

Research Article

Effects of three-month fartlek training on resting and dynamic blood pressure in adolescents: A quasi-experimental study

Fatoni^{1*}, Bilal Ahmad Qureshi², Agam Akhmad Syaukani³, Bekir Erhan Orhan⁴, Hasbi Asyhari¹^{1,5} Department of Physical Education Health and Recreation, Faculty of Sports and Health Sciences, Universitas Negeri Makassar, Wijaya Kusuma Raya Street No. 14, 90222, Indonesia² Department of Sports Sciences, Faculty of Arts and Humanities, University of Sargodha, University Road Sargodha, 40100, Pakistan³ Department of Physical Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Surakarta, Ahmad Yani Street, 57169, Indonesia⁴ Department of Physical Education and Sports Teaching, Faculty of Sports Sciences, Istanbul Aydın University, Beşyol İnönü Cd. No. 38, 34295, Turkey*Corresponding author, email: fatoni@unm.ac.id**ABSTRACT**

Background: Blood pressure regulation is an important indicator of cardiovascular function, which is influenced by physical activity. Aerobic exercise has been shown to lower blood pressure. However, studies on the effects of varying intensity training, such as fartlek, on resting blood pressure and dynamic responses during physical activity are limited, particularly in younger populations. Objective: This study aimed to analyze resting blood pressure adaptation and the dynamic blood pressure response after participation in a 3-month fartlek training program. Methods: This quasi-experimental pretest–posttest study involved 59 male adolescents (13-14 years) selected through purposive sampling. A three-month fartlek program was conducted. Blood pressure at rest, during activity, and during recovery was measured using a bicycle test and a digital sphygmomanometer, and analyzed with paired t-tests and Cohen's d. Result: Resting systolic blood pressure decreased from 96.1 ± 11.2 to 91.6 ± 8.0 mmHg ($p < 0.001$; $d = 1.41$), while diastolic pressure decreased from 58.7 ± 9.1 to 57.2 ± 7.1 mmHg ($p < 0.05$; $d = 0.75$). During activity, the decrease in blood pressure was more pronounced at submaximal ($d = 0.58$) than at higher intensities ($d = 0.23$ - 0.24). In the recovery phase, there was a consistent increase in cardiovascular efficiency, with moderate to near-large effect sizes ($d = 0.60$ - 0.72). Conclusion: Fartlek training effectively improves blood pressure regulation and cardiovascular function in young individuals, particularly in enhancing submaximal response efficiency and accelerating hemodynamic recovery after physical activity. Future studies should include control groups and additional physiological parameters to strengthen causal interpretation and generalizability.

ARTICLE HISTORY

Received January 11, 2026

Accepted March 15, 2026

Published April 01, 2026

KEYWORDS

Adolescents; blood pressure; cardiovascular adaptation; dynamic response; fartlek training.

Introduction

Blood pressure represents the force exerted by circulating blood against the arterial walls and serves as a fundamental indicator of cardiovascular function. It consists of systolic pressure, generated during ventricular contraction, and diastolic pressure, occurring during cardiac relaxation. These components reflect the efficiency of cardiovascular regulation in maintaining tissue perfusion and oxygen delivery. Blood pressure is regulated by complex physiological mechanisms, including cardiac output, peripheral vascular resistance, and arterial elasticity (Bar et al., 2021; Lim, 2022; Suárez-Roca et al., 2024).

Blood pressure is dynamic and can change in response to various physiological conditions, including physical activity. When a person performs physical activity, the metabolic needs of the tissues increase, requiring the cardiovascular system to adapt through increased heart rate, cardiac output, and changes in blood pressure to maintain oxygen supply to the working tissues (Arora et al., 2023; Carrara et al., 2024; Silva et al., 2021). The blood pressure response during physical activity and during recovery reflects the cardiovascular system's ability to adapt to the physiological stress of exercise (Álvarez-Pitti et al., 2022; Čurović, 2025). Therefore, evaluating blood pressure not only at rest but also during physical activity and recovery provides a more comprehensive understanding of cardiovascular function.

Regular physical exercise is known to provide various cardiovascular health benefits, including lowering systolic and diastolic blood pressure. Numerous studies have shown that aerobic exercise can significantly lower blood pressure by improving endothelial function, reducing sympathetic nerve activity, and increasing blood vessel elasticity (Liu et al., 2022; Saladini, 2023). Furthermore, aerobic exercise can increase cardiorespiratory capacity and cardiac efficiency, thereby improving blood pressure regulation in both healthy individuals and those at risk for cardiovascular disease (Alhumaid et al., 2022; Andriana et al., 2025; Laukkanen et al., 2022).

One aerobic exercise method widely used to improve cardiovascular fitness is fartlek training. This training method combines intensity variations within a single training session by alternating periods of high-intensity and low-intensity activity (Fitrian et al., 2023; Xu et al., 2025). This varied training pattern allows for simultaneous stimulation of the aerobic and anaerobic energy systems, thereby increasing aerobic capacity and the efficiency of the cardiovascular response to physical activity.

