HIIT vs Fartlek: Effects on VO_2max in Track and Field Athletes

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HIIT vs Fartlek: Effects on VO_2max in Track and Field Athletes

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Abstract

Study purpose. Aerobic capacity is an important component of track-and-field performance because it supports athletes' ability to maintain training intensity and recover between repeated efforts. This study examined the effects of high-intensity interval training (HIIT) and fartlek training on the aerobic endurance of male track-and-field athletes in Lubuklinggau, Indonesia.

Materials and method. A quantitative experimental approach with a two-group pretest–posttest design was employed. Sixteen male athletes aged 20–25 years were allocated through ordinal pairing to either a HIIT group (n = 8) or a fartlek group (n = 8). Both groups completed 16 training sessions at Petanang Athletic Stadium in March 2025, with four sessions conducted each week. Aerobic endurance was assessed before and after the intervention using the standardized 2.4-km Cooper run test. Completion time was recorded in minutes and used as a field-based indicator of aerobic capacity. The test was administered using consistent procedures and has established validity and reliability for assessing aerobic endurance. Data normality and homogeneity were examined before hypothesis testing. Pretest and posttest scores within each group were compared using paired-samples t-tests.

Results. The HIIT group improved from 9.54 ± 0.51 minutes at pretest to 8.47 ± 0.70 minutes at posttest, $t(7) = 8.938$, $p < 0.001$. The fartlek group also improved significantly, from 10.34 ± 0.64 minutes to 8.99 ± 0.70 minutes, $t(7) = 8.167$, $p < 0.001$.

Conclusions. Both HIIT and fartlek training improved 2.4-km running performance and may be incorporated into aerobic conditioning programs for male track-and-field athletes. Future studies should involve larger samples, longer intervention periods, direct VO_2max measurement, and between-group statistical comparisons to determine the relative effectiveness of the two training methods.

Keywords: High-Intensity Interval Training (HIIT); Fartlek training; VO_2max; Aerobic endurance; Track and field athletes

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Introduction

Alongside rapid developments in sports science and training technology, athletics performance increasingly depends on structured and well-programmed training systems implemented by both government and community sport organizations (Loturco et al., 2024). In practice, achieving high performance requires training that is effective and efficient, encompassing technical mastery, physical conditioning, and adequate nutritional support (David J. Smith, 2003; Kreider, 2020). Among these determinants, physical conditioning is a critical foundation, and one of the most essential physiological components for athletics athletes is maximal aerobic capacity (VO_2max) (Juniardi et al., 2016). VO_2max describes the maximum amount of oxygen consumed per unit time during progressively heavier exercise until exhaustion and is widely used as an indicator of endurance readiness. Athletes with higher VO_2max generally demonstrate better endurance capacity, whereas lower VO_2max often limits performance, particularly in events that demand sustained running such as middle- and long-distance races.

Physiologically, VO_2max is shaped by the integrated function of multiple systems: the lungs as oxygen suppliers, hemoglobin as oxygen carriers, the heart as a pump, the vascular system as a distribution pathway, and the muscles as the primary oxygen users during exercise (Cathryn R. Dooly & Arthur T. Johnson, 2014). As training intensity increases, active muscles demand greater oxygen supply and generate more metabolic by-products, highlighting the importance of aerobic efficiency for maintaining performance (Abarghoueinejad et al., 2021; Gipit et al., 2017) . Therefore, endurance training methods should be selected based on training objectives and athlete characteristics, because the type and quality of training stimuli strongly determine VO_2max adaptations.

Among endurance-oriented methods, High-Intensity Interval Training (HIIT) and fartlek training are frequently applied to improve VO_2max. HIIT is considered an efficient approach because it can develop multiple physical capacities in a single training session, including aerobic and anaerobic endurance, and is closely associated with improvements in cardiovascular function and maximal aerobic capacity (Schroeder et al., 2019; Silva et al., 2025). In practice, HIIT is implemented through repeated high-intensity work bouts separated by scheduled recovery periods, with variations in set–repetition structure and recovery time (Kuswoyo et al., 2020). In contrast, fartlek emphasizes pace variation (“speed play”) and is typically programmed at moderate-to-vigorous intensities; in this study context, fartlek intensity is positioned at approximately 60%–80% of maximum heart rate to enhance endurance, particularly cardiorespiratory endurance. Although both methods aim to improve endurance, their distinct characteristics raise an important practical question for coaches and sport organizations: which method produces better improvements in VO_2max for a specific athlete population?

