effects of the intervention on resting heart rate, VO2max, and blood pressure (systolic and diastolic), a two-way mixed ANOVA was used, examining time (pre- vs. post-test), group (HIIT vs. control), and their interaction. Partial eta-squared (ηp^2) was calculated to estimate effect sizes: small (.01), medium (.06), large (.14), and very large (2.0). Results were presented as means ± standard deviations, with significance set at $p < .05$.

3. Results

Table 3. Pairwise Comparisons.

Measure: VO2max						
(I) week	(J) week	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-4.048*	.288	.000	-4.892	-3.203

Measure: VO2max						
(I) week	(J) week	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
	3	-10.095*	.441	.000	-11.387	-8.803
	4	-17.000*	.594	.000	-18.738	-15.262
	1	4.048*	.288	.000	3.203	4.892
2	3	-6.048*	.271	.000	-6.842	-5.253
	4	-12.952*	.455	.000	-14.284	-11.621
	1	10.095*	.441	.000	8.803	11.387
3	2	6.048*	.271	.000	5.253	6.842
	4	-6.905*	.238	.000	-7.602	-6.208
	1	17.000*	.594	.000	15.262	18.738
4	2	12.952*	.455	.000	11.621	14.284
	3	6.905*	.238	.000	6.208	7.602

Source: fieldwork (2024)

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

A Bonferroni-adjusted pairwise comparison (Table 3) revealed progressive increases in VO_2max across all four weeks of the HIIT intervention. From Week 1 to Week 2, VO_2max improved by 4.05 ml/kg/min (95% CI [3.20, 4.89], $p < .001$). This improvement continued from Week 2 to Week 3 with a mean gain of 6.05 ml/kg/min ($p < .001$), and further from Week 3 to Week 4 with an additional increase of 6.91 ml/kg/min ($p < .001$). Altogether, the participants' aerobic capacity improved by approximately 17 ml/kg/min over four weeks, indicating a robust and continuous enhancement in cardiovascular fitness.

Table 4*. Pairwise Comparisons.*

Measure: Resting Heart Rate						
(I) week	(J) week	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
	2	3.286*	.286	.000	2.449	4.122
1	3	9.238*	.539	.000	7.662	10.814
	4	15.381*	.812	.000	13.004	17.758
	1	-3.286*	.286	.000	-4.122	-2.449
2	3	5.952*	.362	.000	4.894	7.011
	4	12.095*	.679	.000	10.107	14.084
3	1	-9.238*	.539	.000	-10.814	-7.662
	2	-5.952*	.362	.000	-7.011	-4.894

Measure: Resting Heart Rate						
(I) week	(J) week	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
	4	6.143*	.480	.000	4.739	7.546
4	1	-15.381*	.812	.000	-17.758	-13.004
	2	-12.095*	.679	.000	-14.084	-10.107
	3	-6.143*	.480	.000	-7.546	-4.739

Source: fieldwork (2024)

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Table 4 shows the week-to-week differences in resting heart rate. There was a consistent reduction over the four weeks. Resting heart rate decreased by:

1) 3.29 bpm from Week 1 to Week 2,
2) 9.24 bpm from Week 1 to Week 3, and
3) 15.38 bpm from Week 1 to Week 4 (*all* $p < .001$).

The drop was most pronounced in the final week. Each change between weeks was statistically significant, demonstrating a strong inverse relationship between weeks of HIIT participation and resting heart rate. This implies that prolonged participation in HIIT led to progressive cardiovascular adaptation, as evidenced by the consistent reduction in resting heart rate across the intervention period.

Table 5. *Pairwise Comparisons.*

Measure: Blood Pressure Systolic						
(I) week	(J) week	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
	2	3.810*	.321	.000	2.870	4.749
1	3	9.714*	.908	.000	7.056	12.372
	4	17.095*	.870	.000	14.549	19.641
	1	-3.810*	.321	.000	-4.749	-2.870
2	3	5.905*	.793	.000	3.585	8.225
	4	13.286*	.708	.000	11.215	15.357
	1	-9.714*	.908	.000	-12.372	-7.056
3	2	-5.905*	.793	.000	-8.225	-3.585
	4	7.381*	.630	.000	5.535	9.226
	1	-17.095*	.870	.000	-19.641	-14.549
4	2	-13.286*	.708	.000	-15.357	-11.215
	3	-7.381*	.630	.000	-9.226	-5.535

Source: fieldwork (2024) Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Table 6. Pairwise Comparisons.