Several previous studies have reported that aerobic exercise can significantly lower blood pressure and improve cardiovascular function (Choi et al., 2020; Chomiuk et al., 2024; Kiekens & Young, 2022). This is supported by other reviews and meta-analyses that highlight that aerobic duration and intensity play a major role in the antihypertensive effect (Chomiuk et al., 2024), as well as clinical practice recommendations that emphasize the need for 90-150 minutes/week of aerobic exercise for BP benefits (Song et al., 2022; Trindade et al., 2022). However, the current body of literature predominantly emphasizes resting blood pressure, while dynamic responses during exercise and recovery remain underexplored. Moreover, empirical evidence on the medium-term effects of fartlek training on blood pressure adaptation, especially in adolescent populations, is still limited, highlighting a critical gap in the literature.

These limitations indicate a research gap in understanding how fartlek training methods affect blood pressure dynamics at rest, during physical activity, and during recovery. Understanding dynamic blood pressure adaptation is crucial for describing the cardiovascular system's ability to respond to physiological stress during exercise and the recovery process after physical activity.

Based on this background, this study aims to analyze dynamic and resting blood pressure adaptations after a three-month fartlek training program in young individuals. This research is expected to contribute to the scientific understanding of the cardiovascular system's physiological responses to exercise of varying intensities and to add to the empirical evidence on the effectiveness of fartlek training in improving blood pressure adaptation.

Method

Research Design

This study used a quasi-experimental design with a pretest-posttest approach to evaluate changes in resting blood pressure and dynamic blood pressure responses following a three-month fartlek training program. The absence of a control group was justified by practical and ethical considerations in maintaining equal access to physical activity among participants. The study was conducted over three months among male students actively participating in school sports.

Participants

A total of 59 participants were selected using a purposive sampling technique based on the following inclusion criteria: male, aged 13-14 years, in good health, and with no history of cardiovascular disease or metabolic disorders. Participants who did not complete the entire training program or the measurement process were excluded from the analysis.

Participant characteristics showed an average age of 13.02 ± 0.13 years, body weight of 37.07 ± 8.07 kg, and height of 144.51 ± 6.65 cm. All participants followed a structured training program throughout the intervention period. Prior to hypothesis testing, data normality was assessed using the Shapiro-Wilk test to ensure the appropriateness of parametric statistical analysis.

Ethical Approval Statement

This study obtained ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Hasanuddin University prior to implementation. Written informed consent was obtained from all participants and their guardians, and all research procedures were approved by the Hasanuddin University Ethics Committee (Approval Number: 557/H4.8.4.5.31/PP36-KOMETIK).

Procedures

The fartlek training program is implemented for 3 months, with a scheduled training frequency, as part of a cardiovascular fitness improvement program. The training is carried out according to the principle of intensity variation, alternating moderate and high-intensity activities in a single training session. Each training session consists of three stages, namely: a) Warm-up ($\pm 10-15$ minutes) to prepare the cardiovascular and musculoskeletal systems; b) Core training, in the form of variations in speed or intensity (unstructured intervals typical of fartlek) and Cool-down (± 10 minutes) to restore physiological conditions to normal. This approach aims to provide varied physiological stimuli to improve cardiovascular system adaptation optimally.

Research Instruments

Blood pressure was measured with a calibrated digital sphygmomanometer to ensure accuracy. Systolic and diastolic blood pressure were measured at rest, during physical activity, and during the recovery phase to evaluate the dynamic blood pressure response. The measurement procedure was carried out systematically to obtain an accurate picture of the blood pressure response. Participants first underwent a 15-minute rest period before taking the initial resting blood pressure measurement. Afterward, participants underwent a static bicycle test to assess blood pressure responses during physical activity. Measurements were conducted in stages, including a 2-minute rest phase on the bicycle, followed by measurements at minutes 3 and 6 during the activity. Measurements were then continued during a 6-minute recovery phase, at minutes 1, 3, and 6. This series of procedures was designed to provide a comprehensive evaluation of the dynamics of the blood pressure response during physical activity and of the cardiovascular system's recovery after exercise.

Data Analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 24. Descriptive statistics were used to present participant characteristics as mean values and standard deviations. Differences in blood pressure before and after the intervention were analyzed using a paired sample t-test with a significance level of $p < 0.05$. In addition, the effect size (Cohen's d) was calculated to assess the magnitude of the intervention's effect on blood pressure. Effect size values were interpreted as small (0.2), medium (0.5), and large (≥ 0.8). Descriptive analysis was also used to characterize the pattern of blood pressure changes during physical activity and during recovery. All analysis results are presented in tables and narrative descriptions to facilitate interpretation of the cardiovascular system adaptations.