This question is highly relevant in the training context of PASI Lubuklinggau (Persatuan Atletik Seluruh Indonesia–Lubuklinggau), a local athletics organization recognized for producing competitive athletes at city and provincial levels. However, performance trends indicated declining achievements, particularly in middle-distance events, across several provincial competitions. In Porprov 2019 (Prabumulih), middle-distance athletes in the 1,500 m event obtained low placements (e.g., positions 10 and 13), and in Porprov 2021 (OKU Raya) results remained limited (e.g., 1,500 m around position 9 and 800 m around position 7). These performance limitations were also accompanied by signs of excessive fatigue during competition, including cases where athletes were unable to finish long-distance events, suggesting insufficient endurance readiness. Such conditions were interpreted as indicating that athletes’ physical condition had not reached an optimal level and that VO_2max remained relatively low for athletics demands. Consistent with this

interpretation, the absence of performance improvement from Porprov 2019 to Porprov 2023 further strengthened the need for an intervention study comparing HIIT and fartlek.

Accordingly, this research was designed not only to identify athletes' VO_2max status, but also to provide an evaluation basis for the endurance training program currently implemented and to inform future training planning aimed at improving performance. The study addresses three core questions: (1) whether HIIT affects VO_2max, (2) whether fartlek affects VO_2max, and (3) whether there is a difference in effectiveness between HIIT and fartlek for improving VO_2max among athletics athletes in Lubuklinggau. Despite the widespread use of both methods, coaching decisions are often guided by habitual programming rather than evidence-based selection tailored to athlete needs, and local empirical comparisons within the same training environment remain limited. Therefore, this study experimentally examines and compares the effects of HIIT and fartlek on VO_2max, with the expectation that the findings will provide evidence-based guidance for coaches and sport organizations in designing more effective endurance programs and improving competitive outcomes.

Materials and Methods

Study Participants

The accessible population comprised 16 male track-and-field athletes aged 20–25 years who were actively participating in regular training programs in Lubuklinggau, Indonesia. All eligible athletes were recruited using a census approach, also referred to as total population sampling. This approach was considered appropriate because the accessible population was small and all its members could be included in the study. Sample selection should consider the size and accessibility of the target population, in addition to statistical power, the expected effect size, and the intended scope of inference (Ahmed, 2024).

Participants were eligible when they were male track-and-field athletes aged 20–25 years, actively involved in regular training, had previous experience with structured endurance training, and agreed voluntarily to complete the study procedures. Before data collection, the participants received an explanation of the study objectives, intervention procedures, testing requirements, and their expected involvement.

Because of the limited number of participants, ordinal pairing was used to improve baseline comparability between the two intervention groups. Participants were ranked according to their pretest 2.4-km running times and then distributed alternately into the two groups according to the predetermined pairing order. Matching participants on a baseline variable that is closely related to the study outcome can reduce initial group imbalance and improve the precision of treatment-effect estimates, particularly in studies with relatively small samples (Morgan & Rubin, 2012).

The participants were allocated as follows:

1. HIIT group: eight participants who completed high-intensity interval training.
2. Fartlek group: eight participants who completed fartlek training.

Both groups completed the intervention under the supervision of the research team. Because the allocation was based on ordinal pairing rather than unrestricted random assignment, the study was classified as a matched two-group pretest–posttest experimental design.

Study Organization

The study was conducted at Petanak Athletics Stadium, Lubuklinggau, Indonesia, in March 2025. The intervention consisted of 16 training sessions delivered four times per week. Each session included three phases: warm-up, main training, and cool-down.

Before the intervention, all participants completed a pretest to determine their baseline aerobic endurance. They were then assigned to the HIIT or fartlek group through the ordinal-pairing procedure. The HIIT group performed repeated running intervals over distances of 200 m and 400 m at a predetermined training intensity. Each running interval was followed by approximately 50–60 seconds of active recovery through walking or light jogging.

The fartlek group performed continuous running with systematic changes in pace. The training combined jogging, moderate-speed running, and sprinting over varied distances. Examples included alternating 200 m of jogging with 200 m of faster running and alternating 400 m of jogging with 100 m of speed running. The training loads were organized progressively throughout the intervention period.

