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Assessing the Effect of High Intensity Interval Training and Fast Continuous Training on Resting Heart Rate and VO_2 Max of Adult Athletes

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ABSTRACT

Cardiovascular fitness, measured through Resting Heart Rate (RHR) and Maximal Oxygen Uptake (VO_2 Max), is critical for optimizing athletic performance. High-Intensity Interval Training (HIIT) and Fast Continuous Training (FCT) are two aerobic conditioning modalities widely used to improve cardiovascular efficiency, but their comparative effects remain insufficiently studied in adult competitive athletes. This study aimed to compare the effects of an 8-week HIIT and FCT program on RHR and VO_2 Max in adult athletes, thereby evaluating the efficacy of each training modality in enhancing aerobic performance. A randomized controlled trial design was employed involving 90 adult athletes (45 males and 45 females, aged 21-26), randomly located into three groups: HIIT (n=30), FCT (n=30), and Control (n=30). RHR and VO_2 Max were assessed during pre- and post-intervention using Polar H10 monitors and Vmax Encore Metabolic Cart, respectively. Data were analysed using ANCOVA (Analysis of Covariance) to control for pre-test differences, followed by Tukey's post-hoc comparison. Post-intervention results revealed statistically significant improvements in both RHR and VO_2 Max across the training groups ($p < 0.05$). The HIIT group exhibited the most significant reduction in RHR (62.72 bpm) and the highest increase in VO_2 Max (52.12 ml/kg/min), outperforming both FCT (RHR = 65.06 bpm; VO_2 Max = 49.40 ml/kg/min) and the Control group (RHR = 70.32 bpm; VO_2 Max = 41.28 ml/kg/min). Effect sizes were large for both RHR ($\eta^2 = 0.950$) and VO_2 Max ($\eta^2 = 0.982$), indicating robust model fit. The findings confirm that both HIIT and FCT are effective in improving cardiovascular parameters among adult athletes, with HIIT demonstrating superior efficacy in a shorter duration. These results support the strategic incorporation of HIIT in training regimens aimed at maximizing aerobic performance and cardiovascular health.

Keywords: High-Intensity Interval Training; Fast Continuous Training; Resting Heart Rate; Maximal Oxygen Uptake; Cardiovascular Fitness; Adult Athletes; Aerobic Capacity; Athletic Performance; Cardiorespiratory Fitness; Training Intervention; Exercise Physiology.

1. Introduction

Cardiovascular fitness is essential for both improving athletic performance and preserving general health. Engaging in physical activity helps the body increase its supply of oxygen more efficiently by increasing the effectiveness of the heart, lungs, and blood vessels. Better energy use, faster recovery, and less tiredness are all supported by increasing cardiovascular endurance and are essential for successful sports performance. It also reduces the chance of developing lifestyle-related illnesses like diabetes mellitus, heart disease, and high blood pressure. Strong cardiovascular fitness benefits athletes by enhancing and sustaining performance. Overall, it is the cornerstone of both a healthy lifestyle and athletic excellence. Talking about cardiovascular fitness, maximum oxygen uptake or VO_2 Max, is commonly considered the golden standard for assessing an individual's aerobic capability. As a clear measure of cardio-respiratory fitness, it represents the maximum rate at which the body can take in and use oxygen during vigorous activity. Greater endurance and effective oxygen transport by the respiratory and circulatory systems are indicated by a higher VO_2 Max [3]. It is a crucial metric in evaluations of athletic performance since it is impacted by several variabilities, such as age, sex, training intensity, and heredity. Conversely, Resting Heart Rate (RHR) is a readily available and non-invasive indicator of cardiovascular efficiency. A well-conditioned heart that pumps more blood with fewer beats is frequently associated with a lower RHR. Consistent aerobic training, which increases stroke volume and develops heart muscles, usually causes this adaptation [12]. Training progress, recovery state, and even early indicators of overtraining or cardiovascular malfunctioning can all be gleaned via RHR monitoring. When combined, VO_2 max and RHR offer complete insight into an athlete's level of cardiovascular fitness. RHR shows how the body has adapted to long-term cardiovascular fitness, whereas VO_2 max represents peak aerobic potential [4].

