



Comparison of changes in estimated $VO_2\text{max}$ following fartlek and continuous running training in adolescent pencak silat practitioners

Perbandingan perubahan estimasi $VO_2\text{max}$ setelah latihan fartlek dan continuous running pada remaja praktisi pencak silat

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ABSTRACT

Background: Cardiorespiratory endurance is an important component of performance in pencak silat because competition requires athletes to sustain performance across repeated bouts of high-intensity activity interspersed with recovery periods. However, evidence comparing changes in aerobic capacity following fartlek and continuous running training among adolescent pencak silat practitioners remains limited.

Objective: This study aimed to compare changes in estimated $VO_2\text{max}$ following fartlek and continuous running training among students participating in a pencak silat extracurricular program.

Methods: A two-group pretest-posttest design was used involving 24 students from SMP Darul Ikhlas Cikarang. Participants were selected using total sampling and were equally allocated to a fartlek group ($n = 12$) and a continuous running group ($n = 12$) through ordinal pairing. Estimated $VO_2\text{max}$ was assessed using the 20-m Multistage Fitness Test before and after the training program. Data were analyzed using assumption tests, paired-samples t-tests to evaluate within-group changes, and an independent-samples t-test to compare changes between groups at a significance level of 0.05.

Results: Estimated $VO_2\text{max}$ in the fartlek group increased from 33.48 to 40.10, while the continuous running group increased from 33.20 to 38.50. Both groups showed significant improvements; however, no significant difference was found in the change in estimated $VO_2\text{max}$ between the fartlek and continuous running groups ($t = 0.693$, $df = 22$).

Conclusion: These findings indicate that both training programs were associated with improvements in estimated $VO_2\text{max}$, but the study did not provide evidence that one method produced a greater improvement than the other.

ABSTRACT

Latar belakang: Daya tahan kardiorespirasi merupakan komponen penting bagi praktisi pencak silat karena aktivitas pertandingan menuntut kemampuan mempertahankan performa selama rangkaian gerak berintensitas tinggi dan fase pemulihan berulang. Namun, bukti yang membandingkan perubahan kapasitas aerobik setelah latihan fartlek dan continuous running pada remaja praktisi pencak silat masih terbatas.

Tujuan: Penelitian ini bertujuan untuk membandingkan perubahan estimasi $VO_2\text{max}$ setelah latihan fartlek dan *continuous running* pada peserta ekstrakurikuler pencak silat.

Metode: Penelitian menggunakan desain *pretest-posttest* dua kelompok dengan melibatkan 24 siswa SMP Darul Ikhlas Cikarang yang dipilih menggunakan *total sampling* dan dibagi secara seimbang ke dalam kelompok fartlek ($n = 12$) dan *continuous running* ($n = 12$) melalui *ordinal pairing*. Estimasi $VO_2\text{max}$ diukur menggunakan 20-m *Multistage Fitness Test* sebelum dan setelah program latihan. Data dianalisis menggunakan uji prasyarat dan paired-samples t-test untuk mengevaluasi perubahan dalam kelompok serta *independent-samples t-test* untuk membandingkan perubahan antarkelompok pada taraf signifikansi 0.05.

Hasil: Estimasi $VO_2\text{max}$ kelompok fartlek meningkat dari 33,48 menjadi 40,10, sedangkan kelompok *continuous running* meningkat dari 33,20 menjadi 38,50. Kedua kelompok menunjukkan peningkatan yang signifikan, tetapi tidak ditemukan perbedaan yang signifikan pada perubahan estimasi $VO_2\text{max}$ antara kelompok fartlek dan *continuous running* ($t = 0,693$; $df = 22$).

Kesimpulan: Kedua program dikaitkan dengan peningkatan estimasi VO_2max , namun penelitian ini tidak menemukan bukti bahwa salah satu metode menghasilkan perubahan yang lebih besar daripada metode lainnya.

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Highlights

- ✓ Both fartlek and continuous running training significantly improved estimated VO_2max in adolescent pencak silat practitioners.
- ✓ Estimated VO_2max increased by $6.62 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ after fartlek and $5.40 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ after continuous running.
- ✓ No significant between-group difference was found in estimated VO_2max changes following the two training programs.