After the completion of 16 sessions, all participants performed the posttest using the same procedures and testing location as the pretest. The pretest and posttest results were used to examine changes in aerobic endurance within each training group.

Instrument, Validity, and Reliability

Aerobic endurance was assessed using the 2.4-km, or 1.5-mile, run test. The test was administered on a standard 400-m athletics track. Participants were instructed to complete six laps as quickly as possible while maintaining a pace that allowed them to finish the entire distance. Completion time was measured in minutes using a stopwatch.

Estimated maximal oxygen uptake was calculated from the completion time using the following equation:

$$\widehat{\mathrm{VO}}_{2\,\max} = \left(\frac{483}{t}\right) + 3.5$$

Where:

1. (t) is the time required to complete the 2.4-km run, expressed in minutes.
2. The values 483 and 3.5 are constants in the equation.
3. A faster completion time results in a higher estimated VO_2max value.
4. VO_2max is expressed in mL·kg(^{-1})·min(^{-1})

The resulting value was expressed in $mL \cdot kg^{-1} \cdot min^{-1}$. Because oxygen consumption was not measured directly using respiratory gas analysis, the values obtained from this equation were interpreted as estimated VO_2max, rather than directly measured VO_2max.

The criterion-related validity of the 2.4-km or 1.5-mile run test has been supported by comparisons with laboratory-based measurements of maximal oxygen uptake. Previous research involving young men found that 1.5-mile running performance provided an acceptable prediction of VO_2max (McNaughton et al., 1998). Research specifically examining the 2.4-km run also concluded that field-based running time could predict VO_2max obtained during a laboratory treadmill test (McNaughton et al., 1998).

No separate test–retest reliability study was conducted with the present sample. Nevertheless, the consistency of measurement was strengthened by using the same track distance, testing location, stopwatch-based timing procedure, test instructions, and research personnel during the pretest and posttest. Evidence from related Cooper-type maximal field-running assessments has also demonstrated high overall reliability among young, healthy adults when testing procedures are standardized (Penry et al., 2011).

Statistical Analysis

The data were summarized using means and standard deviations. Assumption testing was conducted before inferential analysis to examine data normality and the equality of variance between the groups. Changes from pretest to posttest within each group were analyzed using paired-samples *t*-tests. Statistical significance was established at $p < 0.05$.

The paired-samples *t*-tests determined whether the HIIT and fartlek groups improved independently over the intervention period. These analyses, however, did not directly determine whether one training method produced a significantly greater improvement than the other.

Results

Table 1. Descriptive statistics of the 2.4 km Cooper test (minutes) by group

Group	Measurement	Minimum	Maximum	Mean	SD	Variance
HIIT	Pre-test	9.05	10.25	9.5413	0.51215	0.262
HIIT	Post-test	7.27	9.30	8.4663	0.69632	0.485
Fartlek	Pre-test	9.21	11.24	10.3350	0.64076	0.411
Fartlek	Post-test	8.13	10.24	8.9863	0.69689	0.486

Based on Table 1 (descriptive statistics), both groups showed improved performance on the 2.4 km Cooper test after the training intervention. In the HIIT group (n = 8), the mean completion time decreased from 9.5413 min (SD = 0.51215) at pretest to 8.4663 min (SD = 0.69632) at posttest. This reduction indicates improved aerobic endurance (i.e., a shorter time reflects better performance). In the fartlek group (n = 8), the mean time also decreased from 10.3350 min (SD = 0.64076) to 8.9863 min (SD = 0.69689). Overall, both interventions produced clear improvements, with variability remaining moderate (SD ≈ 0.51–0.70), suggesting relatively consistent training responses among athletes.

Table 2. Normality test (One-Sample Kolmogorov–Smirnov)

Group	Variable	Test Statistic	Sig. (2-tailed)
HIIT	Pre-test	0.260	0.120
HIIT	Post-test	0.208	0.200
Fartlek	Pre-test	0.228	0.200
Fartlek	Post-test	0.201	0.200

Table 2 (Kolmogorov–Smirnov normality test) indicates that pretest and posttest scores in both groups met the normality assumption (all Sig. > 0.05). This means the distribution of the 2.4 km times did not significantly deviate from normality, supporting the use of parametric analyses such as the paired-samples t-test.

