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Effect of Fartlek Training on VO_2max in Adolescent Athletes: A Systematic Review

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Abstract

Background: Maximal oxygen uptake (VO_2max) is a key indicator of cardiorespiratory fitness and athletic performance in adolescents. Fartlek training, which integrates variable-intensity exercise within continuous activity, is widely applied to enhance aerobic capacity; however, its effectiveness in adolescent athletes has not been systematically synthesized.
Objective: To evaluate the effectiveness of fartlek training in improving VO_2max among adolescent athletes.
Methods: A systematic review was conducted following PRISMA 2020 guidelines. Literature searches were performed in Google Scholar, Semantic Scholar, and Crossref for studies published between 2015 and 2025. Two independent reviewers conducted study selection and data extraction using predefined PICOS criteria. Experimental and quasi-experimental studies involving adolescent athletes aged 12–18 years were included. Data were synthesized narratively due to heterogeneity in study design and outcome measurement. Risk of bias was assessed descriptively. Risk of bias was assessed using standardized criteria.
Results: A total of 1,187 records were identified, and nine studies were included, comprising approximately 186 participants. Fartlek training improved VO_2max across all studies, with reported increases ranging from 1.0 to 11.6 mL/kg/min. Greater improvements were observed in interventions lasting 4–8 weeks with training frequencies of 2–4 sessions per week. Comparative studies indicated that fartlek training produced effects comparable to or greater than other training methods. However, variability in protocols and measurement methods limited quantitative synthesis. The overall certainty of evidence was low to moderate.
Conclusion: Fartlek training appears to improve VO_2max in adolescent athletes; however, the certainty of evidence is low to moderate due to methodological limitations and heterogeneity. Further high-quality randomized controlled trials with standardized protocols are required.

Keywords
Exercise; Maximal Oxygen Consumption; Adolescent; Athletes; Physical Conditioning; Running

Introduction

Maximal oxygen uptake (VO_2max) is widely recognized as the gold standard indicator of cardiorespiratory fitness and a critical determinant of athletic performance in adolescent populations.[1,2] Higher VO_2max values reflect greater efficiency in oxygen transport and utilization during exercise, which is essential for sustaining prolonged physical activity and optimizing competitive performance.[2,3] In addition to its relevance for athletic outcomes, cardiorespiratory fitness is strongly associated with long-term health, including reduced cardiovascular risk and improved metabolic function in children and adolescents.[4] Global physical activity guidelines emphasize the importance of regular moderate-to-vigorous exercise to support the development of cardiorespiratory fitness during this critical life stage.[5]

From a physiological perspective, VO_2max is influenced by both central and peripheral adaptations within the oxygen transport system.[6] Central adaptations include increased cardiac output and stroke volume, whereas peripheral adaptations involve enhanced mitochondrial density, capillary proliferation, and improved oxidative enzyme activity.[6] These adaptations collectively improve the body's capacity to deliver and utilize oxygen efficiently during exercise.[6] Adolescence represents a particularly sensitive period for these adaptations, as ongoing growth and maturation processes enhance responsiveness to training stimuli.[4,6] Consequently, selecting appropriate and effective training modalities during this developmental phase is essential for maximizing aerobic capacity.

Various exercise interventions have been investigated to improve VO_2max in adolescent athletes.[7,8] High-intensity interval training (HIIT) has demonstrated substantial effectiveness in enhancing aerobic capacity and cardiometabolic outcomes.[7] However, the high physiological demands of HIIT may not be suitable for all adolescents, particularly those with lower baseline fitness or limited training experience, due to the increased risk of fatigue, overtraining, and injury.[7] This limitation highlights the need for alternative training approaches that provide sufficient physiological stimulus while maintaining flexibility and adaptability.