Two well-known aerobic conditioning techniques that are frequently employed in sports and fitness are High-Intensity Interval Training (HIIT) and Fast Continuous Training (FCT). Both the anaerobic and aerobic energy systems are stimulated by HIIT, which consists of brief recovery intervals in between short bursts of intense activity [9]. It has grown popular because of its time-efficient metabolic function, VO_2 max, and cardiovascular health in both athletes and the general public. On the other hand, continuous, moderate-to-intense workouts done without a break are referred to as fast continuous training. FCT is frequently used to build foundational cardiovascular fitness and largely improves aerobic endurance [11]. Both techniques increase aerobic capacity, but because of its greater intensity and metabolic stress, HIIT frequently causes quicker physiological changes.

Fast Continuous Training (FCT) and High-Intensity Interval Training (HIIT) both aim to increase cardiovascular health and aerobic performance, but they accomplish this through distinct physiological processes. Both the aerobic and anaerobic systems are severely strained by HIIT, which is defined by repeated bursts of high-intensity activity separated by rest or low-intensity recovery. In addition to increasing stroke volume and improving oxygen uptake efficiency, this alternation promotes mitochondrial biogenesis, which accelerates cardiovascular adaptations and raises VO_2 max [2]. FCT, on the other hand, focuses mostly on the aerobic system and involves prolonged moderate-to-high intensity work without rest intervals. It progressively increases capillary density, cardiac output, and the body’s capacity to carry and use oxygen effectively over extended periods [8]. Stabilizing heart rate responses during exercise and increasing endurance are two areas in which this training approach excels. Thus, by studying the above paragraphs, we can say that FCT promotes long-term aerobic stability and endurance. At the same time, HIIT produces faster benefits in cardiovascular indicators like blood pressure and resting heart rate. Recent studies also support that both HIIT and FCT elicit favorable cardiovascular adaptations, with HIIT often leading to faster improvements in VO_2 Max and cardiac efficacy across diverse athletic and non-athletic populations [5]. These findings affirm the relevance of comparing these modalities in performance-oriented athletes.

2. Study Objectives

1. To compare the Resting Heart Rate (RHR) and VO_2 Max of Adult athletes before undergoing High-Intensity Interval Training (HIIT) and Fast Continuous Training (FCT).

2. To compare the Resting Heart Rate (RHR) and VO_2 Max of Adult athletes undergoing High-Intensity Interval Training (HIIT) and Fast Continuous Training (FCT) after an 8-week training program.

2.1. Significance of the study

Optimizing athletic performance requires an understanding of the effects that various training modalities have on important physiological markers. The purpose of the study is to evaluate how FCT and HIIT affect resting heart rate and VO_2 max, two crucial parameters of cardiovascular fitness and endurance capacity. Even though lots of comparative studies are being done between FCT and HIIT, there isn’t much comparison study of both the training methods on the two dependent variables, i.e., Resting Heart Rate and VO_2 max of adult athletes. The findings of this study will demonstrate how FCT and HIIT contribute to weekly performance gains, as well as the comparison of two different training modalities on RHR and VO_2 max. The results of this study aid in the creation of a customized training schedule focusing on adult athletes.

3. Methodology

3.1. Participants

The study employed a simple random sampling method to select a total of 90 subjects (45 males and 45 females) aged between 21 to 26 years from the national sports academies and training institutes.