Introduction

Pencak silat is a combat sport that requires a combination of technical skill, speed, strength, anaerobic capacity, and cardiorespiratory endurance. In the sparring category, athletes repeatedly perform sequences of attack, defense, positional movement, and recovery, making the ability to sustain work capacity throughout a bout an important component of physical readiness. The combat sports literature indicates that aerobic capacity contributes to recovery between high-intensity efforts and helps maintain performance during intermittent activity. A meta-analysis of combat-sport athletes showed that high-intensity interval training can improve aerobic capacity, including VO_2max , in both striking and grappling athletes (Vasconcelos et al., 2020). More recent findings in martial arts athletes also suggest that high-intensity interval programs can produce aerobic and physical fitness adaptations that are relevant to the demands of combat sports (Cai et al., 2026; Yue et al., 2025). Therefore, the development of cardiorespiratory capacity should be considered a key component of physical conditioning programs for pencak silat practitioners, including adolescents.

The need to develop aerobic capacity is particularly important in school-age athletes because adolescence is a developmental period in which training responses are still influenced by growth, biological maturation, training experience, and the characteristics of the exercise stimulus. Evidence from adolescent populations indicates that various forms of aerobic training can improve cardiorespiratory capacity, although the magnitude of adaptation may differ according to training intensity and structure. Su et al. (2025), for example, reported that six weeks of sprint interval training and moderate-intensity continuous training both produced meaningful improvements in VO_2peak in adolescent boys, although the two methods elicited different metabolic responses. A meta-analysis by Matzka et al. (2025) also showed that interval training can be an effective strategy for improving aerobic and anaerobic capacity in young athletes. These findings highlight that the selection of training methods for adolescents should consider not only improvements in aerobic capacity but also sport-specific demands and the athlete's ability to tolerate the prescribed training stimulus.

Two methods commonly used to develop aerobic capacity are fartlek training and continuous running. Fartlek combines variations in speed and intensity within a single session, producing an aerobic stimulus interspersed with periods of higher-intensity work, whereas continuous running involves sustained activity at a relatively stable intensity. Several studies have reported beneficial effects of fartlek training on aerobic capacity. Bahtra et al. (2024) found that fartlek training improved VO_2max in 15–17-year-old soccer players and produced greater improvements than small-sided games. Satria et al. (2024) also reported improved aerobic endurance following an eight-week

fartlek program in adolescent futsal players, although circuit training produced a larger improvement in that study. In karate athletes, Wijaya et al. (2024) likewise showed that fartlek can be used as one method for improving VO_2max . These findings suggest that fartlek has the potential to enhance aerobic capacity across different sporting contexts, although the magnitude of the response may depend on participant characteristics and the training program.

In the context of pencak silat, several studies have also shown that interval-based training can improve aerobic capacity. Lubis et al. (2022) reported that five weeks of aerobic interval training in elite pencak silat athletes increased VO_2max while also reducing resting heart rate and several body-composition indicators. Mardinus et al. (2025) found that interval training had a positive effect on VO_2max in pencak silat athletes using the bleep test as the assessment instrument. Subekti et al. (2025) further showed that four weeks of high-intensity interval training improved aerobic capacity and sport-specific speed in young pencak silat athletes. More recently, Al As'ary et al. (2026) reported that long-interval training in 16–18-year-old pencak silat athletes increased VO_2max and reduced resting heart rate compared with a control group. Collectively, these findings strengthen the evidence that interval-based training can stimulate aerobic adaptation in pencak silat practitioners.

Nevertheless, the relative effectiveness of variable-intensity training and continuous training has not shown a fully consistent pattern. Wulandari et al. (2026) compared high-intensity interval training, fartlek, and moderate continuous training over eight weeks and found that all three methods improved indicators of aerobic capacity, although HIIT produced the greatest changes in VO_2max and several biomechanical and recovery-related indicators. In contrast, Su et al. (2025) found that sprint interval training and moderate-intensity continuous training produced relatively similar improvements in VO_2peak in adolescent boys. Other comparative studies in adolescent populations have likewise shown that both interval-based and continuous training can improve cardiorespiratory fitness, with the relative advantage of one method depending on the training protocol, intensity, duration, and participant characteristics (Yang et al., 2025; Yahat, 2025; Zheng et al., 2025). These findings indicate that evidence regarding which method produces greater aerobic adaptation cannot be generalized directly from one population to another.

