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Effects of interval training on cardiovascular endurance and heart rate recovery in competitive male adolescent soccer players

Fahrial Amiq[1abcd], Prayogi Dwina Angga[2ef], Adi Wijayanto[3ef], Andryas Yuniarto[1cd], Muhammad Yanuar Rizky[4de].

[1]Department of Sport Science, Faculty of Sports Science, Universitas Negeri Malang, Malang, East Java, Indonesia.
[2]Department of Elementary School Teacher Education, Faculty of Teacher Training and Education, Universitas Mataram, Mataram, West Nusa Tenggara, Indonesia.
[3]Department of Islamic Elementary School Teacher Education, Faculty of Teacher Training and Education, Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung, Tulungagung, East Java, Indonesia.
[4]Department of Physical Education, Health, and Recreation, Faculty of Health and Science, Universitas Nusantara PGRI Kediri, Kediri, East Java, Indonesia.

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Abstract

Modern soccer requires players to sustain repeated high-intensity efforts, making VO_2Max and Heart Rate Recovery (HRR) important physiological indicators of performance. However, training practices in field settings often rely on intuition rather than objective physiological monitoring. This study aimed to examine changes in VO_2Max and HRR following a structured interval training program among adolescent soccer players. A pre-experimental one-group pretest–posttest design was employed as a preliminary intervention study. The sample consisted of 24 male players aged 16–17 years from Porma FC Malang, selected through purposive sampling based on fitness and competitive criteria. VO_2Max was measured using the Multistage Fitness Test (MFT). At the same time, HRR, defined as the decline in heart rate from peak exercise to one minute after exercise, was assessed using a pulse oximeter. Data were analyzed using descriptive statistics and paired sample t-tests with a significance level of $p < 0.05$. The results showed a statistically significant increase in VO_2Max from 43.23 to 50.02 ml/kg/min ($p < 0.001$, Cohen's $d = 3.45$). HRR also showed a statistically significant change from 152.92 to 179.17 bpm ($p < 0.001$, Cohen's $d = 1.60$). These findings suggest that structured interval training may be associated with changes in VO_2Max and post-exercise recovery responses among adolescent soccer players. Periodic MFT and HRR assessments may provide useful information for monitoring aerobic conditioning and recovery status during training programs. However, these findings should be interpreted cautiously due to the absence of a control group.

Keywords: Soccer conditioning, interval training, VO_2Max, heart rate recovery, adolescent soccer players.

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Authors contribution: a – Preparing concepts; b – Formulating methods; c – Conducting research; d – Processing results; e – Interpretation and conclusions; f - Editing the final version.

Correspondence author: Hendra Mashuri, Universitas Pendidikan Ganesha, Singaraja, Bali, Indonesia.
Email: hendra.mashuri@undiksha.ac.id

INTRODUCTION

As the world's most popular sport, soccer has undergone a significant evolution in its competitive landscape. Modern match-play is increasingly defined by high-intensity and explosive actions, such as rapid changes of direction, repeated sprinting, and vertical jumping, which frequently determine critical match outcomes (Castillo-Rodríguez et al., 2020). This shift has transformed soccer into a highly demanding intermittent sport, requiring athletes to navigate a complex interplay between low-intensity tactical positioning and high-intensity metabolic efforts (Metaxas et al., 2019). Consequently, the ability to tolerate fatigue and sustain performance under these escalating physical demands has become a primary focus for sports scientists and practitioners alike (Hostrup & Bangsbo, 2023).

To respond to these physical demands, players require an adequate physiological foundation. While soccer performance involves multiple physical components, including explosive power, speed, and agility (Dawud & Hariyanto, 2020), cardiovascular endurance and VO_2Max are important physiological indicators of the ability to sustain physical performance throughout prolonged match activity and to recover between repeated high-intensity efforts (Miranda et al., 2021). In addition to VO_2Max, Heart Rate Recovery (HRR) has gained increasing attention as a physiological indicator related to post-exercise recovery responses. HRR reflects the reduction in heart rate following exercise and may indirectly indicate the efficiency of autonomic recovery after physical exertion (Kusuma et al., 2020; Işıkdemir et al., 2025). Faster HRR is commonly associated with better physiological recovery responses and may support players' ability to tolerate repeated high-intensity actions during soccer performance. Therefore, improving these physiological responses may support conditioning development in adolescent soccer players.