Table 1. Inclusion and Exclusion Criteria for selecting subjects

Inclusion Criteria	Exclusion Criteria
Adult athletes are in their prime physiological stage.	Athletes have a history of metabolic, cardiovascular, and respiratory diseases.
Athletes actively engaged in competitions and have 1 year of training age.	Musculoskeletal disorders of injuries that prohibit athletes from engaging in Fast continuous, and High-intensity training.
Athletes have a normal baseline Resting Heart Rate between 50-90 bpm.	Using drugs that alter metabolism or heart rate.
Consent to abstain from other aerobic training regimens during the intervention period.	Smoking or substance abuse within the past 6 months can affect VO_2 max and RHR.

3.2. Variables

Following the aim of the study, the research selected two different types of training methods, i.e., High Intensity Interval Training (HIIT) and Fast Continuous Training (FCT), as independent variables to assess how two aerobic training methods affect cardiovascular fitness parameters differently. Resting Heart Rate (RHR), the number of heart beats per minute (bpm) while at complete rest, and Maximal Oxygen Uptake (VO_2 max), the rate of maximum oxygen consumption during exercise expressed in ml/kg/min, were selected as dependent variables.

3.3. Instruments

The Polar H10 (Chest Strap Type) heart rate monitor was used to measure the RHR, and the Vmax Encore Metabolic Cart was used to measure each subject's VO_2 max.

3.4. Research Design

The researcher used a randomized control trial method for the study. 90 subjects were divided into 3 groups (30 each), with 15 male and 15 female athletes in each group: Group A (High-Intensity Interval Training), Group B (Fast Continuous Training), and Group C (Control Group). Each group had a pre-test and a post-test (every week) of two different dependent variables (RHR and VO_2 max).

3.5. Training Intervention

The study employed three different training interventions, i.e., High Intensity Interval Training (HIIT), Fast Continuous Training (FCT), and Normal off-season training applied for 8 weeks. To avoid training overload, there were 4 sessions per week, where Group A (HIIT) was trained in the early morning from 6:00 am to 8:30 am. Group B (FCT) and Group C (Control Group) trained simultaneously in the evening from 4:00 pm to 6:30 pm. The training load (Intensity × Volume) increased gradually every week.

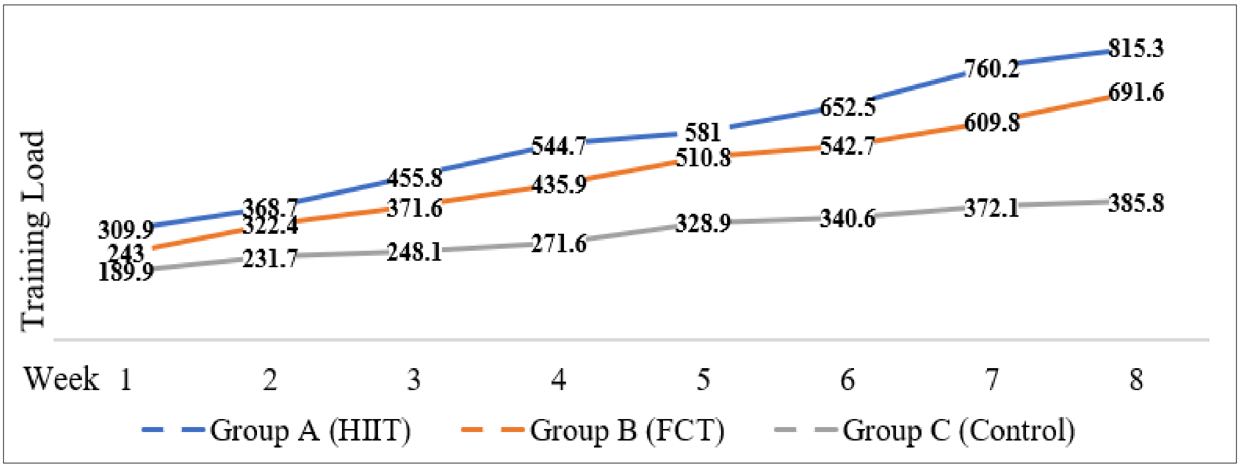

Figure 1. Graphical representation of week-wise Training Load of Groups A, B, and C-over an 8-week Training Program