Fartlek training, characterized by continuous exercise interspersed with spontaneous variations in intensity, represents a hybrid approach that combines elements of aerobic and interval training.[9] Unlike structured interval protocols, fartlek training allows athletes to adjust intensity based on individual capacity and environmental conditions, making it particularly suitable for adolescent populations.[9,10] This flexibility may enhance adherence, reduce monotony, and provide a more individualized training stimulus.[9] Several primary studies have reported improvements in VO_2max following fartlek interventions in adolescent athletes.[11–13]

Despite these promising findings, the existing evidence remains heterogeneous and fragmented. Variability in study design, participant characteristics, intervention duration, training frequency, and VO_2max measurement methods complicates the interpretation of results and limits the ability to draw consistent conclusions.[11,13–18] Furthermore, most available studies are quasi-experimental or pre-experimental in nature, with relatively small sample sizes, which reduces the overall strength of evidence.[11,13,15,16,19]

Importantly, although systematic reviews have examined the effects of exercise interventions such as HIIT on aerobic capacity in youth populations, there is currently no comprehensive systematic review specifically synthesizing evidence on fartlek training in adolescent athletes.[7] This represents a significant gap in the literature, particularly given the practical relevance of fartlek training for coaches and physiotherapists who require flexible and adaptable training strategies.

From a clinical and applied perspective, understanding the effectiveness and optimal characteristics of fartlek training is essential for developing evidence-based exercise prescriptions.[9,11] The absence of a structured synthesis limits the ability to provide clear recommendations regarding training duration, frequency, and expected outcomes.[11,13–16] Addressing this gap is therefore critical to support both performance optimization and safe training practices in adolescent athletes.

Accordingly, this systematic review aims to evaluate the effectiveness of fartlek training in improving VO_2max among adolescent athletes. Specifically, this study addresses the following PICOS framework: (1) Population: adolescent athletes aged 10–19 years; (2) Intervention: fartlek training; (3) Comparator: other training methods or control conditions; (4) Outcomes: VO_2max and aerobic capacity; and (5) Study design: experimental and quasi-experimental studies. By synthesizing the available evidence, this review seeks to clarify the magnitude and consistency of VO_2max improvements associated with fartlek training and to identify key characteristics of effective training protocols.

Methods

This study employed a systematic review design in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[20] The methodological approach was structured to ensure transparency, reproducibility, and comprehensive identification of relevant evidence.[20] This review was not registered in the PROSPERO database. The absence of prior registration is acknowledged as a methodological limitation that may increase the risk of reporting bias.

The eligibility criteria were defined using the PICOS framework. The population included adolescent athletes aged 10–19 years who were actively engaged in structured sports or training programs.[5] The intervention of interest was fartlek training, defined as continuous exercise incorporating variations in intensity, including alternating periods of jogging, running, and sprinting. Comparators included other training modalities such as interval training, circuit training, small-sided games, or control conditions without specific intervention.[9] The primary outcome was maximal oxygen uptake (VO_2max), representing cardiorespiratory fitness.[1,2] VO_2max was operationally defined as maximal oxygen consumption measured either through laboratory-based gas analysis or validated field-based tests such as the multistage fitness test (beep test), Cooper test, or Yo-Yo intermittent recovery test.[2,17,18] Eligible study designs included experimental, quasi-experimental, and pre-experimental studies reporting quantitative VO_2max outcomes.

A systematic literature search was conducted across three electronic databases: Google Scholar, Semantic Scholar, and Crossref. The search was conducted between January 2015 and December 2025, with the final search performed in December 2025. These databases were selected to capture a broad range of interdisciplinary and open-access studies. The search strategy was developed based on the core concepts defined in the PICOS framework, specifically the intervention (fartlek training), outcome (VO_2max), and population (adolescent athletes). To ensure comprehensive retrieval of relevant studies, synonymous terms and related keywords were identified for each concept and systematically combined using Boolean operators. The final search string consisted of three main components: (“fartlek training” OR “speed play training” OR “variable intensity training”) AND (“VO_2max” OR “maximal oxygen uptake” OR “aerobic capacity” OR “cardiorespiratory fitness”) AND (“adolescent” OR “youth” OR “teenage” OR “young athletes” OR “adolescent athletes”). The use of the operator OR within each concept allowed for broader inclusion of relevant terminology, while the operator AND was applied to combine concepts and restrict results to studies that addressed all key elements simultaneously. Although major databases such as PubMed and Scopus were not included in the search strategy, this limitation is acknowledged and may have affected the comprehensiveness of evidence retrieval.

