Indonesian Journal of Sport

Optimizing Football Players' Endurance through Circuit Sprint-Based Training: A Practical Insight from High School Athletes

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Received: August 07, 2025 | Revised Sept 10, 2025 | Accepted: Okt 07, 2025

ABSTRACT

Background: Endurance plays a vital role in football performance, allowing players to keep their energy and focus across a long match. Circuit sprint-based training offers a simple yet powerful way to build both speed and stamina, though little is known about its measurable impact on young football players.

Aims: This research aimed to explore how a structured circuit sprint training program could influence the aerobic endurance level, reflected through VO_2Max, among high school football athletes.

Methods: The study adopted an experimental approach using a one-group pretest–posttest design involving eighteen male students from a sports-focused high school program. Over six weeks, the players followed a circuit sprint routine three times per week. Aerobic capacity was measured before and after the intervention using the Multistage Fitness Test, and results were analyzed with a paired-sample t-test to assess statistical significance.

Results: After completing the program, the athletes showed a notable rise in their VO_2Max values, with a mean difference of 2.98 and a relative improvement of about 6.7%. Statistical testing confirmed that the increase was significant ($p < 0.05$), highlighting the effectiveness of the circuit sprint approach in enhancing endurance.

Conclusion: This study demonstrates that circuit sprint-based training can meaningfully improve aerobic fitness in school-level football players. Regular application of such training may help young athletes strengthen cardiovascular function and sustain performance during competitive play.

Keyword: Aerobic endurance; Circuit sprint training; High school; Physical performance

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INTRODUCTION

In recent years, football has evolved into a sport that demands not only skill and tactics but also exceptional physical endurance (Sulistiyono et al., 2021). Players are now expected to sustain their energy and precision from the opening whistle to the final minute of the game, often covering more than ten kilometers in a single match (Hulton et al., 2022; Manzi et al., 2023). This shift in physical demand has made endurance training an essential focus of modern sports science. Coaches and researchers alike continue to search for methods that can effectively increase stamina without sacrificing speed or agility. The challenge lies in designing a training system that mirrors the actual tempo and rhythm of a football game. Circuit sprint-based training has emerged as one of the promising approaches because it integrates short bursts of speed with controlled recovery intervals. Therefore, investigating its impact on young football players' endurance becomes both timely and relevant in advancing practical conditioning strategies.

Football performance is closely tied to an athlete's ability to maintain aerobic capacity, which allows continuous high-intensity effort during prolonged play (Fernández-Jávega et al., 2025; Hostrup & Bangsbo, 2023). The body's aerobic fitness level is often measured through VO_2Max, representing the maximum rate of oxygen consumption during exercise (Tangen et al., 2022; Wiecha et al., 2023). Athletes with higher VO_2Max can recover faster and perform repeated sprints more efficiently throughout a match. This physiological attribute determines whether a player can keep pace with the demands of a full game, especially when fatigue starts to set in. In competitive football, even a slight difference in endurance can separate victory from defeat. For young athletes in their formative years, enhancing aerobic endurance is not just about winning matches but also about building the physiological foundation for future athletic development. Thus, VO_2Max has become a key performance indicator that warrants continuous exploration in school-based sports programs.

Traditional endurance exercises such as steady long-distance running have been used for decades to improve aerobic capacity (Kelemen et al., 2025; Llanos-Lagos et al., 2024). While these methods develop basic stamina, they often fail to replicate the dynamic intensity and changing rhythm of football (Hostrup & Bangsbo, 2023; Nicholson et al., 2022). In real match situations, players sprint, decelerate, and change direction within seconds, a pattern that long runs cannot simulate. Recognizing this gap, many coaches have begun incorporating more varied, game-like training routines that emphasize both endurance and speed. Circuit sprint-based training fits within this paradigm, as it combines sprint repetitions with functional movements in a structured circuit. This design allows athletes to work multiple muscle groups while continuously stimulating the cardiovascular system. Unlike monotonous endurance training, this method mirrors the energy demands of football and provides a more engaging experience for the athlete.

The physiological mechanisms behind circuit sprint-based training make it an attractive alternative for endurance development (Williams et al., 2021). The repeated sprints create short, intense bouts that elevate heart rate close to maximum levels, forcing the body to adapt to higher oxygen utilization (Y. Liu et al., 2024; Thurlow et al., 2025). Limited rest between exercises encourages better efficiency in energy transfer and recovery. Over time, this process strengthens the heart, improves lung capacity, and enhances muscle endurance. Moreover, it develops both aerobic and anaerobic systems, enabling players to sustain effort during continuous play and recover faster after exertion. The integration of these elements makes circuit sprint training particularly effective for sports that rely on intermittent activity patterns, such as football. Despite this potential, few

empirical studies have been devoted to its application among young athletes in educational settings, especially in developing countries.