Several research gaps can be identified from the existing literature. First, most available studies in pencak silat have evaluated interval training or HIIT in isolation and compared it with routine training or a control group rather than directly with continuous running. Second, studies comparing fartlek and continuous training have more commonly involved sport science students, soccer players, futsal players, or non-pencak silat populations. Third, comparative evidence among school-age pencak silat practitioners remains limited, even though adolescents may respond differently to training than adult athletes. Fourth, several studies have relied on indirect measures of aerobic capacity; therefore, the findings should be interpreted in terms of changes in estimated VO_2max rather than directly measured laboratory VO_2max . Methodological literature indicates that the 20-m shuttle run is a practical field-based tool for estimating cardiorespiratory fitness in children and adolescents, although the resulting estimates remain influenced by the prediction model and participant characteristics (Nevill et

al., 2021a, 2021b). Accordingly, further research is needed to directly compare changes in estimated VO_2max following fartlek and continuous running in adolescent pencak silat practitioners using a two-group pretest–posttest design.

The novelty of this study lies in the direct comparison of two aerobic training models with different stimulus characteristics—fartlek, which involves variations in intensity, and continuous running, which maintains a more stable intensity—in school-age pencak silat practitioners allocated to two groups using ordinal pairing. Unlike previous studies that have primarily compared interval training or HIIT with a control group, the present study focuses on whether changes in estimated VO_2max following these two approaches differ within the context of a school-based pencak silat extracurricular program.

Based on these gaps, this study aimed to analyze changes in estimated VO_2max following fartlek and continuous running training and to compare the magnitude of change between the two groups among pencak silat extracurricular participants. Scientifically, this study is expected to add evidence regarding aerobic responses to two endurance-training approaches in adolescent pencak silat practitioners. Practically, the findings may help teachers, extracurricular instructors, and pencak silat coaches select and design aerobic training methods that are appropriate for school-age participants, without assuming that the absence of a statistically significant difference constitutes evidence that the two methods are truly equivalent.

Materials and Methods

Study Design

This study employed a quantitative approach using a two-group quasi-experimental pretest–posttest design (non-randomized matched two-group pretest–posttest design) (Figure 1). The design was used to evaluate changes in estimated VO_2max before and after two different aerobic training programs—fartlek and continuous running—and to compare the magnitude of change between the two groups. Participants were not randomly allocated; instead, they were assigned to the two groups using an ordinal-pairing procedure based on baseline measurements to achieve relatively comparable initial cardiorespiratory fitness levels.

Two intervention groups were formed: a fartlek group and a continuous running group. Both groups underwent an assessment of estimated VO_2max before the training program (pretest) and after completion of the entire program (posttest). The training program lasted eight weeks. During the intervention period, the primary training activities differed according to the assigned training method, whereas other conditions, where feasible, including the training location, training schedule, measurement procedures, and testing instructions, were kept consistent between groups.

Participants

The participants were all active members of the pencak silat extracurricular program at SMP Darul Ikhlas Cikarang. A total of 24 participants were included using total sampling, whereby all members of the population who met the study criteria were recruited. Following the baseline assessment, participants were ranked according to their estimated VO_2max values and subsequently allocated using an ordinal-pairing procedure to create two groups with relatively comparable baseline cardiorespiratory fitness levels. The fartlek group consisted of 12 participants, and the continuous running group consisted of 12 participants. This matched allocation procedure was used to reduce baseline differences in cardiorespiratory fitness between the groups before the training programs were implemented.

The inclusion criteria were being an active participant in the pencak silat extracurricular program, completing the pretest, being physically able to participate in the training program, and being willing to complete the entire study protocol. Participants were excluded from the analysis if they sustained an injury, did not complete the posttest, or had training attendance below the predetermined minimum requirement.

Instrument

Cardiorespiratory fitness was estimated using the 20-m Multistage Fitness Test (MSFT), also known as the 20-m shuttle run test or beep test. The test was performed on a flat 20-m course marked by two boundary lines. Participants ran back and forth between the two lines in response to audio signals, with running speed progressively increasing at each level. The test was terminated when a participant could no longer maintain the required running speed or failed to reach the line according to the predetermined termination criteria.

Test performance was recorded according to the final level and shuttle successfully completed and was subsequently used to estimate VO_2max in $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Because aerobic capacity was derived from a field-based prediction rather than directly measured through respiratory gas analysis, the outcome of this study is reported as estimated VO_2max .