The search strategy was iteratively refined through preliminary searches to ensure that known relevant studies were captured and that the balance between sensitivity and specificity was maintained. Variations in terminology across studies were considered, including differences in spelling and phrasing, to minimize the risk of missing eligible articles. Because indexing systems differ across databases, the search syntax was adapted accordingly while preserving the same conceptual structure. Filters were applied to restrict results to studies published between 2015 and 2025, and only articles available in English or Indonesian were included.

All identified records were imported into reference management software (Zotero) for organization and duplicate removal. The selection process was conducted using the Rayyan platform to facilitate blinded screening. Two independent reviewers screened titles and abstracts, followed by full-text assessment based on predefined inclusion and exclusion criteria. Discrepancies between reviewers were resolved through discussion and consensus; a third reviewer was not required. Inter-rater agreement was not quantified statistically, which is acknowledged as a limitation.

The study selection process followed the PRISMA framework, consisting of identification, screening, eligibility, and inclusion stages. In the identification stage, 1,187 records were retrieved. After duplicate removal, 98 records remained for screening. During title and abstract screening, irrelevant studies were excluded based on population, intervention, and outcome mismatch. Full-text assessment was subsequently conducted to confirm eligibility. Studies were excluded at this stage if they did not report quantitative VO_2max outcomes, involved non-adolescent populations, or did not include fartlek training as the primary intervention. Ultimately, nine studies met all eligibility criteria and were included in the final synthesis.

Data extraction was conducted using a standardized extraction form developed for this review. Extracted data included author information, publication year, study design, participant characteristics (age, sample size, type of sport), details of the fartlek intervention (duration, frequency, and intensity), VO_2max measurement methods, and main outcomes. Data extraction was performed by one reviewer and verified by a second reviewer to ensure accuracy and consistency.

The methodological quality and risk of bias of the included studies were assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for quasi-experimental and experimental studies.[21] This tool evaluates key domains including selection bias, measurement validity, confounding factors, and statistical analysis.[21] Each study was independently assessed by two reviewers, and discrepancies were resolved through discussion.

The overall risk of bias was categorized as low, moderate, or high based on the proportion of criteria met. This assessment was used to support the interpretation of findings and the overall strength of evidence.

The methodological quality and risk of bias of included studies were assessed descriptively based on key criteria, including study design, sample size, clarity of intervention protocol, and validity of outcome measurement. However, a standardized risk of bias tool such as the PEDro scale or Joanna Briggs Institute (JBI) checklist was not applied. This limitation is acknowledged and may

affect the strength of evidence interpretation. The certainty of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach. The evaluation considered study design, risk of bias, inconsistency, indirectness, and imprecision. Given that most included studies were non-randomized and exhibited methodological limitations, the initial level of evidence was downgraded accordingly.

The primary effect measure considered in this review was the change in VO_2max (pre–post difference) expressed in mL/kg/min. Where available, statistical significance (p-values) and magnitude of change were extracted. Due to substantial heterogeneity in study designs, intervention protocols, and outcome reporting, quantitative synthesis through meta-analysis was not performed. Heterogeneity was inferred qualitatively based on variability in intervention duration, training frequency, participant characteristics, and measurement instruments, rather than quantified using statistical indices such as I^2.