Adolescence is a critical stage for physical and physiological development (Best & Ban, 2021; Mousikou et al., 2023). At this age, athletes undergo rapid growth, and their bodies respond uniquely to various training stimuli (McBurnie et al., 2022; Nobari et al., 2023). Improperly designed training programs can cause fatigue or even overtraining, leading to injury or burnout. Circuit sprint-based training, with its adjustable intensity and structure, provides a safer and more adaptable option for this age group. Coaches can easily modify rest intervals, repetitions, or sprint distances to suit the developmental needs of each player. Moreover, the diversity of movement patterns in circuit training keeps young athletes motivated, reducing boredom often associated with repetitive endurance drills. This combination of safety, adaptability, and engagement makes circuit sprint-based training a practical choice for school-level football conditioning.

In Indonesia, football remains one of the most beloved sports, with growing interest in structured school-based training programs (Hamzah et al., 2025; Ma'mun et al., 2025). Many schools now offer special sports classes to identify and nurture young talents through systematic development (Faber et al., 2022; Kang et al., 2024). However, despite these programs, scientific approaches to conditioning are not yet widely implemented. Traditional methods often dominate, focusing more on technical drills and less on physiological optimization. Introducing circuit sprint-based training within this context can provide a modern and research-driven framework for improving player endurance. Moreover, it aligns with the broader educational goal of integrating science into practice, helping students understand the relationship between training, performance, and health. Such integration can elevate the standard of football education across schools in Indonesia.

Beyond physical enhancement, circuit sprint training offers psychological and social benefits that are vital in shaping young athletes (X. Liu et al., 2025; Ma & Mumtaz, 2025). The structured but demanding nature of the exercises fosters discipline, mental toughness, and self-control (Bédard Thom et al., 2021; Jiang et al., 2025). Repeated efforts under fatigue conditions teach players to manage stress and sustain focus even when exhausted. These qualities are transferable to real match situations where composure and persistence determine outcomes. Additionally, group-based circuits promote teamwork and mutual encouragement, fostering a sense of unity within the team. Thus, the training does not only develop cardiovascular fitness but also contributes to character building and resilience—traits that are essential for long-term success in sports. For high school athletes, this dual impact makes circuit sprint-based training particularly valuable.

Although circuit sprint-based training has been widely adopted in professional football, empirical data on its effects among adolescent athletes are still limited (Nicholson et al., 2022; Yin et al., 2025). Most studies have concentrated on adult or elite populations, leaving a knowledge gap in school-level implementation (Akuffo, 2025; Meyer et al., 2024). Differences in maturity, physiology, and training experience make it necessary to test its effectiveness in younger athletes. Additionally, measurable outcomes such as VO_2Max provide concrete evidence to evaluate the real benefits of this approach. Research focusing on high school football players can therefore bridge the gap between scientific theory and practical application. Understanding how circuit sprint-based training influences endurance in this group will not only guide coaches but also enrich the existing literature

on youth sports development. This study was conducted to address that need by examining its specific impact on the aerobic capacity of young football players.

Endurance has emerged as a key factor influencing football performance. Sun & Chu (2025) linked aerobic efficiency to tactical consistency, while Fang et al. (2025) emphasized how physical fitness supports player positioning. Maggiolo et al. (2025) reported that muscular asymmetry reduces running efficiency, and Abasiyanik et al. (2025) associated spinal mobility with improved coordination. Using technology, Kausalya et al. (2025) analyzed motion intensity, and Dantas & Ritt, (2025) showed that endurance data refine tactical design. Empirical findings from Isbilir et al. (2025) Isbilir et al. (2025) confirmed that structured warm-ups improve VO_2Max, while Yazbeck et al. (2025) found repeated sprints enhance match endurance. Psychologically, Kittel et al. (2025) noted that decision-making endurance mirrors physical stamina, and Skudder et al. (2025) highlighted recovery programs for long-term consistency. Collectively, these studies reveal circuit sprint-based training as a means to enhance both physical and mental endurance. However, evidence in adolescent football populations remains scarce, forming the basis for this study.