Results and Discussion

Results

Characteristics of Research Participants

A total of 59 male participants aged 13–14 years completed the entire study. General participant characteristics, including age, weight, and height, are presented in [Table 1](#).

Table 1. Characteristics of Participants

Variable	Mean ± SD	Min–Max
Age (years)	13.02 ± 0.13	13–14
Weight (kg)	37.07 ± 8.07	25–64
Height (cm)	144.51 ± 6.65	129–159

The data in [Table 1](#) show that participants had relatively homogeneous age distributions, with greater variation in weight and height. This reflects a representative population of early adolescents, with anthropometric variations still within the normal range.

Changes in Resting Blood Pressure

Changes in systolic and diastolic blood pressure at rest before and after the three-month fartlek training program are presented in [Table 2](#). The results demonstrated a significant reduction in both systolic and diastolic blood pressure following the intervention. The decrease in systolic blood pressure (4.5 mmHg) was associated with a large effect size ($d = 1.41$), indicating a substantial physiological impact. Meanwhile, the reduction in diastolic pressure showed a moderate-to-large effect ($d = 0.75$), suggesting improved vascular regulation.

Table 2. Changes in Resting Systolic and Diastolic Blood Pressure Before and After Three Months of Fartlek Training

Variable	Before Training (Mean ± SD)	After Training (Mean ± SD)	Mean Difference	p-value	Cohen’s d	Effect Size Interpretation
Systolic Blood Pressure (mmHg)	96.1 ± 11.2	91.6 ± 8.0	4.5 ± 3.2	<0.001*	1.41	Large
Diastolic Blood Pressure (mmHg)	58.7 ± 9.1	57.2 ± 7.1	1.5 ± 2.0	<0.05*	0.75	Moderate-Large

The implementation highlights how educational technology fosters the engagement necessary for student success. Technical validation showed that sensor reliability reached optimal levels, ensuring the data is a dependable foundation for performance evaluation. Although network congestion occasionally impacted latency, the system maintained the speeds required for immediate feedback. The trial results further demonstrate that leveraging data analytics within an IoT framework effectively identifies patterns in student learning and athletic achievement.

As illustrated in [Figure 1](#), the downward trend in both variables is visually evident, with a more pronounced decline in systolic blood pressure. This graphical pattern corroborates the statistical results presented in [Table 2](#), underscoring the effectiveness of Fartlek training in improving cardiovascular function.

Dynamic Blood Pressure Response During Exercise

Blood pressure response during physical activity was evaluated using a static bicycle test at several intensity levels. The results of the analysis are presented in [Table 3](#). The results showed a decrease in systolic blood pressure across all activity phases after the intervention. The largest decrease was found

in the initial activity phase (resting on a bicycle) with a moderate effect size ($d = 0.58$), indicating an increase in the efficiency of the cardiovascular response under submaximal conditions.

Table 3. Dynamic Systolic Blood Pressure Response During Exercise with Effect Size

Measurement Time	Before Training (Mean ± SD)	After Training (Mean ± SD)	Mean Difference	Cohen's d	Effect Size
Resting on bicycle (2 min)	104.0 ± 9.6	98.8 ± 8.0	5.2	0.58	Moderate
Minute 3 exercise	111.9 ± 15.9	108.1 ± 8.3	3.8	0.24	Small
Minute 6 exercise	119.1 ± 15.4	115.6 ± 10.0	3.5	0.23	Small

Conversely, in the higher activity phase (minutes 3 and 6), the decrease in blood pressure showed a small effect size ($d = 0.23-0.24$), indicating that cardiovascular adaptation during higher-intensity activity is more limited than during the low-to-moderate intensity phase.

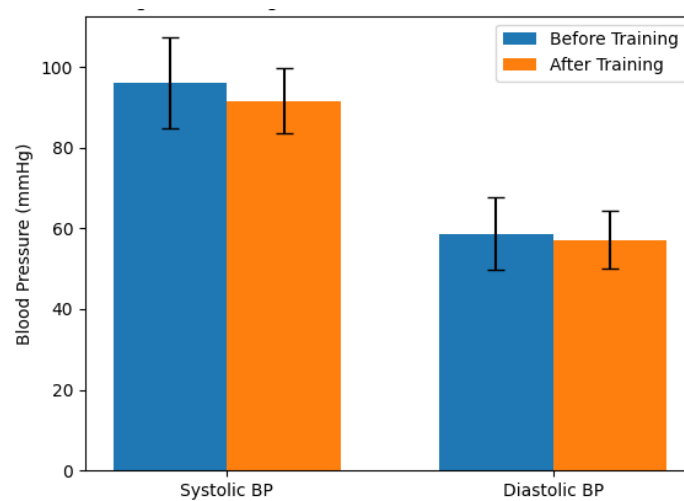


Figure 1. Decrease in Resting Systolic and Diastolic Blood Pressure Following Three Months of Fartlek Training

