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An Evaluation Of Selected Endurance Training Approaches And Their Effects On Motor Fitness, Physiological Efficiency, And Haematological Profiles Among Collegiate Athletes

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Abstract: Background: Endurance training is crucial for enhancing athletic performance, particularly by improving motor fitness, physiological functions, and hematological parameters. However, limited research has compared the effects of various endurance training protocols within the same population under controlled conditions.

Purpose: This study aimed to investigate the comparative effects of Continuous Running, Alternate Pace Running, Fartlek Training, and Combined Training on selected motor fitness, physiological, and hematological variables among college-level male students.

Methods: Sixty male college students aged 18–25 years were randomly assigned to four experimental groups (n = 15 each): Continuous Running (CRG), Alternate Pace Running (APR), Fartlek Training (FTG), and Combined Training (CTG). Each group underwent its respective training for 12 weeks, 5 days per week. Variables such as speed, muscular endurance (sit-ups), aerobic capacity (Cooper test), vital capacity, breath-holding time, pulse rate, hemoglobin level, and RBC count were assessed pre- and post-intervention. Data were analyzed using ANCOVA, followed by post hoc tests to determine intergroup differences.

Results: ANCOVA revealed significant improvements ($p < 0.05$) in all tested variables across groups, with the Combined Training group showing the largest gains in motor fitness and physiological and hematological outcomes. Post hoc comparisons confirmed the superiority of CTG over other training protocols.

Conclusion: All four endurance training protocols positively influenced performance and health-related variables, but Combined Training yielded the most comprehensive benefits. These findings underscore the importance of integrating multiple endurance modalities to maximize physiological and hematological adaptations....

Keywords: : Endurance training, continuous running, fartlek training, physiological variables, motor fitness, hematological parameters, combined training, ANCOVA, college athletes

Introduction

Endurance training is a cornerstone of athletic development, particularly in sports where sustained performance is critical. In recent years, there has been a growing interest in the comparative effects of different endurance training modalities on both motor fitness and various physiological and hematological parameters. Traditional continuous training, characterized by steady-state exercise, has long been favored for its ability to enhance aerobic capacity and endurance (Liu et al., 2021). However, alternative approaches such as alternate pace running and fartlek training, which incorporate variable intensities and intermittent recovery, have been suggested to provide distinct physiological stimuli that may lead to superior adaptations in speed and muscular endurance (Hernandez & Lopez, 2021; Rahman et al., 2020).

Continuous run training, where exercise is maintained at a constant pace, has been shown to improve cardiovascular efficiency and increase vital capacity (Kim et al., 2022). In contrast, alternate pace running and fartlek training incorporate bursts of higher intensity interspersed with lower intensity recovery periods, thereby promoting adaptations not only in aerobic metabolism but also in anaerobic energy systems. These intermittent modalities have been linked to improvements in lactic acid clearance and enhanced muscular endurance (Singh et al., 2023). More recently, combined training protocols that integrate continuous and intermittent elements have emerged as a promising approach to simultaneously target multiple aspects of endurance, resulting in comprehensive enhancements in motor fitness, physiological function, and hematological status (Almeida et al., 2022).

Physiological measures such as vital capacity, resting pulse rate, and breath holding time serve as important indicators of respiratory and cardiovascular adaptations following endurance training. Improvements in these variables are closely associated with enhanced oxygen uptake and utilization, which are critical for sustained athletic performance (Liu et al., 2021). Moreover, hematological variables such as hemoglobin concentration and red blood cell count are fundamental to understanding the oxygen-carrying capacity of the blood. Changes in these parameters have been observed in response to various endurance training protocols, underscoring their relevance in evaluating training outcomes (Hernandez & Lopez, 2021). Elevated levels of hemoglobin, for instance, have been correlated with improved endurance performance, while modifications in lactic acid levels provide insights into metabolic adaptations during high-intensity efforts (Rahman et al., 2020).

Despite the substantial body of literature on endurance training, there remains a paucity of research directly comparing the isolated and combined effects of continuous, alternate pace, and fartlek training on a comprehensive set of performance, physiological, and hematological outcomes. This study aims to address this gap by systematically evaluating these training modalities among college athletes. The outcomes are expected to offer valuable insights into how different endurance training strategies influence key performance markers, thereby guiding the development of optimized training regimens tailored to the specific needs of athletes.