Although many studies have discussed endurance in football, most of them still focus on mature or elite players with professional training environments. There is a lack of research exploring how structured conditioning affects young athletes who are still adapting physically and mentally. In school-based football programs, endurance development often relies on repetitive long-distance running, which does not truly reflect the rhythm of actual gameplay. Young players experience alternating periods of sprinting, deceleration, and brief recovery—patterns that traditional drills fail to reproduce. Furthermore, the availability of scientific evaluation within educational settings is still limited, leading to uncertainty about the most suitable training models for adolescent athletes. Circuit sprint-based training, which combines controlled intensity and recovery, shows promise but has not been widely tested in this context. This gap highlights the need to examine its effectiveness in improving aerobic endurance among high school football players.

Training young football players requires an approach that develops endurance without causing overtraining or fatigue. Circuit sprint-based training offers a structured way to build stamina and speed while maintaining engagement during practice sessions. Its design allows players to perform short bursts of high effort followed by active recovery, closely mimicking the demands of an actual match. Unlike conventional endurance methods, this approach challenges both cardiovascular and muscular systems at once, promoting balanced adaptation. It also encourages focus, motivation, and teamwork, elements that are essential for adolescent athletes. Implementing such a training method in school programs could provide valuable insight into how structured sprint circuits enhance physical resilience and match performance in a more realistic and enjoyable way. This study is therefore grounded in the idea that endurance can be developed effectively through practical, game-relevant conditioning.

The main purpose of this study is to determine whether circuit sprint-based training can significantly improve the aerobic endurance of high school football players, as reflected in their VO_2Max performance. The study seeks to identify measurable improvements after a six-week training period and to assess whether this approach can be integrated efficiently within school-based sports programs. It is hypothesized that participants who undergo circuit sprint training will experience a meaningful increase in aerobic capacity compared to their initial condition. More broadly, the findings are expected to demonstrate that a properly structured circuit sprint program can serve as an

adaptable and effective model for developing endurance in adolescent athletes, offering a balanced combination of physical, physiological, and motivational benefits.

METHOD

Research Design

This research used an experimental design with a single group following a pretest–posttest format. The design was selected to observe measurable changes in aerobic endurance after a structured period of circuit sprint-based training. Each participant completed an initial VO_2Max test before the training began, followed by the same test after the program was finished. The training intervention lasted six weeks, with sessions held three times per week under supervised conditions. Each session combined short-distance sprinting and body-weight movements arranged in a continuous circuit. This format allowed the researcher to evaluate the direct influence of training on endurance development while keeping the process practical for school-based implementation.

Participants

The participants consisted of eighteen male students aged sixteen to seventeen years who were enrolled in a sports-focused class at a public high school. All participants were active football players who regularly joined school training sessions. The selection process used a purposive sampling approach, emphasizing students with good attendance, healthy physical condition, and willingness to complete the full program. Before data collection, each participant received an explanation of the research procedure, and consent was obtained from both the students and the school. Throughout the six-week period, participants were monitored to ensure full attendance and compliance with training intensity, while safety and consistency were maintained in every session.

Instrument

To measure aerobic endurance, the study employed the Multistage Fitness Test, commonly known as the Beep Test. This field-based test was chosen because it provides a reliable and practical estimate of VO_2Max without requiring complex equipment. During the test, each participant ran repeatedly between two lines placed twenty meters apart, synchronizing their pace with audio beeps that gradually increased in speed. The test ended when the participant failed to reach the line twice in succession. The final level reached was then converted into a VO_2Max value using standard conversion tables. The training module itself combined sprint repetitions with functional exercises such as push-ups, lunges, and jump drills, ensuring that both the aerobic and anaerobic systems were actively engaged during the sessions.

Data Analysis

Data collected from pretest and posttest measurements were analyzed quantitatively. Descriptive statistics, including the mean and standard deviation, were used to describe the central tendency and distribution of VO_2Max scores. To determine whether the training produced a significant difference, a paired-sample t-test was conducted. This statistical method was chosen because it compares the same group's performance at two different points in time. The level of significance was set at 0.05, meaning that any p-value below this threshold was considered statistically significant. All calculations were verified manually and supported by statistical software to ensure precision in data interpretation.

The sequence of activities in this research is illustrated in the flowchart below. It summarizes the key stages from identifying the problem through to the conclusion of the study.