3.6. Measurement of variables

Throughout every training session, the Polar H10 heart rate (HR) monitor was used to constantly track heart rate to guarantee adherence to the recommended intensity levels. Before starting the 8-week training program, a pre-test was conducted to measure the RHR and VO_2 max through a Polar H10 HR monitor and Vmax Encore Metabolic Cart, respectively. Post-tests were taken from all the subjects from the 3 groups, each at the end of the 8-week training program. To ensure measurement reliability, RHR readings using the Polar H10 device were taken in the early morning (6:30-7:00 AM) after 10 minutes of seated rest in a controlled environment. All participants were measured in a seated position to ensure consistency across all time points.

3.7. Statistical Analysis

The athletes' data were analyzed using SPSS version 27. The researcher first described the nature of the data of athletes' Resting Heart Rate (RHR) and Maximum Oxygen Uptake (VO_2 max) through descriptive statistics using Mean and Standard Deviation. To compare the effect of HIIT and FCT on RHR and VO_2 Max researcher used ANCOVA between the Week 8 post-test of athletes from Groups A, B, and C by considering the measures of pre-test as a covariate. If the results were statistically significant at a 5% significance level, Tukey’s (post-hoc) test will be used for a pairwise comparison between the three groups.

4. Results and Findings

4.1. Descriptive Statistics

To represent descriptive statistics of the data of athletes from Group-A (HIIT), Group-B (FCT), and Group-C (Control) on both the variables RHR and VO_2 max mean (M), the most reliable measure of central tendency, was used along with the standard deviation (SD) to identify the average amount of deviation of all the values from the mean.

Table 2. Mean (M) and Standard Deviation (SD) of Resting Heart Rate (RHR) and VO_2 Max of athletes of three different groups

Groups		**Group A (HIIT)**				**Group B (FCT)**				**Control C (Control)**			
		RHR		**VO_2 Max**		**RHR**		**VO_2 Test**		**RHR**		**VO_2 Max**	
	N	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Pre-Test	30	69.57	2.35	39.69	2.46	69.85	3.04	40.17	2.96	70.36	2.41	41.36	2.47
Post-Test	30	62.72	2.52	52.12	2.44	65.06	2.99	49.40	2.97	70.32	2.49	41.28	2.32

The descriptive statistics across the three groups based on the mean score reveal distinct trends in Resting Heart Rate (RHR) and VO_2 Max over the 8-week training program. Group B (FCT) demonstrated better cardiovascular efficiency with a drop in RHR from 69.85 bpm ± 3.04 at pre-test to 65.06 bpm ± 2.99 at post-test (week 8), and an improvement in VO_2 Max from 40.17 ml/kg/min ± 2.96 to 49.40 ml/kg/min ± 2.97. Group A (HIIT), on the other hand, showed a significant increase in VO_2 Max from 39.69 ml/kg/min ± 2.46 to 52.12 ml/kg/min ± 2.44 and a moderate decrease in RHR from 69.57 bpm ± 2.35 to 62.72 bpm ± 2.52. Group C (Control), undergoing a normal training schedule, displayed a very low VO_2 Max change (41.36 ± 2.47 to 41.28 ± 2.32) and rather steady RHR values (70.36 ± 2.41 to 70.32 ± 2.49).

4.2. Inferential Statistics

The researcher conducted an ANCOVA of the post-test measure of RHR of athletes undergoing HIIT, FCT, and Control to identify whether the differences are statistically significant or not. While controlling for the Pre-Test measures of these three groups.