In summary, while continuous training has been the traditional method for improving endurance, emerging evidence suggests that incorporating intermittent and combined training strategies may yield more pronounced improvements across various performance metrics. The present research investigates these training methods by examining their impact on motor fitness parameters, such as aerobic, speed, and muscular endurance, as well as on vital capacity, breath holding time, resting pulse rate, and hematological indices, including hemoglobin concentration and red blood cell count. By integrating recent findings (Almeida et al., 2022; Hernandez & Lopez, 2021; Kim et al., 2022;

Liu et al., 2021; Rahman et al., 2020; Singh et al., 2023), this study seeks to contribute to the evolving understanding of endurance training adaptations and to inform evidence-based practice in sports science.

Materials and Methods

Participants

Sixty male college athletes, aged between 18 and 25 years, were recruited for the study. All participants were actively engaged in collegiate sports and were medically cleared for high-intensity endurance training. They were randomly assigned into four equal groups (n = 15 per group): Group I (Continuous Run Training), Group II (Alternate Pace Run Training), Group III (Fartlek Training), and Group IV (Combined Training). Table 1 summarizes the basic demographic characteristics of the participants.

Table 1. Participant Demographics

Group	Sample Size	Age (years, Mean ± SD)
Continuous Run (I)	15	20.5 ± 1.8
Alternate Pace Run (II)	15	20.7 ± 1.9
Fartlek Training (III)	15	20.6 ± 1.7
Combined Training (IV)	15	20.4 ± 1.8
Total	60	20.55 ± 1.8

Methods

Each group underwent a distinct endurance training protocol over a period of 12 weeks. The Continuous Run Training group performed steady-state running at 60–70% of their maximum heart rate for 30 minutes per session. The Alternate Pace Run Training group completed interval-based runs with alternating periods of high- and low-intensity segments over predetermined distances. The Fartlek Training group engaged in unstructured sessions featuring variable speeds and terrains for 30–40 minutes per session. The Combined Training group followed a rotational schedule that incorporated elements from the other three training methods. All sessions were conducted three times per week under supervision. In addition, pre- and post-intervention assessments were administered to measure motor fitness (50-meter sprint, sit-ups, Cooper's 12-minute run), physiological parameters (vital capacity via spirometry, breath-holding time, and resting pulse rate via palpation), and hematological indices (hemoglobin concentration and red blood cell count determined via standard laboratory procedures). Table 2 summarizes the tests used for the various dependent variables

Table 2. Dependent Variables and Test Instruments

Variable Type	Parameter	Test/Instrument
Motor Fitness	Speed	50-meter sprint
	Muscular Endurance	Sit-ups (1-minute test)
	Aerobic Endurance	Cooper's 12-minute run/walk
Physiological	Vital Capacity	Spirometer
	Breath-Holding Time	Stopwatch

	Resting Pulse Rate	Palpation (Radial artery)
Hematological	Hemoglobin Concentration	Blood analysis (venous sampling)
	Red Blood Cell Count	Hemocytometer

Procedure

Before initiating the training protocols, all participants underwent baseline (pre-test) assessments for the selected variables. Following the pre-test, each group participated in their designated training program for 12 weeks, with sessions scheduled on alternate days (three sessions per week) during the early morning (6:00 AM to 8:00 AM). Each session began with a 10-minute warm-up that included jogging and dynamic stretching, followed by the main training session, and concluded with a 10-minute cool-down period consisting of static stretching. Participants in the Continuous Run group maintained a constant pace; those in the Alternate Pace group performed intervals of high intensity followed by recovery periods; the Fartlek group executed unstructured pace changes based on perceived exertion; and the Combined group rotated among the three training methods on a weekly basis. After the training period, a post-test was conducted under identical conditions to assess changes in performance. A training schedule is provided in Table 3

Table 3. Sample Training Schedule (per week)

Day	Continuous Run (Group I)	Alternate Pace (Group II)	Fartlek Training (Group III)	Combined Training (Group IV)
Monday	30 min steady-state run	Intervals (30 min total)	35 min variable pace	Steady + Intervals mix
Wednesday	30 min steady-state run	Intervals (30 min total)	35 min variable pace	Variable (Fartlek style)
Friday	30 min steady-state run	Intervals (30 min total)	35 min variable pace	Rotational mix of methods

Statistical Analysis

Data from the pre- and post-tests were analyzed using SPSS version 20. Descriptive statistics (means ± standard deviations) were computed for all measured variables. To determine the effectiveness of each training method, one-way Analysis of Covariance (ANCOVA) was used with the pre-test scores as covariates to control for baseline differences. Post hoc comparisons were conducted using Scheffe's test. Statistical significance was set at $p < 0.05$.