The 20-m shuttle run is widely used as a practical field-based method for estimating cardiorespiratory fitness in children and adolescents. However, the resulting VO_2max values are estimates and may be influenced by the prediction equation and participant characteristics (Nevill et al., 2021a, 2021b). Therefore, the testing procedure and conversion model should be reported consistently to facilitate replication.

Statistical analysis

Data were analyzed using descriptive and inferential statistics. Descriptive data were presented as mean $\pm$ standard deviation (SD) to summarize estimated VO_2max before and after the training program in each group. Individual change scores were calculated as posttest minus pretest values.

The assumption of normality was examined using the Shapiro–Wilk test, which is appropriate for small sample sizes, while homogeneity of variance between groups was assessed using Levene’s test. The significance level was set at $\alpha = 0.05$.

Changes in estimated VO_2max from pretest to posttest within each group were analyzed using paired-samples *t*-tests. To compare the magnitude of change between the fartlek and continuous running groups, change scores were analyzed using an independent-samples *t*-test. The results were reported as mean $\pm$ SD, *t* values, degrees of freedom (*df*), and *p* values.

Results

The analysis showed that both groups experienced increases in estimated VO_2max following the training programs. In the fartlek group, mean estimated VO_2max increased from $33.48 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ at pretest to $40.10 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ at posttest, with a mean change of $6.62 \pm 4.31 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Meanwhile, the continuous running group increased from 33.20 to $38.50 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, with a mean change of $5.40 \pm 3.50 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (Table 1).

Paired-samples *t*-tests showed significant increases in estimated VO_2max in both the fartlek group, $t(11) = 5.32$, $p < .001$, and the continuous running group, $t(11) = 5.34$, $p < .001$. These findings indicate that post-intervention estimated VO_2max values were significantly higher than pre-intervention values within each group.

Before hypothesis testing, the assumptions of normality and homogeneity of variance were examined. Based on the available diagnostic results, the data met the assumptions required for the application of parametric tests.

To determine whether the magnitude of change differed between the two training programs, estimated VO_2max change scores were compared using an independent-samples t-test. The results are presented in Table 2.

The fartlek group showed a descriptively greater mean increase in estimated VO_2max than the continuous running group (6.62 vs. 5.40 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). However, the independent-samples t-test indicated that this between-group difference in change was not statistically significant, $t(22) = 0.693$, $p = .496$. Therefore, the study found no statistical evidence that the change in estimated VO_2max following fartlek training differed from that observed following continuous running.

Group	Pretest	Training program	Posttest
Fartlek	O_1	X_1	O_2
Continuous running	O_1	X_2	O_2

Note: O_1 = measurement of estimated VO_2max before the training program; X_1 = fartlek training program; X_2 = continuous running training program; O_2 = measurement of estimated VO_2max after the training program.

Figure 1. Two-group pretest-posttest study design

Table 1

Changes in estimated VO_2max before and after the training programs

Group	n	Pretest mean	Posttest mean	$\Delta \text{Mean} \pm \text{SD}$	t	p
Fartlek	12	33.48	40.10	6.62 ± 4.31	5.32	< 0.001
Continuous running	12	33.20	38.50	5.40 ± 3.50	5.34	< 0.001

Note. Δ = posttest – pretest; estimated VO_2max is expressed in $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.

Table 2

Comparison of changes in estimated VO_2max between the fartlek and continuous running groups

Group	n	ΔMean	SD	t	df	p
Fartlek	12	6.62	4.31	0.693	22	0.496
Continuous running	12	5.40	3.50			

Discussion

The findings showed that estimated VO_2max increased significantly following the training program in both the fartlek and continuous running groups. The fartlek group showed a mean increase of 6.62 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, whereas the continuous running group increased by 5.40 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Although the improvement was descriptively greater in the fartlek group, the between-group difference in change was not statistically significant. Thus, the main finding of this study is that both forms of training were associated with improvements in cardiorespiratory capacity, but there was no evidence that one method produced a greater increase in estimated VO_2max than the other.