Given the substantial heterogeneity observed across the included studies in terms of study design, participant characteristics, intervention protocols, and outcome measurement methods, a quantitative meta-analysis was not considered appropriate. Instead, a narrative synthesis approach was adopted to systematically summarize and interpret the findings. Narrative synthesis is recommended in systematic reviews where statistical pooling is not feasible due to methodological and clinical diversity, as it allows for the structured comparison of patterns, relationships, and trends across studies while preserving the context of individual findings.[1] Statistical heterogeneity was not quantified using I^2 due to the absence of pooled analysis. However, heterogeneity was assessed qualitatively based on variability in study design, intervention duration, training frequency, and outcome measurement methods.

This approach enables the identification of consistencies and variations in the effects of fartlek training on VO_2max, while accounting for differences in intervention duration, training frequency, and measurement techniques. Furthermore, narrative synthesis provides a transparent framework for integrating evidence from studies with diverse designs, particularly when the available data lack sufficient homogeneity for robust statistical aggregation.[1],[2]No formal assessment of publication bias (e.g., funnel plot or Egger's test) was conducted due to the limited number of included studies. This represents an additional limitation. A formal assessment of publication bias (e.g., funnel plot or Egger's test) was not conducted due to the limited number of studies. This limitation may increase the risk of overestimating the intervention effect.

Results

The study selection process was conducted in accordance with the PRISMA 2020 framework to ensure transparency and reproducibility in identifying and screening relevant studies.[20] This process involved sequential stages of identification, deduplication, screening, eligibility assessment, and final inclusion, each performed using predefined criteria.[20] The detailed flow of study selection, including the number of records at each stage and the reasons for exclusion, is presented in Figure 1 and described below in a structured text format to facilitate reproducibility.