Training programs need to be systematically organized to effectively optimize these physiological outcomes (Prastyawan et al., 2025). Among various conditioning methods, interval training has become widely used because its alternating work-to-rest structure resembles the intermittent

characteristics of soccer match-play (Riansa et al., 2025). By alternating high-intensity exercise bouts with structured recovery periods, interval training has been proposed as a conditioning method that may be associated with improvements in estimated VO_2Max and recovery-related physiological responses. Previous studies suggest that such responses may be linked to adaptations in oxygen transport and utilization during exercise (Gibala & Hawley, 2017; Hernawan & Putra, 2023). In addition, previous studies have shown that interval-based conditioning programs are associated with improvements in VO_2Max and recovery-related responses in soccer and other intermittent sports contexts (Kuswoyo et al., 2020; Y. Fang et al., 2021; Mamoribo et al., 2023).

Despite the growing theoretical and empirical support for interval training, several gaps remain between sports science recommendations and field implementation. Observations and interviews with coaches across different competitive contexts, ranging from elite academies to regional leagues, indicate that many training programs are still largely governed by personal intuition and empirical experience rather than standardized evidence-based protocols (Haugen, 2021). Furthermore, physiological monitoring, particularly Heart Rate Recovery (HRR), is still rarely implemented systematically during training sessions despite its relevance for evaluating post-exercise recovery responses, recovery capacity, and training readiness. This lack of standardization and objective monitoring may limit the accurate evaluation of athletes' physiological adaptation to training. Although previous studies have examined interval training in soccer conditioning, limited empirical evidence has simultaneously investigated cardiovascular endurance, VO_2Max, and HRR among adolescent soccer players within applied regional-club settings (Sitompul et al., 2025). These limitations highlight the need for additional evidence regarding physiological responses associated with structured interval training in youth soccer contexts.

Therefore, this study aims to examine pretest-to-posttest changes in cardiovascular endurance, VO_2Max, and Heart Rate Recovery (HRR)

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following a structured interval training program among adolescent soccer players. The contribution of this study lies in integrating VO_2Max and HRR as complementary physiological indicators to support conditioning monitoring, training evaluation, and a broader understanding of physiological responses in youth soccer settings.

METHODS

This study employed a pre-experimental design using a one-group pretest-posttest approach to evaluate physiological changes following a structured interval training intervention. This design was selected due to practical limitations in controlling training allocation within the club setting. Although the design allows preliminary evaluation of intervention-related changes, the absence of a control group may limit causal inference and internal validity. Assessments were conducted twice, before (pretest) and after (posttest) the intervention period, to evaluate changes in the dependent variables following the 16-session training program.

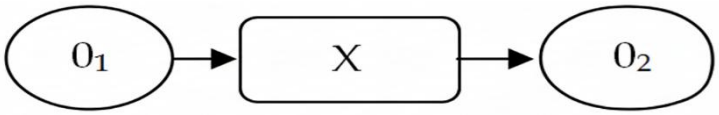

Figure 1. One-Group Pretest-Posttest Design Framework

Note: O_1: Baseline assessment of aerobic capacity (MFT) and Heart Rate Recovery (HRR); X: The 16-session structured interval training intervention; O_2: Final assessment of aerobic capacity and HRR after the intervention period.

The study was conducted at the training facility of Porma FC in Kota Malang, a youth soccer club affiliated with PSSI Malang that regularly participates in regional youth league competitions and inter-club tournaments in East Java. From a total population of 85 male soccer players at Porma FC, 24 adolescent players were selected using a purposive sampling technique. The inclusion criteria were: (1) male, (2) aged 16–17 years, (3) medically fit, and (4) actively participating in competitive events. Purposive sampling was used to ensure that participants met the physiological and competitive requirements relevant to the intervention program. All participants attended at least 95% of the scheduled training sessions, indicating a high level of compliance throughout the intervention period.