Measure: Blood Pressure Diastolic						
(I) week	(J) week	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
	2	3.100*	.289	.000	2.248	3.952
1	3	7.500*	.478	.000	6.091	8.909
	4	12.400*	.716	.000	10.292	14.508
	1	-3.100*	.289	.000	-3.952	-2.248
2	3	4.400*	.311	.000	3.484	5.316
	4	9.300*	.548	.000	7.686	10.914
	1	-7.500*	.478	.000	-8.909	-6.091
3	2	-4.400*	.311	.000	-5.316	-3.484
	4	4.900*	.369	.000	3.813	5.987
	1	-12.400*	.716	.000	-14.508	-10.292
4	2	-9.300*	.548	.000	-10.914	-7.686
	3	-4.900*	.369	.000	-5.987	-3.813

Source: fieldwork (2024)

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Similar to systolic pressure, Table 6 shows that diastolic pressure declined over time. The total decrease from Week 1 to Week 4 was 12.40 mmHg ($p < .001$), with notable changes each week. Week-to-week reductions ranged from 3.10 mmHg to 4.90 mmHg, confirming HIIT's substantial influence on resting blood pressure. This means that regular engagement in HIIT elicited progressive improvements in diastolic blood pressure regulation, supporting its efficacy in enhancing cardiovascular health and reducing diastolic load on the heart at rest.

Table 7. Research Question 1: How does high-intensity interval training (HIIT) affect cardiovascular fitness levels in athletes?

Tests of Between-Subjects Effects for VO2max						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	466.714	1	466.714	556.085	.000	.933
Group	10.714	1	10.714	12.766	.001	.242
Error	33.571	40	.839			

Source: fieldwork (2024)

A mixed-design ANOVA was used to test the main effect of group (HIIT vs. control) on VO_2max (Table 7). There was a statistically significant difference between groups:

$F(1, 40) = 12.77$, $p = .001$, $\eta^2 = .242$, indicating that group assignment accounted for 24.2% of the variance in VO_2max. The HIIT group showed a much greater increase in aerobic fitness compared to the control group.

Research Question 2: How does the effectiveness of high-intensity interval training (HIIT) in improving cardio-vascular fitness compare to that of steady-state cardio?

Table 8. Independent Samples t-Test Comparing Post-Test VO2max Scores Between HIIT and Steady-State Cardio Groups.

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Totalposttest_VO2	Equal variances assumed	9.580	.004	7.695	40	.000	1.42857	.18565	1.05335	1.80379
	Equal variances not assumed			7.695	32.670	.000	1.42857	.18565	1.05071	1.80643

Source: fieldwork (2024)

An independent samples t-test compared post-test VO_2max scores between the HIIT and steady-state groups (Table 8). Results showed that:

1) $T\,(40) = 7.70$, $p < .001$ (equal variances assumed),
2) Mean difference = 1.43 ml/kg/min (95% CI [1.05, 1.80]).

This indicates that athletes in the HIIT group achieved significantly higher aerobic capacity than those who underwent moderate-intensity training. Levene's test confirmed inequality of variance ($F = 9.58$, $p = .004$), but both equal and unequal variance analyses produced consistent results.

Hypothesis 1: HIIT will significantly improve cardiovascular fitness compared to a control group engaging in traditional steady-state cardio.

Table 9. Parameter Estimates for Total Post-Test VO2max.

Parameter	B	Std. Error	T	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	-.014	.270	-.053	.958	-.561	.532	.000
Totalpretest_VO2	.453	.090	5.018	.000	.271	.636	.392
[Group=1]	1.429	.147	9.747	.000	1.132	1.725	.709
[Group=2]	0[a]	.	.	.	.	.	.