The improvement observed in the fartlek group is consistent with several previous studies. Bahtra et al. (2024) showed that fartlek training can improve VO_2max in adolescent soccer players, while Satria et al. (2024) reported improved aerobic endurance following an eight-week fartlek program in adolescent futsal players. In the context of pencak silat, Mardinus et al. (2025) also reported increased VO_2max following interval training, whereas Subekti et al. (2025) found improvements in physical fitness after high-intensity interval training in young pencak silat athletes. These findings are further supported by systematic reviews and meta-analyses showing that high-intensity interval training can improve aerobic capacity in combat-sport and martial arts athletes (Yue et al., 2025; Cai et al., 2026). On the other hand, the improvement in the continuous running group is also consistent with evidence that sustained aerobic training can enhance cardiorespiratory capacity. Su et al. (2025), for example, found that both moderate-intensity continuous training and sprint interval training improved aerobic capacity in adolescent boys. Therefore, the absence of a significant between-group difference in the present study is consistent with evidence suggesting that different training patterns can produce aerobic adaptations when the training stimulus is sufficient.

From a physiological perspective, the increase in estimated VO_2max in both groups can be explained by repeated stimulation of the cardiorespiratory system. Fartlek training involves variations in intensity, exposing the body alternately to periods of higher-intensity work and active recovery. This pattern may increase the demands placed on oxygen transport and utilization as well as on recovery between higher-intensity efforts. Such mechanisms are relevant to the intermittent nature of combat sports (Yue et al., 2025; Cai et al., 2026). In contrast, continuous running maintains a relatively stable aerobic workload over a longer duration, thereby providing a sustained stimulus to the cardiorespiratory system. Comparative evidence also indicates that both interval and continuous training can improve aerobic capacity, although the magnitude and pattern of adaptation may depend on training intensity, volume, program duration, and participant characteristics (Bi et al., 2026; Su et al., 2025; Wulandari et al., 2026). Therefore, the improvements observed in both groups are physiologically plausible, whereas the relatively small between-group difference in change may not have been large enough to reach statistical significance in the present sample.

Clinical implications

From a practical perspective, both fartlek and continuous running may be considered as alternative training methods for developing cardiorespiratory capacity in school-age pencak silat extracurricular participants. Fartlek may be useful when coaches wish to incorporate variations in speed and intensity within a single session, whereas continuous running may be used to provide a more stable aerobic stimulus that is relatively easy to control. However, the present findings do not demonstrate that the two methods are equivalent, nor do they show that one method is superior. Accordingly, the choice of training method should be based on program objectives, participant characteristics, the stage of training, and the coach's ability to regulate training intensity and volume.

Study limitations

This study has several limitations. The sample size was relatively small and was drawn from a single pencak silat extracurricular program, which limits the generalizability of the findings. Group allocation was conducted using ordinal pairing without randomization; therefore, the potential influence of confounding factors cannot be completely ruled out. Cardiorespiratory capacity was also assessed using the 20-m Multistage Fitness Test, meaning that VO_2max was estimated rather than directly measured using respiratory gas analysis (Nevill et al., 2021a). In addition, the study did not control for factors such as physical activity outside the training program, dietary intake, sleep, biological maturation, and other training loads that may have influenced aerobic responses. Future studies should include larger samples, use randomization and control groups where feasible, directly measure VO_2max , and apply more standardized monitoring of training intensity and load to clarify differences in responses to fartlek and continuous running.

Conslusions

Based on the findings, both fartlek and continuous running training were associated with improvements in estimated VO_2max among school-age pencak silat extracurricular participants. Although the fartlek group showed a descriptively greater mean improvement than the continuous running group, the between-group difference in change was not statistically significant. These findings indicate that both methods may be used as alternative approaches to developing cardiorespiratory capacity, but the study does not provide evidence that one method is superior or that the two methods are truly equivalent.

The choice of training method should therefore be tailored to the objectives of the training program, participant characteristics, and the prescribed intensity and volume. Future research should involve larger samples, incorporate randomization and stronger control procedures, and use more accurate measures of aerobic capacity to clarify potential differences in responses between the two training methods.

Author contributions

Conceptualization: M.R. and D.N.R.; Methodology: M.R. and D.N.R.; Investigation: M.R.; Data curation: M.R.; Formal analysis: M.R. and D.N.R.; Project administration: M.R.; Supervision: D.N.R.; Visualization: M.R.; Writing – original draft: M.R.; Writing – review & editing: M.R. and D.N.R. Both authors have read and approved the final version of the manuscript and agree to be accountable for the integrity and accuracy of the work.