Table 3. Test of Between-Subjects Effect for Interaction Between Group A, B, and C and Pre-Test (RHR)

Analysis of Covariance (ANCOVA)					
Group	Type III Sum of Squares	df	Mean Square	F-Statistics	Sig.
Pre-Test (RHR)	.868	2	.434	.984	.378

As the p-value of 0.378 is greater than the 0.05 significance level therefore we failed to reject the null hypothesis, and the outcomes are not statistically significant. This means that the grouping factor did not significantly interact with pre-test scores, and there are no discernible differences in RHR between the groups at the pre-test level. Therefore, all groups began at a similar baseline of RHR before the training program, as indicated by the statistical similarity of the pre-intervention Resting Heart Rate (RHR). As per the results shown in Table No. 9, we are in a position to run ANCOVA to assess whether the difference in the mean score of all three groups is statistically significant or not.

Table 4. ANCOVA Results for Post-Test RHR after considering Pre-Test measures as a Covariate

ANCOVA (Pre-Test as Covariate)						
Group	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Post-Test	726.03	2	363.01	823.44	.001	.950

R Squared = .975

By controlling the measures of pre-test, this table displays the findings of an ANCOVA for post-test RHR at Week 8. After adjusting for pre-test RHR, the ANCOVA results showed a highly significant difference between groups (F = 823.44, p <.001). A relatively significant effect size is shown by the partial eta squared value of 0.950, which suggests that group differences account for 95% of the variance in post-test RHR. Furthermore, a robust model fit is indicated by the R-squared value of 0.975, which shows that the training accounts for 97.5% of the variation in the RHR. These findings demonstrated that there is a statistically significant and notable improvement in the post-test measures of RHR across three different groups after the training programs

To identify which training method reduced the maximum Resting Heart Rate (RHR) of athletes from Groups A, B, and C., Tukey HSD post-hoc test comparing the three training groups was computer based on their Post-Test RHR at Week 8. The analysis reveals that HIIT significantly reduced RHR more than FCT, with a mean difference of -2.3453 (p =.003), indicating lower RHR in the HIIT group. Additionally, HIIT showed a highly significant difference from the Control group, with a mean difference of -7.6073 (p <.001), suggesting a much lower RHR. FCT also significantly differed from the control group, with a mean difference of -5.2620 (p <.001), showing FCT to be more effective than no training. All p-values were below 0.05, and none of the 95% confidence intervals included zero, confirming the statistical significance of each pairwise comparison. Overall, HIIT emerged as the most effective training method for reducing RHR, followed by FCT.

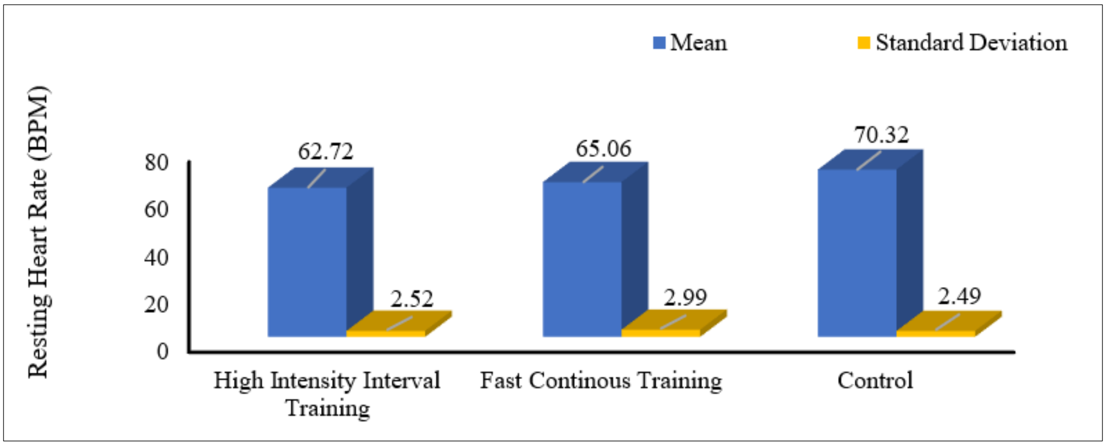

Figure 2. Mean and Standard Deviation of the Resting Heart Rate of athletes' post-test assigned to three different training programs

