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Effectiveness of Fartlek Training on Maximum Oxygen Consumption and Resting Pulse Rate in A Relay Runner: A Case Study

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ABSTRACT
Background: Relay running demands high aerobic capacity and cardiovascular efficiency due to intermittent high-intensity efforts and rapid recovery requirements. Fartlek training, a variable-intensity "speed play" method, has shown promise for enhancing endurance performance, but its effects on individual relay runners warrant detailed case examination.
Case Presentation: A 20-year-old male relay runner (height: 178 cm, weight: 72.5 kg, BMI: 22.9 kg/m²) with three years of competitive experience participated in a six-week Fartlek training program. The intervention consisted of three supervised sessions per week, each comprising 10-15 minutes warm-up, 20-30 minutes of variable-intensity continuous running (alternating between 80-90% and 50-60% of maximum heart rate), and 10-15 minutes cool-down.
Measurements: Maximum oxygen consumption (VO_2max) was estimated using the Queen College Step Test, and resting pulse rate (RPR) was measured via pulse oximetry after 10 minutes of quiet rest. Assessments were conducted at baseline (Week 1) and post-intervention (Week 6).
Results: Following the six-week intervention, the participant demonstrated a 9.35% increase in VO_2max (from 49.2 to 53.8 $ml \cdot kg^{-1} \cdot min^{-1}$) and an 8.82% reduction in resting pulse rate (from 68 to 62 bpm). These improvements exceeded the minimal clinically important differences reported in endurance training literature and were consistent with group-level outcomes from the parent randomized controlled trial.
Conclusion: This case study provides evidence that a six-week Fartlek training program can produce clinically meaningful improvements in aerobic capacity and cardiovascular efficiency in a relay runner. The findings support the incorporation of Fartlek training into periodized conditioning regimens for relay athletes.
Keywords: Fartlek training, relay runner, VO_2max, resting pulse rate, case study, aerobic capacity

1. INTRODUCTION
1.1 Background
Relay running presents unique physiological challenges distinct from individual distance or sprint events. The intermittent nature of relay participation—characterized by alternating periods of maximal or near-maximal effort followed by passive recovery between legs—

creates a distinct stress profile on the cardiovascular and metabolic systems [1,2]. Relay competitors must execute repeated high-intensity running bouts while recovering as completely as possible between exchange periods, necessitating robust aerobic capacity and efficient cardiovascular regulation [3].

Maximum oxygen consumption (VO_2max) represents the body's maximal rate of oxygen utilization during progressive exercise and is widely recognized as the gold standard measure of cardiorespiratory fitness and aerobic endurance capacity [4]. In relay runners, VO_2max values comparable to those reported for middle-distance and long-distance track athletes have been documented, with elite performers achieving levels exceeding 70 $ml \cdot kg^{-1} \cdot min^{-1}$ [5,6].

Resting pulse rate (RPR) serves as a practical, non-invasive window into cardiovascular health and autonomic nervous system function [7]. Chronic exposure to the hemodynamic demands of aerobic exercise induces a constellation of cardiovascular adaptations in endurance-trained athletes, collectively resulting in reduced resting heart rate—a phenomenon termed "athlete's bradycardia" [8]. Lower resting pulse rates are associated with favorable autonomic recovery profiles, including accelerated heart rate recovery following exercise cessation and enhanced heart rate variability [9].

1.2 Fartlek Training

Fartlek training, which translates from Swedish as "speed play," was developed in the 1930s by Swedish coach Gösta Holmér [10]. This training modality presents a compelling alternative to more rigidly structured interval and continuous training regimens due to its inherent flexibility and responsiveness to individual effort perception [11]. In Fartlek training, athletes spontaneously alternate between periods of faster running (at or above lactate threshold intensity) and slower recovery jogging, with the duration, intensity, and sequence of intervals dictated by perceived effort and terrain features rather than predetermined time or distance parameters [12].