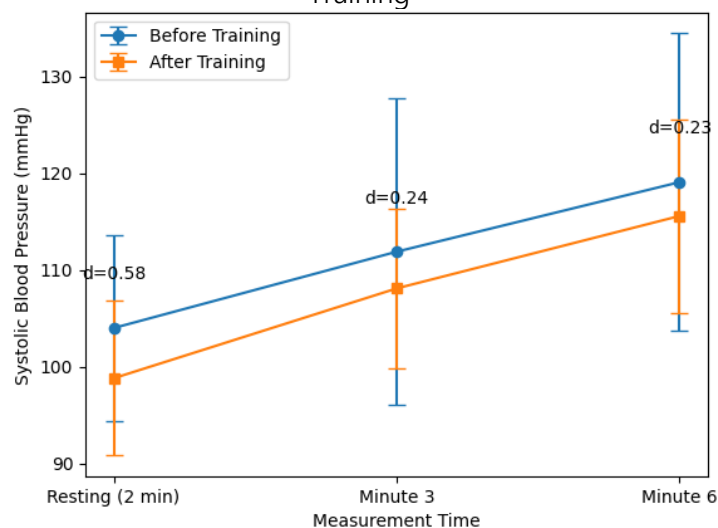


Figure 2. Dynamic Changes in Systolic Blood Pressure Across Exercise Phases Before and After Fartlek Training

Figure 2 shows a consistent reduction in systolic blood pressure across all measurement phases following the intervention. The most notable decrease occurs during the resting phase, with a moderate effect size, indicating improved cardiovascular efficiency under low-intensity conditions. In contrast,

during higher exercise intensities (minute 3 and minute 6), the reductions in systolic blood pressure are less pronounced and correspond to smaller effect sizes. This pattern suggests that while Fartlek training effectively enhances cardiovascular responses at rest and during submaximal activity, the magnitude of adaptation becomes relatively limited as exercise intensity increases.

Blood Pressure Response During Recovery

Blood pressure responses during the recovery phase after physical activity are presented in Table 4. The results showed that systolic blood pressure consistently decreased during the recovery phase at all time points after the intervention. The effect size was moderate to nearly large ($d = 0.60-0.72$), indicating an increase in cardiovascular recovery efficiency after physical activity. The relatively stable decrease throughout the recovery phase indicates that the fartlek training program contributed to improved autonomic regulation and accelerated homeostasis after physical activity.

Table 4. Dynamic Systolic Blood Pressure Response During Exercise with Effect Size

Recovery Time	Before Training (Mean ± SD)	After Training (Mean ± SD)	Mean Difference	Cohen's d	Effect Size
Recovery 1 min	110.1 ± 9.0	105.0 ± 8.0	5.1	0.60	Moderate
Recovery 3 min	103.9 ± 8.9	99.2 ± 6.5	4.7	0.61	Moderate
Recovery 6 min	99.9 ± 7.3	95.0 ± 6.2	4.9	0.72	Moderate-Large

The findings demonstrate that the three-month fartlek training program produced significant improvements in cardiovascular function, as evidenced by a substantial reduction in resting blood pressure (large effect size), improved blood pressure responses during physical activity, and enhanced recovery efficiency (moderate to large effect sizes).

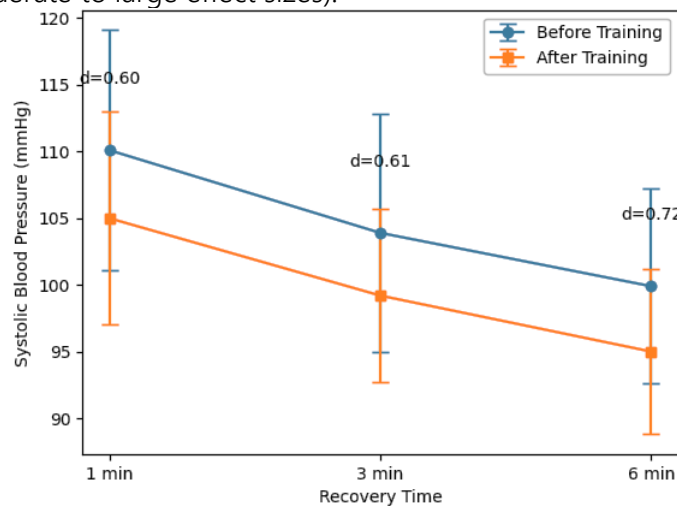


Figure 3. Changes in Systolic Blood Pressure During Recovery Following Three Months of Fartlek Training (Mean ± SD)

As illustrated in Figure 3, systolic blood pressure consistently decreased at all recovery time points following the intervention, demonstrating a clear and progressive decline from the first to the sixth minute of recovery. This pattern indicates improved post-exercise cardiovascular regulation, as the body returns to baseline conditions more efficiently. The reduction observed at each time interval suggests enhanced recovery capacity, which is further supported by moderate to near-large effect sizes ($d = 0.60-0.72$). Notably, the magnitude of reduction becomes more apparent at later recovery stages, reflecting improved autonomic control, particularly faster parasympathetic reactivation and reduced sympathetic dominance after exercise. These findings highlight the role of Fartlek training in

accelerating physiological recovery processes and promoting more efficient cardiovascular adaptation following physical exertion.