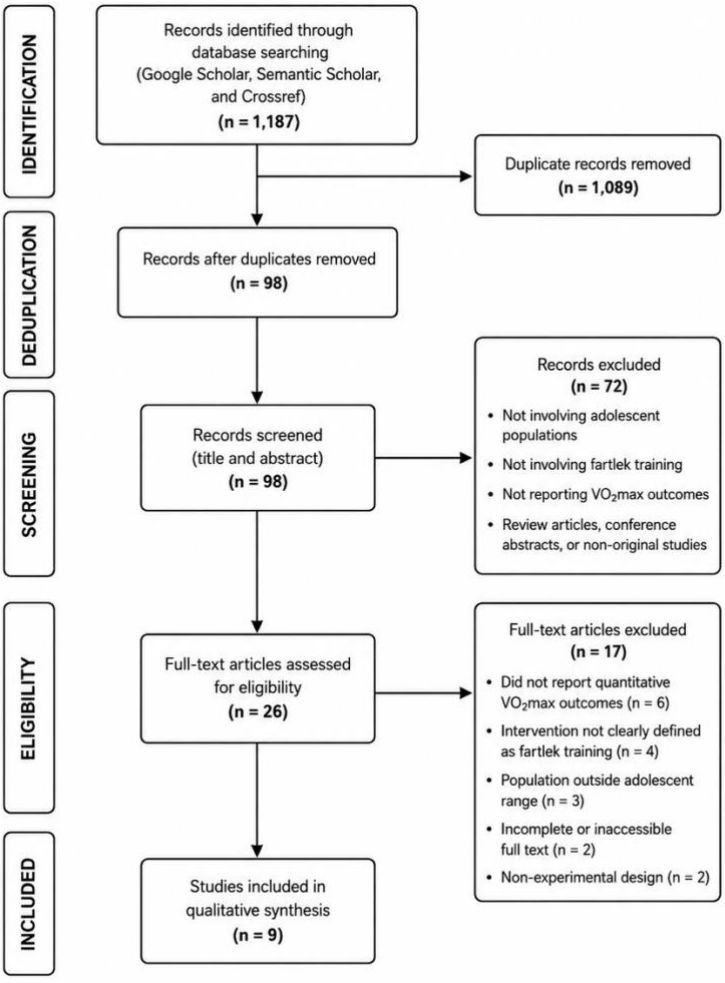

Figure 1. Flow Diagram of Literature Search and Study Selection

Across the nine included studies, a total of approximately 186 adolescent athletes aged 12–18 years were analyzed. Sample sizes ranged from 12 to 30 participants. Most participants were involved in team sports such as football, futsal, and basketball. The majority of studies employed quasi-experimental or pre-experimental designs with pretest–posttest approaches, while a smaller number used two-group comparative designs. VO_2max was primarily measured using validated field-based instruments, including the multistage fitness test (beep test), Cooper test, and Yo-Yo intermittent recovery test.[2,17,18] Intervention characteristics varied across studies. Training duration ranged from 4 weeks to 3 months, with frequencies of 2–4 sessions per week. However, several studies did not report complete details regarding frequency or session structure, indicating inconsistency in reporting.

The characteristics and main findings of the included studies are summarized in Table 1 to provide a structured comparison of study design, participant characteristics, intervention protocols, and VO_2max outcomes.

Table 1. Characteristics and Main Findings of Included Studies

No	Author (Year)	Sample (n; age; sport)	Study Design	VO_2max Measurement	Intervention (Duration; Frequency)	VO_2max (Pre–Post, mL/kg/min)	Main Findings
1	Muryadi et al. (2022)[16]	26; 13–14 yrs; football	Quasi-experimental (2 groups)	Cooper Test	4 weeks; 3 sessions/week	37.83 → 40.82	Significant improvement; comparable to circuit training
2	Bahtra et al. (2024)[11]	20; 15–17 yrs; football	Quasi-experimental (2 groups)	Yo-Yo IR Test	5 weeks; 3 sessions/week	41.57 → 42.88	Significant improvement; superior vs small-sided games
3	Bhutada & Ladha (2024)[13]	30; 12–17 yrs; basketball	Experimental	Beep Test	4 weeks; not reported	34.23 → 40.38	Significant increase ($p < 0.001$)
4	Bici & Kasa (2025)[14]	15; 18 yrs; football	Experimental	Cooper Test	8 weeks; 2 sessions/week	50.86 → 59.74	Significant improvement
5	Jamaludin et al. (2023)[19]	25; 13–14 yrs; football	Quasi-experimental (2 groups)	Beep Test	12 weeks; not clear	Not standardized*	Both methods improved VO_2max
6	Wili & Purnomo (2023)[15]	18; 15–17 yrs; futsal	Quasi-experimental	Beep Test	4 weeks; 4 sessions/week	34.23 → 45.87	Large improvement (Δ11.64)
7	Setiawan et al. (2023)[22]	20; 16–18 yrs; football	Pre-experimental	Beep Test	Not clear; 12 sessions	36.54 → 37.54	Small but significant increase
8	Abdurahman & Hermanzoni (2019)[23]	20; 15–16 yrs; football	Quasi-experimental (2 groups)	Beep Test	6 weeks; 3 sessions/week	29.9 → 31.5	Significant improvement
9	Septiawan et al. (2025)[24]	12; 18–19 yrs; futsal	Pre-experimental (2 groups)	Beep Test	Not clear; 10 sessions	43.52 → 45.23	Significant improvement

*VO_2max values in Jamaludin et al. were originally reported in level/stage format (beep test) and could not be directly converted into mL/kg/min due to insufficient data.

All included studies reported improvements in VO_2max following fartlek training interventions. The magnitude of improvement ranged from approximately 1.0 to 11.6 mL/kg/min.[11,13–16,19,22–24] A narrative quantitative synthesis indicated that the mean increase in VO_2max across studies ranged approximately from 4.5 to 6.0 mL/kg/min. Although individual study effects varied, the consistent direction of improvement supports the effectiveness of fartlek training. Studies with intervention durations of 4–8 weeks and training frequencies of 2–4 sessions per week tended to demonstrate greater improvements. Variability in outcomes was observed across studies. For instance, one study reported a substantial increase (Δ11.64 mL/kg/min), whereas another reported a modest improvement (Δ1.00 mL/kg/min). These differences may be influenced by baseline fitness levels, training intensity, and adherence. However, effect sizes and confidence intervals were not consistently reported in the primary studies, limiting further quantitative synthesis.