The physiological rationale for Fartlek training can be understood through contemporary exercise metabolism and cardiovascular control principles. As an athlete transitions from submaximal steady-state running to brief supramaximal efforts interspersed throughout a continuous session, metabolic demands fluctuate between primarily relying on oxidative phosphorylation and recruiting glycolytic energy pathways [13]. This recurring shift in substrate utilization and energy system engagement stimulates multiple physiological domains, including mitochondrial biogenesis, capillary density augmentation, and enhanced metabolic waste buffering and clearance [14]. Concurrent variations in heart rate and cardiac output coincident with changes in running intensity provide a potent stimulus for cardiovascular remodeling, potentially explaining the observed reductions in resting and submaximal heart rates [15].

1.3 Rationale for Case Study

While randomized controlled trials have established the efficacy of Fartlek training at the group level [16,17,18], individual responses to training interventions can vary considerably due to genetic factors, training history, and psychological characteristics [19]. Case study methodology enables detailed examination of individual training responses, providing clinically relevant insights that complement group-level findings. This case study examines the effects of a six-week Fartlek training program on VO_2max and RPR in a competitive relay runner, with the aim of documenting individual physiological adaptations to this training modality.

2. CASE DESCRIPTION

2.1 Participant Characteristics

The participant was a 20-year-old male relay runner recruited from T.T. Nagar Stadium, Bhopal, India. His demographic and anthropometric characteristics are summarized in Table 1.

Table 1: Baseline Participant Characteristics

Characteristic	Value
Age (years)	20
Gender	Male
Height (cm)	178
Weight (kg)	72.5
Body Mass Index (kg/m²)	22.9
Training Experience (years)	3
Primary Event	4×400m relay

The participant had been engaged in organized athletic training and competition for three years prior to enrollment, training approximately 4-5 sessions per week. He reported no history of significant musculoskeletal injury, cardiovascular disease, or neurological conditions. Written informed consent was obtained prior to participation, and the study protocol received approval from the Institutional Ethics Committee of People's College of Paramedical Sciences and Research Centre (PCPS&RC), People's University, Bhopal.

2.2 Inclusion and Exclusion Criteria

The participant met the following inclusion criteria: (1) age between 18-30 years, (2) minimum one year of continuous participation in organized athletic training, (3) active engagement in relay running competition, and (4) provision of voluntary written informed consent. Exclusion criteria included: (1) unwillingness to participate, (2) serious uncontrolled medical conditions, (3) recent musculoskeletal injury (within preceding three months), (4) neurological deficits, and (5) cardiovascular or systemic illness that could influence heart rate responses or exercise capacity.

3. METHODS

3.1 Study Design

This case study was conducted as part of a larger randomized controlled trial examining the effectiveness of Fartlek training on VO_2max and RPR in relay runners. The participant was assigned to the Fartlek training group and underwent a six-week supervised training intervention with pre-test and post-test assessments.

3.2 Training Intervention

The participant completed a six-week Fartlek training program consisting of three supervised sessions per week, with at least 48 hours between sessions to ensure adequate recovery. Each session was structured as follows:

Warm-Up (10-15 minutes): Low-intensity jogging and dynamic stretching exercises targeting the quadriceps, hamstrings, gluteals, and gastrocnemius-soleus complex. The warm-up aimed to elevate core temperature, increase muscle blood flow, and prepare the cardiovascular and musculoskeletal systems for the subsequent training demands.

Fartlek Training Main Session (20-30 minutes): The participant engaged in continuous running while spontaneously varying pace according to the "speed play" concept. He alternated between periods of high-intensity running (80-90% of age-predicted maximum heart rate) and active recovery (50-60% of maximum heart rate). Rather than adhering to fixed intervals, the participant was encouraged to respond to perceived effort and utilize terrain variations to influence intensity fluctuations—the hallmark of authentic Fartlek training methodology.

Cool-Down (10-15 minutes): Low-intensity walking and static stretching exercises to facilitate gradual cardiovascular recovery, promote venous return, and maintain flexibility. Static stretches were held for 15-30 seconds per muscle group.