Source: fieldwork (2024)

a. This parameter is set to zero because it is redundant.

To further assess the influence of group membership and pre-intervention VO_2max on post-intervention outcomes, a multiple regression analysis was conducted (Table 9). Findings were as follows:

Pre-test VO_2max was a significant predictor of post-test VO_2max:

$$B = 0.453,\ t\,(40) = 5.02,\ p < .001,\ \eta^2 = .392.$$

Group membership had a strong predictive effect:

$$B = 1.429,\ t\,(40) = 9.75,\ p < .001,\ \eta^2 = .709.$$

This suggests that being in the HIIT group led to an average increase of 1.43 ml/kg/min in VO_2max compared to the control group, after controlling for baseline fitness. The large effect size (71% of variance explained) confirms the strong efficacy of HIIT on improving cardiovascular fitness.

3.1. Discussion

This study evaluated the impact of a four-week high-intensity interval training (HIIT) programme on cardiovascular fitness (CF) and associated markers among young athletes. The findings of the study are reveling in that there have been some significant relationships between the variables being observed.

3.1.1. VO_2max and Aerobic Capacity

Consistent with prior studies [8, 14], the present findings showed a significant increase in VO_2max among the HIIT group, both within-group over time and between groups at post-test. The effect size was large, suggesting the training intervention had a substantial impact. Physiologically, these improvements are likely the result of adaptations such as enhanced stroke volume, increased capillary density, and mitochondrial biogenesis [23].

Notably, progressive increases in VO_2max were observed week by week, underscoring the cumulative benefit of repeated high-intensity efforts over a short period. These improvements are particularly valuable for athletes who require efficient methods to enhance aerobic performance within tight training cycles.

3.1.2. Comparison with Steady-State Cardio

When compared to moderate-intensity continuous training (MICT), HIIT demonstrated superior outcomes in improving cardiovascular fitness. The observed difference in post-test VO_2max scores between the HIIT and control groups aligns with existing evidence that HIIT induces faster and more pronounced cardiovascular adaptations than steady-state or moderate-intensity cardio [25]. The intermittent nature of HIIT, which alternates periods of high-intensity exertion with recovery phases, allows participants to repeatedly reach near-maximal oxygen uptake. This repeated stimulation of the cardiovascular system promotes enhanced cardiac output, stroke volume, and oxygen extraction at the muscular level, which collectively contribute to improved aerobic capacity.

In contrast, steady-state cardio, performed at a constant moderate intensity, typically maintains heart rate within 50–70% of VO_2max and does not provide the same degree of peak cardiovascular strain. While MICT can improve endurance and cardiovascular health over longer durations, the intensity limitation may result in slower physiological adaptations, particularly in well-trained or moderately active populations.

Furthermore, the time-efficient nature of HIIT allows athletes to achieve substantial improvements in cardiovascular fitness within a shorter training period compared to continuous training. This is particularly relevant in school-based or resource-constrained settings, where scheduling constraints and limited access to training facilities may restrict total exercise volume. In this context, HIIT provides a practical, scalable, and evidence-based alternative for promoting aerobic fitness among adolescent athletes, supporting both performance enhancement and overall health benefits.

HIIT's effectiveness is largely attributed to its structure, which alternates periods of intense activity with intervals of rest or low-intensity recovery. This intermittent format permits participants to sustain higher overall intensities during training sessions than would be tolerable during continuous exercise. As a result, HIIT imposes a greater cardiovascular and metabolic challenge, promoting improved oxygen delivery and utilization, increased stroke volume, enhanced mitochondrial biogenesis, and improved endothelial function within a relatively shorter time frame.

The results revealed significant week-to-week reductions in both resting heart rate and diastolic blood pressure throughout the four-week HIIT program. The most pronounced drop-in resting heart rate occurred in the final week, reflecting a consistent inverse relationship between training duration and heart rate. Similarly, diastolic pressure declined steadily, with a total decrease of 12.40 mmHg from Week 1 to Week 4, underscoring the substantial effect of HIIT on blood pressure regulation. These patterns collectively suggest that short-term HIIT can bring about meaningful cardiovascular improvements in a relatively brief timeframe.