Several studies compared fartlek training with other training modalities, including circuit training, interval training, and small-sided games.[11,16,23,24] These studies generally demonstrated that fartlek training produced improvements in VO_2max that were comparable to or greater than alternative methods.[11,16,23,24] However, not all comparisons showed statistically significant differences, indicating that effectiveness may depend on specific training conditions.

Most studies reported statistically significant improvements in VO_2max ($p < 0.05$). However, reporting of effect sizes, confidence intervals, and variability measures was inconsistent, limiting the ability to perform quantitative synthesis. The included studies were predominantly quasi-experimental or pre-experimental with small sample sizes and limited methodological rigor.[11,13–16,19,22–24] The absence of randomization, blinding, and standardized protocols indicates a generally low to moderate level of evidence. Overall, fartlek training consistently improved VO_2max in adolescent athletes across all included studies. However, substantial heterogeneity in study design, intervention protocols, and outcome reporting limits the generalizability and strength of conclusions.

The risk of bias assessment indicated that the majority of included studies were of moderate methodological quality. Common limitations included lack of randomization, small sample sizes, and insufficient reporting of intervention protocols. Only a limited number of studies adequately controlled for confounding variables. Overall, the risk of bias across studies was judged to be moderate to high, which may affect the internal validity of the findings.

Based on the GRADE framework, the overall certainty of evidence was rated as low to moderate. This rating reflects limitations in study design, heterogeneity in intervention protocols, and inconsistent reporting of outcomes across studies. To ensure a rigorous evaluation of the internal validity of the included studies, a systematic methodological quality assessment was conducted using the Joanna Briggs Institute (JBI) critical appraisal checklist for quasi-experimental and experimental studies. This assessment aimed to identify potential sources of bias related to study design, participant selection, intervention implementation, outcome measurement, and statistical analysis. Each study was independently evaluated based on predefined criteria, and the results were synthesized to provide an overall judgment of methodological quality. The findings of this assessment are presented in Table 2.

Table 2. Methodological Quality Assessment (JBI)

Study	Clear Cause–Effect	Similar Participants	Control Group	Multiple Measurements	Follow-up Complete	Outcome Reliable	Appropriate Analysis	Overall Quality
Muryadi et al. (2022)[16]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Moderate
Bahtra et al. (2024)[11]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Moderate
Bhutada & Ladha (2024)[13]	Yes	Yes	No	Yes	Yes	Yes	Yes	Moderate
Bici & Kasa (2025)[14]	Yes	Yes	No	Yes	Yes	Yes	Yes	Moderate
Jamaludin et al. (2023)[19]	Yes	Unclear	Yes	No	Yes	Unclear	Yes	Low
Wili & Purnomo (2023)[15]	Yes	Yes	No	Yes	Yes	Yes	Yes	Moderate
Setiawan et al. (2023)[22]	Yes	Yes	No	No	Yes	Yes	Yes	Low
Abdurahman & Hermanzoni (2019)[23]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Moderate
Septiawan et al. (2025)[24]	Yes	Yes	No	No	Yes	Yes	Yes	Low

The methodological quality assessment using the JBI checklist indicated that most studies were of moderate quality. Common limitations included the absence of control groups, incomplete reporting of repeated measurements, and unclear participant comparability in some studies. Three studies were rated as low quality due to methodological weaknesses, including insufficient outcome reporting and lack of structured intervention protocols. In addition to the assessment of methodological quality at the individual study level, the overall certainty of evidence for the primary outcome was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach. This framework provides a structured evaluation of the confidence in the estimated effects by considering factors such as risk of bias, inconsistency, indirectness, imprecision, and potential publication bias. The GRADE assessment was applied to synthesize the strength of the evidence across studies and to support the interpretation of the findings in a transparent and standardized manner. The results of this evaluation are summarized in Table 3.