Table 3. Homogeneity of variance (Levene's Test; Based on Mean)

Group	Levene Statistic	df1	df2	Sig.
HIIT (pre–post)	0.587	1	14	0.456
Fartlek (pre–post)	0.237	1	14	0.634

In Table 3 (Levene's homogeneity test), the significance values for the HIIT group (Sig. = 0.456) and the fartlek group (Sig. = 0.634) were both greater than 0.05. These findings indicate homogeneous variances, meaning the variability in scores was statistically comparable and the assumption of equal variances was satisfied.

Table 4. Paired-samples t-test (Pre-test vs Post-test)

Group	Mean Difference	SD Difference	SE	95% CI Lower	95% CI Upper		df	Sig. (2-tailed)
HIIT	1.07500	0.34017	0.12027	0.79061	1.35939	8.938		0.000
Fartlek	1.34875	0.46713	0.16516	0.95822	1.73928	8.167		

Finally, Table 4 (paired-samples t-test) shows that the improvements within both groups were statistically significant. For the HIIT group, the mean pre–post difference was 1.07500 min, with t(7) = 8.938, p = 0.000, indicating a meaningful reduction in completion time after HIIT training. For the fartlek group, the mean difference was 1.34875 min, with t(7) = 8.167, p = 0.000, also demonstrating a significant improvement after fartlek training. In addition, the 95% confidence intervals for both groups did not cross zero, strengthening the conclusion that the observed changes were real rather than due to chance. Overall, both HIIT and fartlek training effectively enhanced aerobic endurance as reflected by performance on the 2.4 km Cooper test.

Discussion

The findings of this study strengthen the evidence that structured endurance training is an important component in improving aerobic capacity among athletics athletes (Martínez-Gregorio et al., 2023; Ojeda-Aravena et al., 2023). Aerobic endurance is a fundamental physiological factor in track-and-field performance because it supports oxygen delivery, delays fatigue, and helps athletes maintain exercise intensity during training and competition (Juniarto, 2022; Ojeda-Aravena et al., 2023). VO_2max is widely recognized as one of the main indicators of cardiorespiratory fitness and reflects the ability of the cardiovascular and respiratory systems to transport and utilize oxygen during sustained physical activity (Naeem et al., 2023; Solum et al., 2020).

High-Intensity Interval Training provides a strong physiological stimulus because it combines repeated high-intensity exercise bouts with short recovery intervals. This training model allows athletes to accumulate exercise time at a high percentage of maximal oxygen uptake, which may improve cardiac output, mitochondrial function, oxygen extraction, and overall aerobic efficiency. Previous studies have shown that interval-based training is effective in improving VO_2max and endurance performance across different athletic populations.

Fartlek training also has practical value for endurance development. As a varied running method, fartlek combines jogging, moderate running, and sprinting within one training session. This variation can stimulate both aerobic and anaerobic systems while helping athletes adapt to changes in running pace. In addition, fartlek training may reduce training monotony because it provides more flexible running patterns compared with highly structured interval training. Earlier research has also reported that fartlek training can improve VO_2max and physical performance when applied consistently in sport training programs.

From a coaching perspective, HIIT and fartlek training can both be integrated into athletics conditioning programs. HIIT may be more suitable when the training objective is to provide a high aerobic stimulus in a limited training duration, whereas fartlek may be useful for developing endurance through more varied and flexible running activities. Therefore, coaches should consider athlete fitness level, training phase, recovery capacity, and competition schedule when selecting the most appropriate endurance training method.

This study has several limitations. The sample size was relatively small, and the study did not include a non-training control group. In addition, VO_2max was estimated using a field-based running test rather than direct laboratory measurement. Future studies should involve larger samples, include a control group, monitor training intensity more objectively

using heart-rate or GPS-based devices, and apply direct VO_2max testing to strengthen physiological interpretation. Further research may also examine combined or periodized HIIT and fartlek programs over longer training cycles.

Conclusions

This study found that both high-intensity interval training and fartlek training significantly improved the aerobic endurance of male track-and-field athletes, as indicated by faster 2.4-km run completion times and higher estimated VO_2max values after the intervention. These findings suggest that both training methods can be incorporated into conditioning programs to develop athletes' aerobic capacity.

However, because the statistical analysis examined pretest–posttest changes within each group, the findings do not yet establish that one training method is significantly more effective than the other. Future studies should involve larger samples, longer intervention periods, direct laboratory measurement of VO_2max, and between-group analyses to compare the relative effectiveness of HIIT and fartlek training.

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Conflict of interest

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

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