Ethical statement

This study was conducted in accordance with generally accepted ethical principles for research involving human participants. Formal ethical clearance from an institutional ethics committee was not obtained. Permission to conduct the study was obtained from SMP Darul Ikhlas Cikarang prior to data collection, and the research procedures were coordinated with the school and the extracurricular pencak silat instructor. Participants' privacy, confidentiality, and welfare were maintained throughout the study.

Informed consent

Formal written informed consent from parents or legal guardians was not obtained. The study was conducted with permission from the school, and the participants were informed about the study procedures and the voluntary nature of participation. Participant confidentiality was maintained throughout the study.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely to improve language, grammar, and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the accuracy, integrity, and content of the publication.

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Conflicts of interest

The authors declare no conflicts of interest.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to appropriate ethical and privacy considerations.

References

- Al As'Ary, M. H., Pranoto, A., Suyoko, A., Adila, F., Heza, F. N., Saputra, Y. D., Sudijandoko, A., Pramono, M., Arief, N. A., & Orhan, B. E. (2026). Long-interval training effects on VO_2max , resting heart rate, and body composition in Pencak Silat athletes aged 16–18 years. *Pedagogy of Physical Culture and Sports*, 30(1), 52–61. <https://doi.org/10.15561/26649837.2026.0105>
- Báez-San Martín, E., Tuesta, M., Nieto-Jimenez, C., Ojeda-Aravena, A., Rojas-Valverde, D., Yáñez-Sepúlveda, R., & Alvear-Ordenes, I. (2025). Validity, reliability, and sensitivity of the Brazilian Jiu-Jitsu cardiorespiratory fitness test: A methodological approach based on combat specificity. *Applied Sciences*, 15(20), 11124. <https://doi.org/10.3390/app152011124>
- Bahtra, R., Zelino, R., Bafirman, Fajri, H. P., Valencia, W. G., Susanto, N., García-Jiménez, J. V., & Pavlovic, R. (2024). Enhancing VO_2Max : Contrasting effects of fartlek training and small-sided games. *Journal of Physical Education and Sport*, 24(2), 441–448. <https://doi.org/10.7752/jpes.2024.02054>
- Bi, Z., Yin, M., Xu, K., Marcotte-Chénard, A., Zhong, Y., Gu, Z., Vollaard, N., Metcalfe, R., Nassis, G., Girard, O., Bishop, D., & Li, Y. (2026). One size does not fit all: A meta-analysis of 115 trials comparing high-intensity interval and moderate-to-vigorous-intensity continuous training across diverse participants, protocols, and outcomes. *Scandinavian Journal of Medicine & Science in Sports*, 36(3), e70243. <https://doi.org/10.1111/sms.70243>
- Cai, M., Cai, H., Liu, C., & Qi, K. (2026). Effect of high-intensity interval training on aerobic capacity, physical fitness, and body composition in martial arts athletes: A systematic review and meta-analysis of randomized controlled trials. *Frontiers in Nutrition*, 13, 1792680. <https://doi.org/10.3389/fnut.2026.1792680>
- Lubis, J., Thongdaeng, N., Haqiyah, A., Sukur, A., Abidin, D., Irawan, A. A., Sumartiningsih, S., & Hanief, Y. N. (2022). The effect of five-week aerobic interval training on the body composition of Pencak Silat elite athletes. *International Journal of Kinesiology and Sports Science*, 10(2), 16–24. <https://doi.org/10.7575/aiac.ijkss.v10n.2p.16>
- Mardinus, A., Sofyan, D., Hadi, R. S., Barlian, E., Ihsan, N., Astuti, Y., & Ockta, Y. (2025). Effectiveness of interval training in increasing VO_2max in Pencak Silat athletes. *Sport TK*, 14, Article 11. <https://doi.org/10.6018/sportk.643791>
- Matzka, M., Lenk, M., Meixner, B., & Sperlich, B. (2025). Meta-analysis of high-intensity interval training and