Table 3. GRADE Evidence Profile for VO_2max Outcome

Outcome	No. of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Certainty
VO_2max improvement	9	Quasi-experimental, Experimental	Serious	Serious	Not serious	Serious	Suspected	Low–Moderate

To facilitate the interpretation of the evidence for clinical and practical application, a summary of findings table was constructed. This table presents the key outcome, the magnitude of effect, and the corresponding level of certainty based on the GRADE assessment. The summary aims to provide a concise and accessible overview of the main findings of this review, allowing readers to quickly understand the direction, consistency, and strength of the evidence. The results are presented in Table 4.

Table 4. Summary of Findings

Outcome	Participants	Effect	Certainty of Evidence	Interpretation
VO_2max increase	186 adolescents	Mean increase ~4.5–6.0 mL/kg/min	Low–Moderate	Fartlek training likely improves VO_2max, but results should be interpreted cautiously due to study limitations

The GRADE assessment indicated that the certainty of evidence for VO_2max improvement was low to moderate. This rating reflects serious concerns related to study design limitations, inconsistency in intervention protocols, and imprecision due to small sample sizes. Although all studies reported positive effects, the lack of randomized controlled trials and standardized outcome reporting reduces confidence in the magnitude of effect.

Discussion

The findings of this systematic review indicate that fartlek training is consistently associated with improvements in VO_2max among adolescent athletes, although the magnitude of these improvements varies across studies.[11,13–16,19,22–24] This overall pattern supports the premise that variable-intensity training can effectively stimulate cardiorespiratory adaptations during adolescence, a developmental period characterized by heightened physiological responsiveness to exercise.[7,10] The observed increases in VO_2max, which ranged from modest to substantial, suggest that fartlek training can serve as a viable modality for enhancing aerobic capacity; however, the variability in effect size highlights the influence of contextual and methodological factors.[11,13–16,24]

From a physiological standpoint, the improvements in VO_2max observed across the included studies are consistent with established mechanisms of adaptation to aerobic and mixed-intensity training. Fartlek training, by integrating fluctuating intensities within continuous exercise, imposes both central and peripheral demands on the cardiovascular and muscular systems.[9] This dual stimulus is likely to enhance stroke volume and cardiac output, thereby improving oxygen delivery, while simultaneously promoting peripheral adaptations such as increased mitochondrial density and oxidative enzyme activity, which enhance oxygen utilization.[4,10] These mechanisms align with broader evidence indicating that training modalities incorporating intensity variation are effective in improving aerobic capacity in youth populations.[7,8]

When interpreted in relation to other training methods, the findings suggest that fartlek training produces effects on VO_2max that are generally comparable to those of structured interventions such as high-intensity interval training (HIIT), circuit training, and small-sided games.[11,16,24] While HIIT has been widely recognized for its strong impact on cardiorespiratory fitness, its structured high-intensity demands may not be optimal for all adolescent athletes, particularly those with lower baseline fitness or limited training experience.[7] In contrast, fartlek training offers a more flexible and self-regulated intensity structure, which may enhance adherence and reduce the risk of excessive fatigue.[9] This adaptability represents a practical advantage in applied settings, particularly in youth training environments where individual variability is pronounced.[9,10] Nevertheless, the current evidence does not unequivocally

demonstrate the superiority of fartlek training over other methods, and its relative effectiveness appears to be context-dependent rather than universally dominant.