Results

The study examined the effects of four different endurance training protocols Continuous Running, Alternate Pace Running, Fartlek Training, and Combined Training on selected motor fitness, physiological, and hematological variables. The results are presented in tables and explained below.

Motor Fitness Variables

Improvements were observed across all motor fitness variables. Notably, the Combined Training group recorded the most significant improvements in speed, sit-ups, and Cooper test scores

Table 1. Pre and Post-Test Means of Motor Fitness Variables

Group	Speed (s) Pre	Speed (s) Post	Sit-ups Pre	Sit-ups Post	Cooper Test (m) Pre	Cooper Test (m) Post
Continuous Run	8.2	7.8	35	40	2200	2400
Alternate Pace	8.1	7.6	36	42	2250	2500
Fartlek Training	8.3	7.5	34	44	2150	2550
Combined Training	8.2	7.4	35	45	2180	2600

Physiological Variables

All groups showed marked improvement in vital capacity and breath-holding time. Resting pulse rate decreased across groups, with the **Combined Training** group showing superior enhancement in all measures

Table 2. Pre and Post-test Means of Physiological Variables

Group	Vital Capacity (L) Pre	Vital Capacity (L) Post	Breath Holding (s) Pre	Breath Holding (s) Post	Pulse Rate (bpm) Pre	Pulse Rate (bpm) Post
Continuous Run	3.5	3.9	40	50	72	68
Alternate Pace	3.6	4.0	42	53	71	67
Fartlek Training	3.4	4.2	39	55	73	65
Combined Training	3.5	4.3	41	57	72	64

Hematological Variables

Substantial increases in hemoglobin and red blood cell counts were evident post-training. Again, the **Combined Training** group showed the highest post-test values

Table 3. Pre and Post-test Means of Hematological Variables

Group	Hemoglobin (g/dL) Pre	Hemoglobin (g/dL) Post	RBC Count (mill/mm³) Pre	RBC Count (mill/mm³) Post
Continuous Run	13.5	14.0	4.8	5.1
Alternate Pace	13.6	14.2	4.9	5.2
Fartlek Training	13.4	14.5	4.7	5.3
Combined Training	13.5	14.7	4.8	5.4

ANCOVA Analysis

ANCOVA revealed statistically significant differences between groups in all tested variables, with p-values less than 0.05, indicating that training protocols had a significant effect on outcomes

Table 4. ANCOVA Summary for All Variables

Variable	F-value	p-value	Significance
Speed	8.32	0.001	Yes
Sit-ups	9.74	0.000	Yes
Cooper Test	10.56	0.000	Yes
Vital Capacity	7.89	0.001	Yes
Breath Holding	11.21	0.000	Yes
Pulse Rate	6.54	0.002	Yes
Hemoglobin	9.12	0.000	Yes
RBC Count	8.75	0.001	Yes

Post Hoc Analysis

Post hoc comparisons confirmed that the **Combined Training** group outperformed other groups significantly in all variables

Table 5. Most Effective Training Method per Variable

Variable	Most Effective Group
Speed	Combined Training
Sit-ups	Combined Training
Cooper Test	Combined Training
Vital Capacity	Combined Training
Breath Holding	Combined Training
Pulse Rate	Combined Training

Hemoglobin	Combined Training
RBC Count	Combined Training

The study results strongly indicate that all four endurance training programs had a beneficial impact on the selected physical, physiological, and hematological variables. However, the Combined Training program, which integrated elements of continuous, interval, and Fartlek training, was found to be the most effective across all tested domains. Significant improvements were evident in speed, muscular endurance, aerobic capacity, respiratory efficiency, cardiovascular function, and blood profile markers. These results were supported by ANCOVA and post hoc tests, which demonstrated statistically significant differences favoring the Combined Training group ($p < 0.05$). These findings provide empirical support for using a multi-modal endurance training approach to achieve comprehensive improvements in athletic fitness.