- alternative modalities for enhancing aerobic and anaerobic endurance in young athletes. *Physiological Reports*, 13(19), e70598. <https://doi.org/10.14814/phy2.70598>
- Nevill, A. M., De Menezes-Junior, F. J., De Jesus, Í. C., De Fatima Aguiar Lopes, M., Corazza, P. R. P., Tadiotto, M. C., Mota, J., & Leite, N. (2021). Predicting cardiorespiratory fitness using the 20-m shuttle run test: New insights using nonlinear allometry. *Medicine & Science in Sports & Exercise*, 53(8), 1624–1629. <https://doi.org/10.1249/MSS.0000000000002637>
- Nevill, A. M., Ramsbottom, R., Sandercock, G., Bocachica-González, C. E., Ramírez-Vélez, R., & Tomkinson, G. (2021). Developing a new curvilinear allometric model to improve the fit and validity of the 20-m shuttle run test as a predictor of cardiorespiratory fitness in adults and youth. *Sports Medicine*, 51(7), 1581–1589. <https://doi.org/10.1007/s40279-020-01346-0>
- Satria, M. H., Juhani, J., Da'i, M., Isnaini, L. M. Y., Anam, K., & Dwijayanti, K. (2024). Effectiveness of circuit and fartlek exercises to increase aerobic endurance in adolescent futsal players. *International Journal of Disabilities Sports and Health Sciences*, 7(4), 782–795. <https://doi.org/10.33438/ijds.shs.1461483>
- Su, W., Liu, J., Wang, A., Zhang, H., Sun, Y., Yan, Z., Svensson, M., Yu, J.-G., & Zhao, L. (2025). Distinct lipidomic profiles but similar improvements in aerobic capacity following sprint interval training versus moderate-intensity continuous training in male adolescents. *Frontiers in Physiology*, 16, 1475391. <https://doi.org/10.3389/fphys.2025.1475391>
- Subekti, N., Hidayatullah, M. F., Syaifullah, R., Setiyadi, N. A., & Warthadi, A. N. (2025). The effect of four-week high-intensity interval training on increasing physical fitness and specific speed in young Pencak Silat athletes. *Sport TK*, 14, Article 37. <https://doi.org/10.6018/sportk.574961>
- Vasconcelos, B. B., Protzen, G. V., Galliano, L. M., Kirk, C., & Del Vecchio, F. B. (2020). Effects of high-intensity interval training in combat sports: A systematic review with meta-analysis. *Journal of Strength and Conditioning Research*, 34(3), 888–900. <https://doi.org/10.1519/JSC.0000000000003255>
- Wijaya, R. G., Fitri, E. S. M., Nugraha, P. D., Sepriyanto, A., & Zarya, F. (2024). Improving the performance of karate athletes: Fartlek and circuit training in the increasing VO2 max. *Fizjoterapia Polska*, 2024(1), 98–104. <https://doi.org/10.56984/8ZG2EF824g>
- Wulandari, F. Y., Pambudi, N. A., Jatmikanto, R. S., Hafidz, A., Fajar, M. K., Daulay, D. A. A., Widohardhono, R., Andriana, L. M., & Adi, C. (2026). High-intensity interval training outperforms fartlek and continuous training in aerobic and running-mechanics adaptations: Evidence from athletics education. *Physical Education Theory and Methodology*, 26(1), 193–205. <https://doi.org/10.17309/tmf.2026.1.19>
- Yahat, H. (2025). Optimising adolescent health: A comparative study of high-intensity interval training and moderate-intensity continuous training on body composition and cardiovascular fitness in sedentary male youth. *Frontiers in Sports and Active Living*, 7, 1655906. <https://doi.org/10.3389/fspor.2025.1655906>
- Yang, Y., Peng, Y., Min, Q., Lian, Y., Wang, D., Song, X., & Zhou, L. (2025). Effects of combined high-intensity interval and moderate-intensity continuous training vs. moderate-intensity continuous training alone in male adolescents: A randomized controlled trial. *Scientific Reports*, 15(1), 13353. <https://doi.org/10.1038/s41598-025-94949-4>
- Yue, F., Wang, Y., Yang, H., & Zhang, X. (2025). Effects of high-intensity interval training on aerobic and anaerobic capacity in Olympic combat sports: A systematic review and meta-analysis. *Frontiers in Physiology*, 16, 1576676. <https://doi.org/10.3389/fphys.2025.1576676>
- Zheng, W., Yin, M., Guo, Y., Liu, H., Sun, J., Zhu, A., Zhong, Y., Xu, K., Li, H., & Piao, S. (2025). Effects and moderator of high-intensity interval training and moderate-intensity continuous training among children and adolescents with overweight or obesity: A systematic review and meta-analysis. *Frontiers in Physiology*, 16, 1625516. <https://doi.org/10.3389/fphys.2025.1625516>