A critical appraisal of the included studies reveals important methodological limitations that affect the strength of the evidence. The majority of studies employed quasi-experimental or pre-experimental designs without randomization, increasing the risk of selection bias and limiting causal inference. Sample sizes were generally small, and several studies lacked detailed reporting of intervention protocols, including intensity distribution and session structure. These limitations reduce internal validity and complicate comparisons across studies. Furthermore, inconsistencies in VO_2max measurement methods, ranging from different field-based tests to varying reporting units, introduce additional heterogeneity that may influence the observed magnitude of effects. Collectively, these factors suggest that the overall certainty of evidence should be considered low to moderate.

The absence of standardized risk of bias assessment and quantitative synthesis further constrains the interpretation of findings. Without the application of validated tools such as the PEDro scale or Joanna Briggs Institute checklist, it is difficult to systematically evaluate study quality. In addition, the lack of meta-analysis, although justified by heterogeneity, limits the ability to estimate pooled effect sizes and assess statistical heterogeneity using metrics such as I^2. These methodological gaps have been identified as key limitations in systematic reviews and should be addressed in future research to strengthen evidence synthesis.

Despite these limitations, the findings have meaningful clinical and practical implications. The consistent direction of effect suggests that fartlek training can be incorporated into adolescent training programs as a flexible and accessible approach to improving aerobic capacity. The observed pattern indicating greater improvements with training durations of 4–8 weeks and frequencies of 2–4 sessions per week provides a preliminary basis for exercise prescription, although these parameters should be interpreted cautiously given the heterogeneity of included studies. Importantly, the adaptability of fartlek training allows it to be implemented across various sports contexts without requiring specialized equipment, which may enhance feasibility and adherence in real-world settings. Potential publication bias should also be considered, as the inclusion of predominantly open-access studies may have influenced the overall direction of findings.

However, caution is warranted to avoid overgeneralization of these findings. The variability in study quality, combined with potential publication bias due to the inclusion of primarily open-access studies, may overestimate the effectiveness of the intervention. Additionally, the limited number of studies and the absence of long-term follow-up data restrict the ability to assess the sustainability of training effects. These factors underscore the need for more rigorous and standardized research designs.

Future research should prioritize randomized controlled trials with adequate sample sizes and standardized intervention protocols to improve internal validity and comparability. The use of consistent and validated VO_2max measurement methods is also essential to reduce heterogeneity. Furthermore, future systematic reviews should incorporate formal risk of bias assessment and, where feasible, meta-analytic techniques to provide more precise estimates of effect size and evidence certainty. Expanding research to include diverse sports and performance levels would also enhance the generalizability of findings.

In summary, while fartlek training demonstrates consistent potential to improve VO_2max in adolescent athletes, the current body of evidence is limited by methodological weaknesses and heterogeneity. As such, the findings should be interpreted as indicative rather than definitive, highlighting both the promise of this training modality and the need for more robust evidence to support its application. From a clinical perspective, fartlek training may be prescribed for adolescent athletes with a recommended duration of 4–8 weeks and a frequency of 2–4 sessions per week, adjusted to individual fitness levels and sport-specific demands.

Conclusion

This systematic review indicates that fartlek training is associated with improvements in VO_2max among adolescent athletes. The magnitude of improvement appears to be influenced by training duration and frequency, with interventions lasting 4–8 weeks and performed 2–4 times per week showing more consistent benefits. Despite these positive findings, the certainty of evidence remains low to moderate due to methodological limitations, including non-randomized study designs, small sample sizes, and heterogeneity in intervention protocols and outcome measurements.

From a practical perspective, fartlek training can be considered a flexible and accessible approach to improving aerobic capacity in adolescent athletes, particularly in settings where individualized intensity regulation and minimal equipment are preferred. Future research should prioritize well-designed randomized controlled trials with standardized protocols and consistent outcome measures to strengthen the evidence base and enable quantitative synthesis.

Author Contribution

Afwaza Nakhla Chairy Batubara: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft.
Dela Fariha Fuadi: Investigation, Validation, Writing – Review & Editing, Supervision.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Ethics Statement

Ethical approval was not required as this study was based on previously published data and did not involve direct human or animal participants.

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