The reductions were observed at 1, 3, and 6 minutes of recovery, indicating a progressive decline pattern. The effect sizes ranged from moderate to approaching large ($d = 0.60\text{--}0.72$), with the largest effect observed at the 6-minute recovery point. This trend suggests improved cardiovascular recovery efficiency, likely reflecting enhanced autonomic regulation, particularly faster parasympathetic reactivation following exercise.

Discussion

The results of this study indicate that a three-month fartlek training program had a positive effect on blood pressure adaptation in young individuals. The reductions in resting systolic and diastolic blood pressure were not only statistically significant but also clinically meaningful, as indicated by large effect sizes for systolic blood pressure ($d = 1.41$) and moderate-to-large effect sizes for diastolic blood pressure ($d = 0.75$). The findings of this study indicate that fartlek training induces significant cardiovascular adaptations, as evidenced by reductions in both resting and exercise blood pressure. The large effect size observed in systolic blood pressure suggests a clinically meaningful improvement in cardiovascular efficiency. These adaptations are likely mediated by enhanced endothelial function, increased nitric oxide bioavailability, and improved autonomic regulation (Azimkhani et al., 2025; Hedge et al., 2024; Tarumi et al., 2024).

This finding aligns with numerous studies showing that aerobic exercise significantly lowers blood pressure by improving vascular function and cardiac efficiency. Aerobic exercise has been shown to lower blood pressure by improving endothelial function and vasodilatory capacity (Kozàková & Palombo, 2021), as well as increasing baroreflex sensitivity, which plays a role in blood pressure regulation (Alvarez-Araos et al., 2024). Recent meta-analyses also show that aerobic exercise interventions for 8-12 weeks produce clinically significant reductions in blood pressure (Saco-Ledo et al., 2020; Sarnaik & Mirzai, 2025; Schneider et al., 2023). The results of this study strengthen these findings by demonstrating that the fartlek training method is not only effective on resting blood pressure, but also on dynamic blood pressure responses.

Further analysis showed that cardiovascular adaptations did not occur uniformly across activity conditions. The decrease in blood pressure during physical activity showed a moderate effect size in the low-intensity phase ($d = 0.58$), but only a small effect size in the higher-intensity phase ($d = 0.23\text{--}0.24$). This pattern indicates that the initial adaptations to fartlek training are more pronounced in submaximal than in high-intensity conditions. This is likely due to increased cardiac efficiency and more optimal blood flow distribution at low to moderate intensities, while at high intensities, the body still requires a greater hemodynamic response to meet metabolic demands (Kammerlander et al., 2025; Schierbauer et al., 2021). Thus, the dynamic analysis in this study primarily reflects systolic blood pressure responses.

Conversely, results in the recovery phase showed a more consistent increase in adaptation, with moderate to large effect sizes ($d = 0.60\text{--}0.72$) at all recovery time points. These findings suggest that fartlek training plays a significant role in improving cardiovascular recovery efficiency after physical activity. The accelerated reduction in blood pressure during the recovery phase reflects increased regulation of the autonomic nervous system, specifically increased parasympathetic activity and decreased sympathetic activity (Bajdek et al., 2023; Seeley et al., 2021; Sriton et al., 2022).

The superiority of fartlek training over continuous aerobic exercise is also evident in its ability to stimulate more complex physiological adaptations. Variation in intensity in fartlek allows for alternating activation of the aerobic and anaerobic energy systems, thereby increasing metabolic efficiency and tissue oxygenation capacity (Matzka et al., 2025; Santos-Silva et al., 2021). Training with varying intensities can increase arterial elasticity and decrease blood vessel stiffness, thereby lowering blood

pressure (Cavero-Redondo et al., 2023; Königstein et al., 2023; Shishira et al., 2024). Furthermore, increased nitric oxide (NO) bioavailability due to interval training plays a key role in vasodilation and improved endothelial function (Lavier et al., 2021).

The resulting blood pressure adaptations can be explained by improved vascular endothelial function. Aerobic exercise increases the activity of the enzyme endothelial nitric oxide synthase (eNOS), which plays a role in NO production. Increased NO levels relax vascular smooth muscle, thereby reducing peripheral resistance and blood pressure (Song et al., 2022). Furthermore, increased antioxidant capacity due to exercise also plays a role in maintaining endothelial function by reducing oxidative stress (Kozàková & Palombo, 2021).

Another significant adaptation occurs in the autonomic nervous system. Moderate aerobic exercise increases parasympathetic activity and decreases sympathetic activity at rest, which impacts heart rate stability and blood pressure (Grässler et al., 2021). This condition also contributes to a faster rate of blood pressure recovery after physical activity, as shown in this study.