To assess whether all three groups: Group A (HIIT), Group B (FCT), Group C (Control) are similar in their pre-test measures of VO_2 Max, Analysis of Covariance (ANCOVA) was used at a 5% significance level

Table 5. Test of Between-Subjects Effect for Interaction Between Group A, B, and C for Pre-Test (VO_2 Max)

Analysis of Covariance (ANCOVA)					
Group*Pre-Test (VO_2 Max)	Type III Sum of Squares	df	Mean Square	F	Sig.
	.805	2	.402	.783	.461

At a 5% significance level (α = 0.05), the F-value of 0.783 and the associated p-value of 0.461 show that there is no statistically significant difference between the three groups' pre-test VO_2 Max scores of athletes undergoing their different training programs. Because the p-value is much higher than 0.05, it can be said that the group's aerobic capacities were statistically comparable before the 8-week training program, which validates the baseline equivalence and the experimental design.

Table 6. ANCOVA results showing group differences in Post-Test VO_2 Max measures after considering Pre-Test measures as covariates

ANCOVA (Pre-Test as Covariate)					
Group	Type III Sum of Squares	df	Mean Square	F	Sig
Post-Test	2290	2	1145.36	2238.65	.001

R Squared = .982

A statistically significant difference in the VO_2 Max post-test measures between the three groups is confirmed by the ANCOVA results, which use the pre-test as a covariate and display a very significant F-value of 2238.65 with a p-value of 0.001. This implies that by Week 8, the three different training programs had a significant effect on aerobic capacity, providing the efficacy of the training regimes. Additionally, A robust model fit is indicated by the R-squared value of 0.982, which shows that the training accounts for 98.2% of the variation in the VO_2 Max.

In a pairwise post-hoc comparison between the three training groups- HIIT, FCT, and Control- for the VO_2 Max Post-Test (Week 8), it was revealed that differences between all groups are statistically significant at the 0.05 level, as indicated by all p-values being less than .001. In particular, the HIIT group outperformed the control group (mean difference = 12.159) and the FCT group (mean difference = 2.91). Additionally, the FCT group did noticeably better than the control group (mean difference = 9.240). This indicates that HIIT was the most effective intervention, followed by FCT.

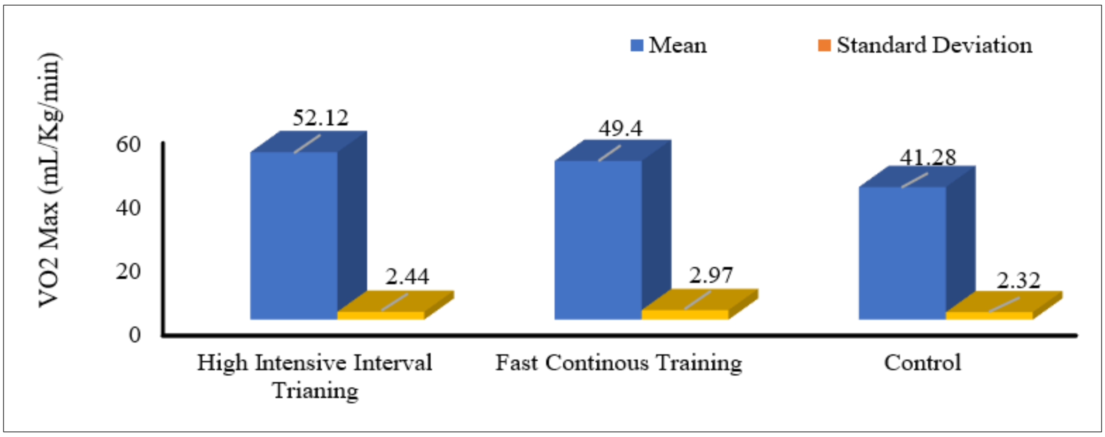

Figure 3. Mean and Standard Deviation of VO_2 Max of athletes' post-test assigned to three different training programs