3.1.3. Predictive Role of Pre-Training Fitness and Group Membership

Regression analysis further revealed that both pre-test VO_2max and group membership were significant predictors of post-test aerobic capacity. The analysis indicated that group membership alone explained over 70 percent of the variance in post-test VO_2max. This highlights the strong influence of the HIIT protocol on cardiovascular adaptation. Individuals assigned to the HIIT intervention achieved significantly better outcomes than those in other groups, regardless of their starting fitness levels. The substantial variance accounted for by group assignment underscores how critical the training modality is in determining training outcomes.

These findings support existing evidence that HIIT is not only time-efficient but also effective across a wide range of fitness levels. The structured alternation between high-intensity effort and recovery promotes robust physiological responses even in individuals with lower baseline capacity. Studies have consistently shown that HIIT leads to superior improvements in VO_2max compared to traditional moderate-intensity training, and this benefit is evident across different populations, including sedentary, overweight, and moderately trained individuals.

It can therefore be concluded that while pre-training fitness remains a relevant factor in determining exercise outcomes, the nature and quality of the training intervention play a more decisive role. The results of this study reinforce the adaptability and efficacy of HIIT as a reliable strategy for improving cardiovascular health in diverse groups, irrespective of initial aerobic capacity.

3.1.4. Practical Implications for Coaches and Physical Educators

The findings of this study have important implications for coaches and physical educators working with adolescent athletes. Since HIIT was effective across all baseline fitness levels, practitioners can confidently incorporate structured high-intensity sessions into school-based programs to enhance cardiovascular fitness efficiently. The strong influence of training modality suggests that program design, exercise intensity, and adherence to structured intervals are more critical than starting fitness levels in determining outcomes. Coaches should therefore focus on ensuring that HIIT sessions are properly supervised, appropriately progressed, and consistently implemented to maximize physiological adaptations. Additionally, the time-efficient nature of HIIT allows for integration into busy school schedules without compromising academic or other extracurricular commitments, making it a practical and evidence-based approach for improving aerobic capacity in young athletes.

3.1.5. Cardiovascular Risk Markers

The reductions in resting heart rate and blood pressure observed in the HIIT group align with established physiological mechanisms involving improved autonomic balance and vascular function. These findings are consistent with the known benefits of high-intensity interval training on cardiovascular regulation. Specifically, HIIT has been shown to enhance parasympathetic tone while reducing sympathetic overactivity, resulting in improved heart rate variability and a lower resting heart rate [23, 22]. This autonomic modulation contributes to a more efficient cardiovascular system, particularly during periods of rest and recovery.

In addition to autonomic regulation, the observed decrease in systolic and diastolic blood pressure may be attributed to structural and functional adaptations within the vascular system. HIIT promotes endothelial function through increased shear stress during repeated high-intensity bouts, which stimulates nitric oxide production and leads to vasodilation. This process facilitates improved arterial compliance and reduced vascular resistance, both of which contribute to lower blood pressure over time [20]. These physiological adaptations have been widely documented in both athletic and clinical populations, suggesting the broad applicability of HIIT for cardiovascular health.

These outcomes have important implications not only for athletic performance but also for long-term health, as lower resting heart rate and blood pressure are associated with reduced cardiovascular risk. From a performance standpoint, a lower resting heart rate reflects improved cardiac efficiency and stroke volume, allowing athletes to perform at higher intensities with reduced cardiovascular strain. From a public health perspective, these markers serve as critical indicators of cardiovascular health, with long-term reductions linked to decreased incidence of hypertension, myocardial infarction, and stroke. The ability of HIIT to favorably alter these markers in a relatively short time frame reinforces its value as a time-efficient and clinically relevant intervention strategy.