The interval training program was implemented four times per week over four consecutive weeks, resulting in a total of 16 training sessions. Each session began with a 10-minute warm-up, followed by repeated running intervals performed at approximately 80–90% of maximum heart rate (HRmax). Participants completed 30-second work intervals followed by 30-second active recovery periods using a 1:1 work-to-rest ratio. Each session consisted of 2–3 sets with 6–8 repetitions per set. Training volume was progressively increased throughout the intervention period by gradually increasing the number of repetitions and sets according to participants' adaptation and training tolerance. Each session concluded with a 10-minute cool-down period.

The dependent variables were VO_2Max and Heart Rate Recovery (HRR). VO_2Max was assessed using the Multistage Fitness Test (MFT/Bleep Test), a field-based assessment that has demonstrated acceptable validity and reliability for estimating VO_2Max in adolescent athletes and soccer players. Heart Rate Recovery (HRR) was assessed using a validated pulse oximeter. Peak heart rate was recorded immediately after completion of the exercise protocol, while recovery heart rate was recorded after one minute of passive recovery. HRR was calculated as the difference between peak exercise heart rate and heart rate measured one minute after exercise, with higher values indicating a greater post-exercise heart rate reduction. All measurements were conducted under standardized conditions using the same device and evaluator. Participants remained seated during the one-minute passive recovery period to ensure consistency across measurements.

Descriptive statistics and paired sample t-tests were used to analyze the data. Prior to inferential analysis, data normality was assessed using the Shapiro–Wilk test. Effect sizes were calculated using Cohen's d to quantify the magnitude of pretest-to-posttest changes. They were interpreted according to conventional criteria, with values of 0.20 indicating small effects, 0.50 indicating medium effects, and 0.80 indicating large effects. All

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statistical analyses were performed using SPSS version 26.0, and statistical significance was established at $p < 0.05$.

RESULTS

After completion of the 16-session interval training program, the pretest and posttest data analysis for cardiovascular endurance and post-exercise heart rate recovery in 24 adolescent soccer players from Porma FC Kota Malang are presented in the following tables.

Table 1. Descriptive Data for Aerobic Capacity and HRR

Variable	Category	Mean	Median	Min	Max	SD
Aerobic Capacity (MFT)	Pretest	43.23	43.95	34.3	49.3	3.84
	Posttest	50.02	49.6	41.5	55.0	3.36
Heart Rate Recovery (HRR)	Pretest	152.92	155.0	110.0	190.0	16.54
	Posttest	179.17	180.0	150.0	220.0	17.42

Table 1 presents the descriptive statistics for estimated VO_2Max and Heart Rate Recovery (HRR) before and after the interval training program. Estimated VO_2Max increased from 43.23 ml/kg/min at pretest to 50.02 ml/kg/min at posttest, while HRR increased from 152.92 bpm to 179.17 bpm. HRR in this study was calculated as the difference between peak exercise heart rate and heart rate measured one minute after exercise; therefore, higher HRR values indicate a greater decline in heart rate following exercise.

Table 2. Assessment of Data Normality

Variable		Sig.(p)	Result
MFT	Pretest	0.164	Normal
	Posttest	0.273	Normal
Heart Rate Recovery (HRR)	Pretest	0.101	Normal
	Posttest	0.112	Normal

Normality testing indicated that all variables were normally distributed ($p > 0.05$), supporting the use of parametric analysis.

Table 3. Results of Paired Sample T-Test

Variable	Mean Difference	t(df)	p-value	Cohen's d
Estimated VO_2Max	-6.787	-16.918 (23)	<0.001	3.45
Heart Rate Recovery (HRR)	-26.250	-7.856 (23)	<0.001	1.60

The paired sample t-test showed a statistically significant pretest-to-posttest difference for estimated VO_2Max, $t(23) = -16.918$, $p < 0.001$. A statistically significant pretest-to-posttest difference was also observed for Heart Rate Recovery (HRR), $t(23) = -7.856$, $p < 0.001$.