5. Discussion

The study compared the effects of Fast Continuous Training (FCT) and High Intensity Interval Training (HIIT) on adult athletes' VO_2 Max and Resting Heart Rate (RHR). Based on the statistical analysis conducted in the study, both High-Intensity Interval Training (HIIT) and Fast Continuous Training (FCT) significantly enhanced cardiovascular parameters, with varying efficacy. ANCOVA results revealed that after 8 weeks, HIIT produced the most substantial improvement in VO_2 Max ($F = 2238.65$, $p < 0.001$) and the greatest reduction in Resting Heart

Rate (RHR) ($F = 823.44$, $p < 0.001$), with effect sizes indicating that 98.2% and 97.5% of the variances in VO_2 Max and RHR, respectively, were due to training. These results are consistent with other research showing that interval and aerobic training dramatically improve cardiac autonomic control, lowering RHR by increasing parasympathetic activity and stroke volume [4,5,13]. Post-hoc Tukey further confirmed that HIIT significantly outperformed both FCT and the Control group in reducing RHR (mean difference with FCT = -2.35, $p = 0.003$) and enhanced VO_2 Max (mean difference with FCT = 2.91, $p < 0.001$). While FCT also showed significant improvements compared to the control, its effect was less pronounced than HIIT. These findings support the earlier research showing that FCT increases aerobic capacity through sustained oxygen utilization over time [8,9,11]. These findings strongly support HIIT as the more effective modality for improving aerobic performance and cardiovascular efficiency in adult athletes within a short intervention period. While these results provide valuable insight, it's important to recognize that cardiovascular responses to training can differ across age groups and training backgrounds. For instance, previous studies found that adolescents and older populations may adapt differently to interval or continuous training modalities [1,7,11]. These highlight the importance of expanding the research to diverse populations.

6. Conclusion

Fast Continuous Training and High Intensity Interval Training both significantly improved cardiovascular fitness in adult athletes, according to the findings of the study. While HIIT produced more noticeable and quicker improvements in VO_2 Max and Resting Heart Rate. Both approaches were found to be effective by statistical analysis, with HIIT surpassing FCT in the majority of criteria. These results demonstrate the need to include structured aerobic training in sports regimens and support the choice of training modalities according to individual physiological reactions and performance objectives.

6.1. Future suggestions

1. Expand age diversity: Future studies may include younger and older athlete populations to determine the generalizability of training effects across age groups.

2. Assess long-term outcomes: Investigate the long-term sustainability and retention of cardiovascular improvements after different training modalities beyond the 8-week intervention.

3. Analyze sport-specific effects: Conduct research with athletes from varied sports disciplines to explore how training interventions interact with sport-specific demands and physiological profiles.

4. Include additional physiological markers: Future research can incorporate more comprehensive markers such as blood lactate, cardiac autonomic function, and metabolic adaptations for a multidimensional assessment.

5. Evaluate individual responsiveness: Explore factors influencing individual variability in adaptation, such as genetics, baseline fitness, and psychological motivators, to enhance personalized training approaches.

6.2. Limitations

The study offers solid results about the relative effects of HIIT and FCT on adult athletes' resting heart rate and VO_2 Max. The result may not be as applicable to the younger and older athletic populations due to the relatively small age range of participants (ages 21-26). Additionally, the sample was homogeneous in terms of training background, which may not reflect variability in athletic conditioning.

Declarations

Source of Funding

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare that they have no conflict of interest.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature search, review, analysis, and manuscript writing equally.

Ethical Approval

This study was reviewed, and formal ethical approval was waived by the Institutional Ethics Committee of Swarnim Gujarat Sports University, as it involved routine training interventions with no invasive procedures or risk to subjects.

Informed Consent

Informed consent was obtained from all participants, who were briefed about the nature, purpose, and voluntary nature of their participation.

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