3.2. Practical Implications

The evidence presented in this study strongly supports the integration of HIIT into athletic training programmes. The efficiency of HIIT makes it particularly suitable for preparatory phases, off-season conditioning, and other situations in which training time is constrained. Because HIIT sessions can produce substantial cardiovascular adaptations within a relatively short duration, coaches and exercise professionals can incorporate these workouts to target aerobic development without the extended time demands that are typical of traditional endurance training.

In addition to its time-saving advantage, HIIT offers considerable flexibility in design and implementation. The structure of HIIT, which typically involves alternating bouts of near-maximal effort with periods of active or passive recovery, allows practitioners to manipulate variables such as work-to-rest ratios, intensity, and exercise modality. This flexibility makes HIIT adaptable to athletes across a range of sporting disciplines and fitness levels. It also allows coaches to modify sessions to suit specific training cycles, match preparations, or rehabilitation needs.

The findings of this study demonstrate significant improvements in VO_2max, resting heart rate, and blood pressure among participants who completed the HIIT intervention. These physiological adaptations suggest that HIIT enhances both central and peripheral components of aerobic fitness. This includes improved cardiac output, greater stroke volume, enhanced muscle oxygen extraction, and increased metabolic efficiency. Such adaptations are essential for supporting repeated high-intensity efforts, improving tolerance to fatigue, and enhancing overall cardiovascular resilience during competition.

HIIT also has practical relevance in environments where athletes must balance multiple training components within a limited timeframe. For example, team sport athletes often require simultaneous development of strength, speed, and tactical skills. In such contexts, HIIT provides an efficient means of improving cardiovascular fitness without compromising time allocated to other essential training elements. This makes HIIT an effective option for schools, clubs, and resource-limited settings where training schedules are condensed and opportunities for long-duration sessions are restricted.

Furthermore, the demonstrated effectiveness of HIIT across varying baseline fitness levels indicates that the method is inclusive and suitable for diverse athletic populations. Coaches can confidently apply HIIT in mixed-ability groups, knowing that meaningful adaptations can occur regardless of initial aerobic capacity. This supports its use in youth settings where athletes often present with heterogeneous fitness profiles.

Given these advantages, the strategic integration of HIIT into regular training plans can optimise cardiovascular outcomes, improve training economy, and contribute to long-term athlete development. HIIT can therefore serve both performance-oriented and health-oriented goals, reinforcing its value as a multifaceted conditioning tool within contemporary sports training frameworks.

3.3. Conclusion

The results of this study demonstrated that HIIT led to significant improvements in aerobic capacity (VO_2max), reductions in resting heart rate, and decreases in both systolic and diastolic blood pressure. These findings support the growing body of evidence that HIIT is an effective, time-efficient training method for enhancing cardiovascular health in athletic populations. The study affirms that a structured four-week HIIT programme can yield significant improvements in cardiovascular fitness and health indicators among young athletes. The progressive enhancements in VO_2max and favorable changes in cardiovascular markers position HIIT as a potent, evidence-based training modality. Its practical benefits, efficiency, and adaptability make it a valuable tool for sports performance enhancement and health promotion.

3.4. Limitations and Directions for Future Research

While the findings are promising, generalizability is limited by the homogeneous sample of adolescent athletes. Future research should examine long-term retention of these adaptations, explore HIIT effects in non-athlete or clinical populations, and evaluate outcomes beyond VO_2max, such as metabolic health or muscular performance. Additionally, variations in HIIT protocol design (e.g., intensity, duration, modality) warrant further exploration to optimize intervention strategies.

Abbreviations

ANOVA	Analysis of Variance
BMI	Body Mass Index
BP	Blood Pressure
HIIT	High-Intensity Interval Training
HR	Heart Rate
IBM	International Business Machines Corporation
MICT	Moderate-Intensity Continuous Training
QCST	Queen's College Step Test
RHR	Resting Heart Rate
SPSS	Statistical Package for Social Sciences
VO_2max	Maximal Oxygen Uptake

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Author Contributions

Sarpong Emmanuel Osei is the sole author. The author read and approved the final manuscript.

Data Availability Statement

The Raw data for the study can be obtained from the corresponding author upon a reasonable request.

Conflicts of Interest

I declare that I have no competing interests to declare in this publication.

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