3.3 Outcome Measures

Maximum Oxygen Consumption (VO_2max): VO_2max was estimated using the Queen College Step Test, a validated field-based submaximal exercise test. The participant stepped up and down on a 16.25-inch (41.3-cm) bench at a rate of 24 cycles per minute for 3 minutes, following a four-step sequence (up-up-down-down) guided by a metronome set to 96 beats per minute. Immediately upon test completion, the participant was seated, and heart rate was measured by palpation of the radial artery for 60 seconds, commencing within 5 seconds of test conclusion. VO_2max was calculated using the validated prediction equation for males:

$$VO_2max\ (ml \cdot kg^{-1} \cdot min^{-1}) = 111.33 - [0.42 \times \text{post-exercise heart rate (bpm)}]$$

Resting Pulse Rate (RPR): RPR was measured using a portable finger-clip pulse oximeter. The participant sat quietly for 10 minutes in a comfortable, temperature-controlled room prior to assessment, avoiding talking, electronic device use, and any activity that could elevate heart rate. Following the rest period, the pulse oximeter sensor was placed on the index finger, and the displayed heart rate value was allowed to stabilize. The RPR was recorded when a steady reading was obtained for three consecutive seconds, expressed in beats per minute (bpm).

3.4 Assessment Schedule

Assessments were conducted at two time points:

- **Pre-test (Week 1):** Baseline measurements prior to commencement of the training intervention
- **Post-test (Week 6):** Follow-up measurements within three days of completing the six-week training program

All assessments were performed at the same time of day (morning hours) to control for diurnal variations in physiological parameters.

3.5 Training Log and Compliance

The participant maintained a standardized training log recording the date, session duration, distance covered (estimated), perceived intensity, and any adverse events or unusual fatigue. Research staff reviewed the training log weekly to monitor compliance and address any concerns.

4. RESULTS

4.1 Training Compliance

The participant attended 17 out of 18 scheduled training sessions (94.4% compliance rate), exceeding the prespecified acceptable threshold of 80%. No adverse events or injuries were reported during the intervention period. The participant reported progressive increases in perceived fitness and enjoyment of the training sessions.

4.2 Maximum Oxygen Consumption (VO_2max)

Table 2 presents the pre-test and post-test VO_2max values for the participant, along with the calculated change.

Table 2: Changes in Maximum Oxygen Consumption (VO_2max)

Time Point	Post-Exercise Heart Rate (bpm)	Calculated VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	Change
Pre-test (Week 1)	148	49.2	-
Post-test (Week 6)	137	53.8	+4.6 (+9.35%)

Following the six-week Fartlek training intervention, the participant demonstrated a 4.6 $ml \cdot kg^{-1} \cdot min^{-1}$ increase in VO_2max, representing a 9.35% improvement from baseline. This improvement exceeds the minimal clinically important difference of approximately 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ reported for endurance athletes [20].

4.3 Resting Pulse Rate (RPR)

Table 3 presents the pre-test and post-test RPR values for the participant.

Table 3: Changes in Resting Pulse Rate (RPR)

Time Point	Resting Pulse Rate (bpm)	Change
Pre-test (Week 1)	68	-
Post-test (Week 6)	62	-6 (-8.82%)

The participant demonstrated a 6 bpm reduction in resting pulse rate following the six-week intervention, representing an 8.82% improvement from baseline. This reduction indicates enhanced cardiovascular efficiency and favorable autonomic nervous system adaptation.

4.4 Comparison with Group-Level Data

Table 4 compares the participant's improvements with the mean improvements observed in the Fartlek training group (n=20) from the parent randomized controlled trial.

Table 4: Individual vs. Group Improvements

Outcome Measure	Participant Improvement	Fartlek Group Mean Improvement (n=20)
Δ VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	+4.6	+4.09 ± 2.19
Δ VO_2max (%)	+9.35%	+9.13%
Δ RPR (bpm)	-6	-6.25 ± 3.53
Δ RPR (%)	-8.82%	-8.63%

The participant's improvements were consistent with the mean group-level responses, falling within one standard deviation of the group mean for both outcome measures. This concordance suggests that the participant demonstrated a representative response to the Fartlek training intervention.

5. DISCUSSION

5.1 Interpretation of Findings

This case study examined the effects of a six-week Fartlek training program on maximal oxygen consumption and resting pulse rate in a competitive relay runner. The participant demonstrated clinically meaningful improvements in both outcome measures: a 9.35% increase in VO_2max and an 8.82% reduction in RPR.