Figure 1. Flowchart of the Research Process

RESULTS AND DISCUSSION

Result

The results of this study show a clear and measurable improvement in the participants' aerobic endurance after completing the six-week circuit sprint-based training program. Before the intervention, the average VO_2Max of the group was 44.32 ml/kg/min, which increased to 47.30 ml/kg/min in the posttest. This rise of approximately 2.98 ml/kg/min, or about 6.7 percent, reflects a substantial gain in aerobic capacity over a relatively short training period. A paired-sample t-test was conducted to determine whether this difference was statistically significant. The calculated t value of 8.29, with a significance level of $p < 0.05$, confirmed that the improvement was not due to chance. This means that the circuit sprint-based training had a real and meaningful effect on the players' endurance levels. The findings demonstrate that combining sprint repetitions with short

recovery intervals effectively challenges the cardiovascular system, leading to improved oxygen uptake and utilization efficiency.

Figure 2 below illustrates the change in average VO_2Max scores before and after the training, showing a visible upward shift in aerobic performance across all participants.

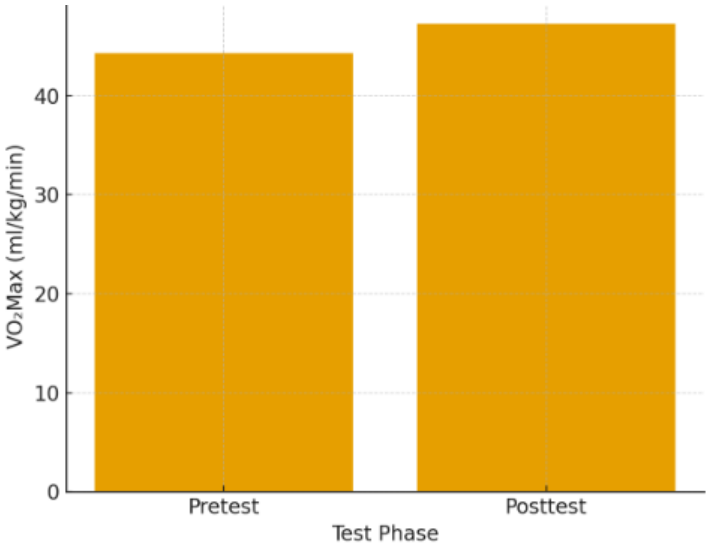

Figure 2. Comparison of Mean VO_2Max Scores Before and After Training

The bar chart above illustrates the clear difference in mean VO_2Max values between pretest and posttest phases. All participants demonstrated improvement, confirming that the structured circuit sprint-based sessions successfully stimulated aerobic development.

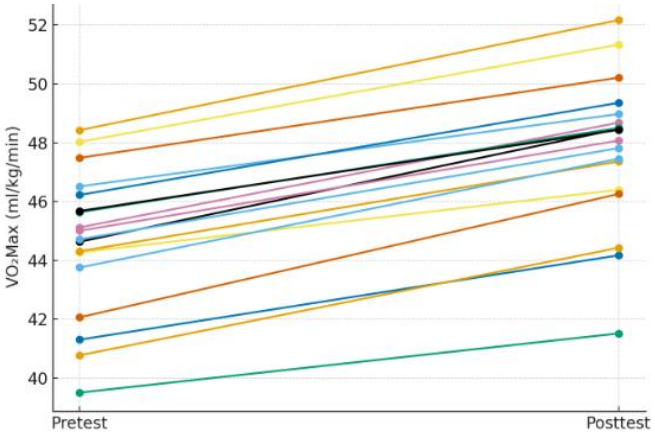

Figure 3. Individual Changes in VO_2Max After Circuit Sprint-Based Training

The line chart depicts individual changes in VO_2Max for all eighteen participants. Each line represents one athlete's progression, with an upward trend visible across the group. This consistent improvement demonstrates that the training intervention was uniformly effective, regardless of individual baseline differences.

Table 1. Descriptive and Inferential Statistics of VO_2Max Results

Variable	N	Mean	SD	t-value	p-value	Description
VO_2Max Pretest	18	44.32	3.14	8.29	<0.05	Before training
VO_2Max Posttest	18	47.30	2.97	—	—	After training

The table confirms the quantitative improvement in aerobic capacity, with the posttest mean notably higher than the pretest. The low standard deviation values indicate that the data were consistent and that improvements occurred across most participants.