Limitations of Study

This study has several limitations. The lack of a control group and randomization limits causal inference and increases the potential for confounding. The use of purposive sampling with a relatively homogeneous sample also limits the generalizability of the findings. Furthermore, external factors such as diet and daily physical activity were not controlled, and potential bias due to maturational effects in adolescents could have influenced the study results. Although normality tests were performed using the Shapiro-Wilk test, potential measurement bias and the relatively short intervention duration may limit the interpretation of long-term physiological outcomes. Furthermore, the analysis in this study focused primarily on systolic blood pressure, while diastolic responses during dynamic activity were not comprehensively explored. Therefore, a more integrative study is needed in future research.

Conclusions

A three-month fartlek training program has been shown to significantly improve blood pressure regulation in adolescents, as demonstrated by reductions in resting systolic and diastolic blood pressure, with large and moderate-to-large effect sizes, respectively. During physical activity, blood pressure reduction was more pronounced at submaximal intensities. At the same time, during the recovery phase, a consistent increase in cardiovascular efficiency was observed with moderate to near-large effect sizes.

These findings indicate that fartlek training is effective in improving cardiovascular function, particularly in optimizing hemodynamic responses to submaximal activity and accelerating post-exercise recovery. In practice, this method can be applied in physical education and coaching as a flexible aerobic exercise to improve adolescent fitness, with potential benefits for early hypertension prevention and cardiovascular risk reduction. However, given the quasi-experimental design without a control group, results should be interpreted with caution. Future studies should use controlled experimental designs and include additional physiological parameters.

Authors' contributions

F, BAQ, AAS, BEO, and HA contributed to the research concept and design. F and BEO contributed to the collection and/or assembly of data. AAS, BEO, and HA contributed to the data analysis and interpretation. BAQ, AAS, BEO, and HA contributed to writing the article. BEO also contributed to the critical revision of the article. All authors contributed to the final approval of the article.

Competing interests

The authors declare no competing interests.

AI Disclosure Statement

During the preparation of this manuscript, the author used Scite AI to assist in searching for scientific references. All results have been critically reviewed, verified, and edited by the author to ensure scientific accuracy, clarity of presentation, and compliance with academic standards. The author takes full responsibility for the integrity and content of this manuscript.

Data Availability Statement

The data supporting the findings of this study are available upon request to the corresponding author. The data are not publicly available to protect the privacy of the study participants.

Funding

This research did not receive external funding.

Publisher's Note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or a claim its manufacturer may make, is not guaranteed or endorsed by the publisher.

References

- Alhumaid, W., Small, S. D., Kirkham, A. A., Becher, H., Pituskin, E., Prado, C. M., Thompson, R. B., Haykowsky, M. J., & Paterson, D. I. (2022). A contemporary review of the effects of exercise training on cardiac structure and function and cardiovascular risk profile: insights from imaging. *Frontiers in Cardiovascular Medicine*, *9*, 753652. [[Crossref](#)]
- Alvarez-Araos, P., Jiménez, S., Salazar-Ardiles, C., Núñez-Espinosa, C., Paez, V., Rodríguez-Fernández, M., Raberin, A., Millet, G. P., Iturriaga, R., & Andrade, D. C. (2024). Baroreflex and chemoreflex interaction in high-altitude exposure: possible role on exercise performance. *Frontiers in Physiology*, *15*, 1422927. [[Crossref](#)]
- Álvarez-Pitti, J., Herceg-Čavrak, V., Wójcik, M., Radovanović, D., Brzeziński, M., Grabitz, C., Wühl, E., Drożdż, D., & Melk, A. (2022). Blood pressure response to exercise in children and adolescents. *Frontiers in Cardiovascular Medicine*, *9*, 1004508. [[Crossref](#)]
- Andriana, L. M., Ashadi, K., Wijaya, F. J. M., & Antoni, M. F. . (2025). Low-impact specialized pilates is better than low intensity steady state for increasing fitness level. *Physical Education and Sports: Studies and Research*, *4*(2), 139-151. [[Crossref](#)]
- Arora, Y., Zhao, F., Cheung, M., Stefanski, M., Hosseini-Kakhak, S. A., & Dutta, A. (2023). Mechanistic Insights into Cerebrovascular Effects via Modal Analysis in Type 2 Diabetes and Dementia. *Preprints*. [[Crossref](#)]
- Azimkhani, A., Kasraei, R., Sabeti, H., & Almasoodi, A. (2026). The Effect of Aerobic, Resistance, and Combined Exercise Training on Cardiorespiratory Fitness in Healthy People Aged 60 years and Over: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Biological Research For Nursing*, *28*(1), 72-90. [[Crossref](#)]
- Bajdek, N., Merchant, N., Camhi, S. M., & Yan, H. (2023). Racial differences in blood pressure and autonomic recovery following acute supramaximal exercise in women. *International Journal of Environmental Research and Public Health*, *20*(9), 5615. [[Crossref](#)]
- Bar, S., Nguyen, M., Abou-Arab, O., Dupont, H., Bouhemad, B., & Guinot, P. G. (2021). Dynamic arterial elastance is associated with the vascular waterfall in patients treated with norepinephrine: an observational study. *Frontiers in Physiology*, *12*, 583370.. [[Crossref](#)]
- Carrara, M., Campitelli, R., Guberti, D., Monge Garcia, M. I., & Ferrario, M. (2024). The role of pulse wave analysis indexes for critically ill patients: a narrative review. *Physiological Measurement*, *45*(8), 08TR01. [[Crossref](#)]