DISCUSSION

The present study observed significant pretest-to-posttest changes in estimated VO_2Max and Heart Rate Recovery (HRR) following a 16-session interval training program among adolescent soccer players. Both variables are widely recognized as important physiological indicators in soccer because they reflect aerobic fitness and post-exercise recovery capacity, two attributes required to sustain repeated high-intensity efforts during match play (Pratama et al., 2025). These findings suggest that the intervention period was associated with favorable physiological responses related to aerobic conditioning and post-exercise recovery. Soccer players are required to repeatedly perform high-intensity actions, including sprinting, pressing, accelerating, decelerating, and changing direction throughout a match (Khachatryan, 2024). The ability to sustain these repeated efforts while minimizing fatigue is considered an essential component of soccer-specific fitness and often differentiates successful performance during the later stages of competition.

The observed increase in VO_2Max may indicate improved aerobic conditioning following the intervention period. In soccer, aerobic fitness is important because players are required to repeatedly perform high-intensity actions while maintaining technical and tactical performance throughout a match. Higher VO_2Max values may support repeated sprint ability, facilitate recovery between intense actions, and help maintain performance during pressing situations, transition phases, and the final stages of play. Cardiovascular endurance is therefore considered a key physical component because players must be capable of sustaining repeated efforts without experiencing substantial declines in performance. From a physiological perspective, aerobic endurance is associated with the efficiency of the cardiovascular and respiratory systems in supplying oxygen to working muscles during exercise (Bompa et al., 2019). Similarly, Harsono (2022) emphasized that cardiorespiratory endurance plays an important role in supporting athletic performance and physiological stability during competition. Consequently, the observed increase in estimated VO_2Max

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may reflect favorable physiological responses associated with the demands of soccer participation.

The present findings support previous evidence indicating that interval-based training may contribute to improvements in aerobic fitness among soccer players and other intermittent-sport athletes. Rather than simply demonstrating improvements in VO_2Max, previous studies collectively suggest that repeated high-intensity exercise interspersed with structured recovery periods may enhance oxygen transport, oxygen utilization, and endurance-related physiological responses (Kuswoyo et al., 2020; Buchheit & Laursen, 2022). Similar observations have been reported among adolescent soccer players, where interval-based conditioning programs were associated with improvements in cardiorespiratory fitness and endurance-related performance (Y. Fang et al., 2021). Collectively, these findings suggest that interval training may represent an appropriate conditioning strategy for supporting aerobic development in youth soccer populations. Beyond supporting previous evidence, the current study extends the literature by examining adolescent soccer players within a regional club context and by evaluating Heart Rate Recovery (HRR) alongside VO_2Max. This combined approach provides a broader perspective on conditioning responses because soccer performance depends not only on aerobic capacity but also on the ability to recover efficiently between successive high-intensity efforts.

In addition to aerobic capacity, this study evaluated Heart Rate Recovery (HRR) as a recovery-related physiological outcome. HRR was calculated as the difference between peak exercise heart rate and heart rate measured after one minute of passive recovery; therefore, higher HRR values indicate a greater reduction in heart rate following exercise. HRR is widely recognized as a practical physiological indicator of post-exercise recovery because it reflects the rate at which the cardiovascular system returns toward resting conditions following physical exertion (Sitompul et al., 2025). Previous studies have also suggested that faster HRR is generally associated with better aerobic fitness and more efficient recovery responses

after high-intensity exercise (Umam et al., 2024). The findings showed that participants demonstrated a greater post-exercise heart rate decline after the intervention period than during the pretest condition, suggesting more favorable recovery responses following high-intensity activity. The assessment was conducted under standardized conditions, with peak heart rate recorded immediately after completion of the Multistage Fitness Test (MFT), followed by one minute of passive recovery in a seated position. The same pulse oximeter device and evaluator were used throughout the study to minimize measurement variability. These standardized procedures are important because they help ensure that observed differences between testing occasions more accurately reflect physiological responses rather than methodological inconsistencies.

Although autonomic nervous system activity was not directly measured, HRR may serve as an indirect indicator of post-exercise recovery status. Faster heart rate recovery is often associated with more efficient physiological regulation following exercise and has been linked to higher levels of aerobic fitness (Flatt et al., 2017). Likewise, Putaro et al. (2024) suggested that post-exercise HRR may provide useful information regarding recovery responses and cardiovascular regulation. Previous studies have also reported that athletes with better aerobic fitness generally demonstrate faster HRR due to more efficient cardiovascular regulation following intense activity (Kenney et al., 2019). The findings of the present study are consistent with this perspective, as improvements in estimated VO_2Max were accompanied by more favorable HRR responses. While these variables represent different physiological constructs, their concurrent improvement may indicate complementary physiological responses associated with aerobic conditioning and recovery efficiency.