The observed 4.6 $ml \cdot kg^{-1} \cdot min^{-1}$ increase in VO_2max aligns with previously reported improvements following Fartlek training interventions. Salameh (2013) [16] reported a 16.03% improvement in VO_2max among soccer novices following eight weeks of Fartlek training, while Dinata (2024) [17] documented a 5.02% improvement in football players. The 9.35% improvement observed in this case falls within the range of these previous findings and is consistent with the meta-analytic estimate that structured endurance training can induce VO_2max improvements ranging from 5% to 25%, with the magnitude contingent upon initial fitness level, training intensity, and program duration [21].

The 6 bpm reduction in resting pulse rate (8.82% improvement) is similarly consistent with existing literature. Desai and Poovishnudevi (2024) [22] reported significant reductions in resting pulse rate among recreational football players following twelve weeks of Fartlek training, and Salameh (2013) [16] observed a 13.97% decrease in resting heart rate after an eight-week Fartlek intervention. The mechanisms underlying training-induced bradycardia are well-established and include increased parasympathetic nervous system tone, decreased intrinsic heart rate, and increased stroke volume capacity secondary to eccentric left ventricular hypertrophy [8,15].

5.2 Physiological Mechanisms

The physiological adaptations observed in this case can be explained through multiple interconnected mechanisms operating at central and peripheral levels.

Central Cardiovascular Adaptations: Chronic exposure to the variable-intensity demands of Fartlek training induces eccentric left ventricular hypertrophy, characterized by enlarged chamber dimensions and increased wall thickness that augment stroke volume capacity [23]. This enhanced stroke volume enables the heart to maintain adequate cardiac output at a lower contraction frequency, reducing resting heart rate while preserving hemodynamic stability. The magnitude of RPR reduction observed (6 bpm) is consistent with the degree of training-induced bradycardia documented in endurance athletes [8].

Peripheral Circulatory Adaptations: Concurrent changes within the peripheral circulation include increased capillary-to-fiber ratios in trained skeletal muscle and enhanced endothelium-dependent vasodilation, enabling more efficient oxygen extraction from circulating blood [24]. These adaptations reduce the circulatory burden at any given submaximal work rate, contributing to the observed improvements in exercise tolerance and recovery.

Metabolic Adaptations: Fartlek training promotes mitochondrial biogenesis and upregulates oxidative enzyme activity within working muscles, increasing the capacity to utilize delivered oxygen for adenosine triphosphate (ATP) resynthesis [14]. The recurring shifts between oxidative phosphorylation and glycolytic energy pathways inherent to Fartlek training may stimulate more comprehensive metabolic adaptations compared to steady-state training modalities.

Autonomic Nervous System Adaptations: The reduction in resting pulse rate is primarily attributable to training-induced increases in parasympathetic tone and commensurate decreases in sympathetic outflow to the sinoatrial node [25]. This shift in autonomic balance toward vagal dominance represents a favorable adaptation associated with reduced cardiovascular risk and enhanced recovery capacity [9].

5.3 Relevance to Relay Running Performance

The observed improvements in VO_2max and RPR have direct implications for relay running performance. Relay competition requires athletes to execute repeated high-intensity efforts separated by variable recovery intervals between exchange zones. The physiological stress profile of this intermittent pattern differs fundamentally from continuous distance running or single sprint events [2].

Enhanced Recovery Kinetics: Aerobic fitness positively correlates with recovery efficiency following high-intensity exercise. Athletes with higher VO_2max values demonstrate faster phosphocreatine resynthesis, more rapid lactate clearance, and accelerated heart rate recovery following exercise cessation [26,27]. The 9.35% improvement in VO_2max observed in this case would be expected to enhance the participant's ability to recover between relay legs, potentially enabling better maintenance of power output across successive efforts.

Improved Cardiovascular Efficiency: The 8.82% reduction in resting pulse rate indicates favorable autonomic remodeling characterized by enhanced parasympathetic tone. Lower resting heart rates are associated with accelerated heart rate recovery following exercise and improved heart rate variability, both of which are markers of enhanced cardiovascular fitness and recovery capacity [9]. For relay runners, these adaptations may translate to better preparedness for subsequent efforts and reduced cumulative fatigue across competition.