- Cavero-Redondo, I., Saz-Lara, A., Martínez-García, I., Bizzozero-Peroni, B., Díaz-Goñi, V., Díez-Fernández, A., Moreno-Herráiz, N., & Pascual-Morena, C. (2023). Comparative effect of two types of physical exercise for the improvement of exercise capacity, diastolic function, endothelial function and arterial stiffness in participants with heart failure with preserved ejection fraction (ExIC-FEp study): Protocol for a randomized controlled trial. *Journal of Clinical Medicine*, *12*(10), 3535. [Crossref]
- Choi, H. M., Hurr, C., & Kim, S. (2020). Effects of elastic band exercise on functional fitness and blood pressure response in the healthy elderly. *International Journal of Environmental Research and Public Health*, *17*(19), 7144. [Crossref]
- Chomiuk, T., Niezgodą, N., Mamcarz, A., & Śliż, D. (2024). Physical activity in metabolic syndrome. *Frontiers in Physiology*, *15*, 1365761. [Crossref]
- Curovic, I. (2025). The role of resistance exercise-induced local metabolic stress in mediating systemic health and functional adaptations: could condensed training volume unlock greater benefits beyond time efficiency?. *Frontiers in Physiology*, *16*, 1549609. [Crossref]
- Fitrian, Z. A., Graha, A. S., Nasrulloh, A., Munir, A., Asmara, M., & Irsyad, N. Y. (2023). The effect of circuit training, fartlek, and small-sided games on maximum oxygen consumption capacity building in futsal players. *Health, Sport, Rehabilitation*, *9*(2), 48-60. [Crossref]
- Grässler, B., Thielmann, B., Böckelmann, I., & Hökelmann, A. (2021). Effects of different exercise interventions on heart rate variability and cardiovascular health factors in older adults: a systematic review. *European Review of Aging and Physical Activity*, *18*(1), 24. [Crossref]
- Hedge, E. T., Brazile, T. L., Hughson, R. L., & Levine, B. D. (2025). Plasticity of the heart in response to changes in physical activity. *The Journal of Physiology*, *603*(13), 3665-3677. [Crossref]
- Kammerlander, A., Schneider, S. R., Furian, M., Schwarz, E. I., Lichtblau, M., Ulrich, S., & Müller, J. (2025). Effect of eccentric cycling on oxygen uptake and hemodynamics in patients with chronic obstructive pulmonary disease: a randomized controlled crossover trial. *Respiration*, *104*(9), 637-647. [Crossref]
- Kiekens, C., & Young, V. M. (2022). Can Walking Lower Blood Pressure in Adults?: A Cochrane Review Summary With Commentary. *American Journal of Physical Medicine & Rehabilitation*, *101*(11), 1083-1085. [Crossref]
- Königstein, K., Dipla, K., & Zafeiridis, A. (2023). Training the vessels: molecular and clinical effects of exercise on vascular health—a narrative review. *Cells*, *12*(21), 2544. [Crossref]
- Kozakova, M., & Palombo, C. (2021). Vascular ageing and aerobic exercise. *International Journal of Environmental Research and Public Health*, *18*(20), 10666. [Crossref]
- Laukkanen, J. A., Isiozor, N. M., & Kunutsor, S. K. (2022, June). Objectively assessed cardiorespiratory fitness and all-cause mortality risk: an updated meta-analysis of 37 cohort studies involving 2,258,029 participants. In *Mayo Clinic Proceedings* (Vol. 97, No. 6, pp. 1054-1073). [Crossref]
- Lavier, J., Beaumann, M., Ménetrey, S., Bouzourène, K., Rosenblatt-Velin, N., Pialoux, V., Mazzolai, L., Peyter, A., Pellegrin, M., & Millet, G. P. (2021). High-intensity exercise in hypoxia improves endothelial function via increased nitric oxide bioavailability in C57BL/6 mice. *Acta Physiologica*, *233*(2), e13700. [Crossref]
- Lim, H. S. (2022). Phenotyping and hemodynamic assessment in cardiogenic shock: From physiology to clinical application. *Cardiology and Therapy*, *11*(4), 509-522. [Crossref]
- Liu, W. L., Lin, Y. Y., Mündel, T., Chou, C. C., & Liao, Y. H. (2022). Effects of acute interval exercise on arterial stiffness and cardiovascular autonomic regulatory responses: a narrative review of potential impacts of aging. *Frontiers in Cardiovascular Medicine*, *9*, 864173. [Crossref]
- 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. [Crossref]
- Saco-Ledo, G., Valenzuela, P. L., Ruiz-Hurtado, G., Ruilope, L. M., & Lucia, A. (2020). Exercise reduces