The relationship between aerobic fitness and recovery capacity is particularly important in soccer because players must repeatedly perform high-intensity actions with limited recovery opportunities during training sessions and competitive matches. Previous studies have suggested that interval-based conditioning programs may simultaneously support aerobic

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fitness and recovery-related physiological responses among soccer players (B. Fang et al., 2021; Manuel Clemente et al., 2021). The current findings contribute additional evidence within the context of adolescent regional-club players by demonstrating that monitoring both VO_2Max and HRR may provide a more comprehensive understanding of conditioning responses. Aerobic fitness reflects an athlete's ability to sustain prolonged physical activity, whereas HRR provides additional information regarding post-exercise recovery responses. Considering both indicators together may therefore offer a broader physiological perspective when evaluating adaptation to training in youth soccer programs.

From a physiological perspective, repeated high-intensity exercise may stimulate central and peripheral adaptations associated with oxygen transport, oxygen utilization, and recovery efficiency. However, these physiological mechanisms were not directly measured in the present study and therefore should be interpreted cautiously. Consequently, the observed changes in estimated VO_2Max and HRR should be interpreted as physiological responses recorded during the intervention period rather than direct evidence of specific cardiovascular or muscular adaptations. The posttest VO_2Max value of approximately 50 ml/kg/min may indicate a meaningful improvement in aerobic fitness for adolescent soccer players, although it should not be interpreted as direct evidence of elite-level performance (Slimani et al., 2019; Ghouili et al., 2023). Instead, the findings suggest that the observed physiological responses may be relevant to the aerobic and recovery demands commonly encountered during soccer participation.

The findings of this study also have practical implications for soccer conditioning. Coaches may consider combining structured interval training with periodic monitoring of estimated VO_2Max and HRR to obtain a more comprehensive understanding of players' physiological responses to training. The Multistage Fitness Test (MFT) can be used to monitor aerobic capacity, whereas HRR monitoring may provide additional information on post-exercise recovery. Players demonstrating slower HRR values may

require modified training loads, extended recovery periods, reduced training volume, or closer physiological monitoring before progressing to higher-intensity training sessions. Integrating aerobic capacity assessment and recovery monitoring may therefore assist coaches in making more informed decisions regarding training prescription, recovery management, and athlete readiness throughout the training process.

Several limitations should be acknowledged. First, the sample consisted of only 24 adolescent players from a single soccer club, which may limit the generalizability of the findings to other populations and competitive levels. Second, the absence of a control group restricts the ability to attribute the observed changes exclusively to the interval training program. Finally, external factors such as nutritional intake, sleep quality, additional physical activity, and psychological conditions were not fully controlled during the intervention period. Despite these limitations, the present study provides preliminary evidence regarding the potential value of combining interval training, estimated VO_2Max assessment, and HRR monitoring within youth soccer conditioning programs. These findings may contribute to a more objective approach to training evaluation by encouraging the integration of aerobic fitness and recovery-related indicators in applied youth soccer settings.

CONCLUSION

The findings of this study indicate that structured interval training was associated with pretest-to-posttest changes in estimated VO_2Max and Heart Rate Recovery (HRR) among male adolescent soccer players aged 16–17 years. Significant differences were observed in both physiological indicators, suggesting that interval training may support aerobic conditioning and post-exercise recovery responses in youth soccer players. This study provides preliminary evidence regarding the combined use of estimated VO_2Max and HRR as complementary indicators for monitoring conditioning responses and physiological adaptation in youth soccer training programs. In practical settings, coaches may utilize periodic MFT and HRR assessments to monitor aerobic fitness and recovery status and to support

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training load adjustments when necessary. However, these findings should be interpreted cautiously due to the absence of a control group and the relatively small sample size. Future studies are recommended to employ controlled experimental designs with larger samples to strengthen the interpretation of training-related effects.

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