Discussion

The present study investigated the impact of four endurance training protocols Continuous Running, Alternate Pace Running, Fartlek Training, and Combined Training on selected motor fitness, physiological, and hematological variables in male students. The results revealed statistically significant improvements in all tested variables across all training groups, with the Combined Training group consistently exhibiting the most substantial enhancements. These findings underscore the efficacy of a diversified training strategy that integrates both steady-state and variable-intensity elements.

Improvements in motor fitness, particularly in speed and muscular endurance (sit-ups), are consistent with existing literature emphasizing the positive influence of endurance training on neuromuscular efficiency and anaerobic tolerance. The significant enhancement in speed performance among the Combined Training group is likely due to the intermittent bursts in Fartlek and Alternate Pace Running components, which improve anaerobic energy system contribution and stride economy (Laursen & Buchheit, 2019). Additionally, the sit-up performance improvement reflects improved core muscular endurance, which is crucial for sustained physical activity (Ross et al., 2022).

The aerobic capacity, measured through the Cooper test, showed statistically significant differences, especially favoring the Combined Training group. This is in line with the findings of Helgerud et al. (2007), who demonstrated that combining continuous and interval training protocols leads to superior VO_2max improvements due to increased stroke volume and mitochondrial density. Similar evidence by Tschakert and Hofmann (2022) highlights that the alternation between intensities promotes greater cardiovascular strain and adaptive stimuli, leading to better endurance performance.

Significant improvements in vital capacity and breath-holding time suggest enhanced pulmonary efficiency and respiratory muscle endurance. These adaptations are essential markers of cardiovascular and aerobic fitness and are commonly influenced by consistent aerobic training (Bailey et al., 2019). The Combined Training group's superior performance in these areas may result from the interplay of low and high-intensity stimuli, which challenge and strengthen respiratory muscles more effectively than single-mode training (Garber et al., 2021).

A noteworthy finding was the reduction in resting pulse rate, especially in the Combined and Continuous Running groups. A lower resting heart rate is an indicator of improved parasympathetic tone and cardiac efficiency (Borresen & Lambert, 2008). This adaptation is beneficial for recovery and cardiovascular health and confirms the effectiveness of regular endurance training in autonomic regulation.

Regarding hematological parameters, both hemoglobin concentration and RBC count increased significantly across all groups, with the Combined Training protocol producing the greatest gains. This aligns with the observations of Schmidt and Prommer (2010), who reported that endurance training stimulates erythropoiesis, enhancing the oxygen-carrying capacity of blood. Increased hemoglobin levels facilitate better oxygen delivery to working muscles, thereby improving performance and delaying fatigue (Hauser et al., 2017).

Overall, the study's findings confirm that while all endurance modalities are effective to some degree, Combined Training which strategically integrates continuous, pace-variable, and interval elements provides superior benefits across multiple performance domains. The diversity of physiological stressors in this approach appears to create an optimal environment for systemic adaptations in both cardiovascular and hematological systems. These findings are supported by recent research advocating for hybrid endurance protocols as time-efficient and physiologically comprehensive methods to enhance overall fitness (Sloth et al., 2023; Buchheit & Laursen, 2013).

Conclusion

The findings of this study demonstrate that all four endurance training protocols Continuous Running, Alternate Pace Running, Fartlek Training, and Combined Training significantly improved motor fitness, physiological, and hematological parameters in college-level male students. Notably, the Combined Training group showed superior performance across all variables, indicating that integrating multiple endurance modalities yields more comprehensive adaptations. These results emphasize the importance of diversified training in enhancing both aerobic and anaerobic capacities, respiratory efficiency, cardiovascular health, and hematological status. Future research should consider expanding the participant pool to include female athletes and individuals from different age groups to examine gender and age-related responses to endurance training. Additionally, incorporating long-term follow-ups would help determine the sustainability of these adaptations. Exploring molecular biomarkers, cardiac function imaging, and psychological factors such as motivation and perceived exertion may also provide deeper insight into the multidimensional effects of various endurance training protocols

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