- ambulatory blood pressure in patients with hypertension: a systematic review and meta-analysis of randomized controlled trials. *Journal of the American Heart Association*, *9*(24), e018487. [[Crossref](#)]
- Saladini, F. (2023). Effects of different kinds of physical activity on vascular function. *Journal of Clinical Medicine*, *13*(1), 152. [[Crossref](#)]
- Sarnaik, K. S., & Mirzai, S. (2025). Review of Blood Pressure Control in Vulnerable Older Adults: The Role of Frailty and Sarcopenia. *Journal of Vascular Diseases*, *4*(2), 18. [[Crossref](#)]
- Schierbauer, J., Hoffmeister, T., Treff, G., Wachsmuth, N. B., & Schmidt, W. F. (2021). Effect of exercise-induced reductions in blood volume on cardiac output and oxygen transport capacity. *Frontiers in Physiology*, *12*, 679232. [[Crossref](#)]
- Schneider, V. M., Domingues, L. B., Umpierre, D., Tanaka, H., & Ferrari, R. (2023). Exercise characteristics and blood pressure reduction after combined aerobic and resistance training: a systematic review with meta-analysis and meta-regression. *Journal of Hypertension*, *41*(7), 1068-1076. [[Crossref](#)]
- Seeley, A. D., Giersch, G. E., & Charkoudian, N. (2021). Post-Exercise body cooling: skin blood flow, venous pooling, and orthostatic intolerance. *Frontiers in sports and active living*, *3*, 658410. [[Crossref](#)]
- Shishira, K. B., Vaishali, K., Kadavigere, R., Sukumar, S., Shivashankara, K. N., Pullinger, S. A., & Bommasamudram, T. (2024). Effects of high-intensity interval training versus moderate-intensity continuous training on vascular function among individuals with overweight and obesity—a systematic review. *International Journal of Obesity*, *48*(11), 1517-1533. [[Crossref](#)]
- Silva, R. P. M. ., Gonçalves, A. ., Silva, C. F. da, Bortolini, M. J. S. ., Resende, E. S. ., Gonçalves, L. C. O., Magalhães-Neto, A. M. de ., & Espindola, F. S. . (2024). Correlation Between Blood Lactate and Salivary Biomarkers During Exercise in Women with Hypothyroidism Treated With L-Thyroxine. *Physical Education and Sports: Studies and Research*, *3*(1), 57-76. [[Crossref](#)]
- Santos-Silva, P. R., Duarte, C. C., Osorio, B. B., Greve, J. M. D., & Guimaraes, G. V. (2021). Acute physiological and metabolic responses for 40-minutes of samba dance. *Open Science Journal*, *6*(1), 1-20. [[Crossref](#)]
- Song, Y., Chen, L., Wang, M., He, Q., Xue, J., & Jiang, H. (2022). The optimal exercise modality and intensity for hemodialysis patients incorporating Bayesian network meta-analysis and systematic review. *Frontiers in Physiology*, *13*, 945465. [[Crossref](#)]
- Sriton, B., Ruangthai, R., & Phoemsapthawee, J. (2022). Postexercise hypotension and heart rate variability response after water-and land-based high-intensity interval exercise in prehypertensive obese men. *Journal of Exercise Rehabilitation*, *18*(1), 57. [[Crossref](#)]
- Suarez-Roca, H., Mamoun, N., Mathew, J. P., & Bortsov, A. V. (2025). Noninvasive assessment of temporal dynamics in sympathetic and parasympathetic baroreflex responses. *Physiological Measurement*, *46*(3), 035007. [[Crossref](#)]
- Tarumi, T., Tomoto, T., Sugawara, J., & Zhang, R. (2025). Aerobic exercise training for the aging brain: effective dosing and vascular mechanism. *Exercise and Sport Sciences Reviews*, *53*(1), 31-40. [[Crossref](#)]
- Trindade, C. O., Oliveira, E. C., Coelho, D. B., Casonatto, J., & Becker, L. K. (2022). Effects of aquatic exercise in post-exercise hypotension: a systematic review and meta-analysis. *Frontiers in Physiology*, *13*, 834812. [[Crossref](#)]
- Xu, G., Li, Q., Yang, Q., & Yu, H. (2025). The effect of high-intensity interval training on health-related outcomes in obese adolescents: a systematic review and meta-analysis. *Frontiers in Physiology*, *16*, 1609818. [[Crossref](#)]