Dual-Energy System Development: Fartlek training simultaneously stresses both aerobic and anaerobic energy systems—a characteristic particularly relevant to relay running. Shorter relay efforts (100-400 meters) primarily stress alactic and glycolytic energy systems, while longer legs (800-1600 meters) require increasing reliance on aerobic metabolism [1]. The variable-intensity structure of Fartlek training, alternating between high-intensity surges and active recovery, mirrors the intermittent demands of relay competition and may produce integrated physiological adaptations not achieved through single-modality training.

5.4 Comparison with Alternative Training Modalities

The participant's improvements compare favorably with those expected from conventional high-intensity interval training. In the parent randomized controlled trial, the conventional training group (n=20) demonstrated a 5.45% improvement in VO_2max and a 4.81% reduction in RPR following an equivalent six-week intervention. The participant's 9.35% VO_2max improvement and 8.82% RPR reduction exceed these comparator group means, suggesting that the Fartlek protocol may confer additional benefits beyond those achievable with traditional interval methods.

Several factors may explain this differential effectiveness. First, the stochastic intensity variation inherent to Fartlek training may recruit motor unit populations not consistently engaged during predictable interval-based training, potentially stimulating more comprehensive neuromuscular and metabolic adaptations [28]. Second, the self-regulated, perception-guided nature of Fartlek training may enable athletes to work at intensities better aligned with their current physiological state, optimizing the training stimulus across sessions. Third, the reduced monotony and increased autonomy associated with Fartlek training may enhance psychological engagement and motivation, potentially influencing physiological outcomes through psycho-neuroendocrine pathways [29].

5.5 Clinical and Practical Significance

The improvements observed in this case exceed established thresholds for clinically meaningful change. For VO_2max, a minimal clinically important difference of approximately 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ has been proposed for endurance athletes [20]; the participant's 4.6 $ml \cdot kg^{-1} \cdot min^{-1}$ improvement substantially exceeds this threshold. For resting pulse rate, reductions of 5-10 bpm are generally considered physiologically meaningful in athletic populations [8]; the participant's 6 bpm reduction falls within this range.

From a practical perspective, the six-week, three-session-per-week Fartlek protocol employed in this case is logistically feasible, requires no specialized equipment beyond a suitable running surface, and can be readily adapted to accommodate individual athlete characteristics and facility constraints. The participant reported high enjoyment and low monotony, factors that may enhance long-term adherence compared to rigidly structured interval programs.

5.6 Limitations

Several limitations warrant consideration when interpreting these findings. First, as a single case study, the results may not generalize to other relay runners with different training backgrounds, genetic profiles, or competitive levels. Second, VO_2max was estimated using a field-based submaximal test rather than direct gas analysis, introducing measurement error and potentially limiting precision. Third, the absence of direct performance outcome measures (e.g., relay leg times, competition results) precludes definitive conclusions about the translation of physiological improvements to competitive performance. Fourth, the study did not control for potential confounding variables such as nutritional status, sleep quality, or concurrent training activities that may have influenced the observed outcomes.

6. CONCLUSION

This case study provides evidence that a six-week Fartlek training program can produce clinically meaningful improvements in maximal oxygen consumption (9.35% increase) and resting pulse rate (8.82% reduction) in a competitive relay runner. The observed improvements are consistent with group-level findings from the parent randomized controlled trial and exceed established thresholds for minimal clinically important differences. The variable-intensity structure of Fartlek training, alternating between high-intensity surges and active recovery, appears well-suited to the intermittent physiological demands of relay competition.

These findings support the incorporation of Fartlek training into periodized conditioning regimens for relay runners seeking to enhance aerobic capacity and cardiovascular efficiency. The logistically feasible protocol (six weeks, three sessions per week, 20-30 minutes of variable-intensity running) can be readily implemented by coaches and athletes with access to a suitable running surface. Future research should examine the effects of Fartlek training on direct performance outcomes in relay competition, investigate optimal dosing parameters (duration, frequency, intensity distribution), and explore potential synergistic effects when combined with other training modalities.

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