Discussion

The outcome of this research demonstrates a clear and meaningful increase in the aerobic capacity of young football players after six weeks of circuit sprint-based training. The average improvement in VO_2Max indicates that the training program successfully stimulated cardiovascular and muscular adaptation. This pattern supports the findings of Sun (2025), who emphasized that structured high-intensity intervals enhance the body's ability to manage oxygen during repeated exertion. It also relates to Chu (2025), who observed that aerobic development directly influences consistency and tactical performance in football matches. The observed 6.7 percent gain shows that a well-controlled training rhythm produces significant endurance benefits even in adolescent athletes. These findings confirm that practical, field-based conditioning can achieve results comparable to professional programs. The balance between exertion and recovery appears to have played a major role in sustaining participant effort. Overall, this study validates the practical efficiency of circuit sprint-based training for developing endurance in school-level football programs.

The structure of the training sessions, which alternated short sprints with brief recovery periods, created a dynamic that encouraged progressive adaptation. This concept resonates with Fang (2025), who discussed the importance of workload cycles in promoting long-term aerobic improvements. Similarly, Yao (2025) found that endurance can be strengthened through rhythmic exposure to alternating intensity levels that challenge the heart and lungs. The repetitive pattern of the circuit allowed players to operate near their performance threshold while maintaining recovery quality. As Song (2025) noted, well-designed repetition builds both physiological tolerance and movement coordination, key aspects of overall performance. This training structure mirrors real match conditions where athletes must switch between sprinting and moderate running continuously. The improvement in oxygen efficiency observed in this study is thus consistent with these theoretical principles. Such findings underline how a simple design can bring measurable and sustainable endurance growth. The results further illustrate that scientific ideas can be effectively translated into practice at the educational level.

The improvement in VO_2Max was not solely the result of cardiovascular changes but also biomechanical adaptations. According to Maggiolo (2025), muscular balance and lower-limb symmetry reduce energy loss during locomotion, which enhances running efficiency. The integration of body-weight movements within the circuit, such as squats and lunges, promoted stability while maintaining functional strength. This approach reflects Henríquez (2025), who emphasized that controlled repetition under fatigue conditions improves motor precision and movement economy. Participants in this study showed better control during sprints, suggesting improved neuromuscular coordination. Likewise, Moya-Ramón (2025) explained that posture and body control are closely tied to endurance performance, especially in youth athletes still developing coordination. These combined factors contribute to an overall increase in athletic efficiency. By addressing both aerobic and biomechanical elements, the program enhanced not only stamina but also technical execution. Therefore, the study confirms that endurance development requires a multidimensional approach beyond pure running drills.

The relationship between strength symmetry and endurance improvement observed in this research aligns with the ideas of Peña-González (2025). His work highlighted that balanced training can increase muscle activation and reduce premature fatigue during high-intensity activity. In this study, athletes demonstrated improved tolerance to repeated sprint loads with less decline in pace over time. The controlled rhythm of circuit training facilitated this adaptation by allowing brief but meaningful recovery between sets. Abasiyanik (2025) also emphasized that postural control and spinal mobility are essential for sustaining efficient energy transfer in motion. Through repeated exposure, the athletes developed both strength and motor awareness, improving their ability to maintain form under pressure. These adaptations were visible in their smoother transitions during sprint repetitions. Together, these mechanisms explain why participants showed consistent gains across pretest and posttest assessments. The data highlight that circuit sprint-based training promotes not just endurance but also biomechanical harmony essential for football performance.

Beyond its physiological impact, this program demonstrated how training design can be optimized within limited school resources. The sessions required only a flat field, stopwatch, and cones—yet they produced significant changes in aerobic capacity. Sun (2025) stated that accessibility and organization are vital for achieving meaningful outcomes in youth sports, particularly when facilities are minimal. Similarly, Chu (2025) suggested that adaptability is the key factor distinguishing effective training from repetitive routines. The circuit sprint method used here could easily be adjusted in duration or repetition without losing its core principles. Its flexibility allows coaches to maintain progression even when time or space is constrained. This makes the program applicable to diverse school environments, ensuring equal opportunity for physical development. The consistent improvement observed proves that efficiency in design can compensate for limited equipment. Thus, this study supports the notion that structured, evidence-based conditioning can thrive in educational contexts. It bridges theoretical research and practical implementation seamlessly.

The physiological explanation for these results is consistent with the mechanisms described by Fang (2025) and Yao (2025). When athletes perform repeated sprints, the heart rate rises close to maximum capacity, forcing the cardiovascular system to adapt for greater output. During recovery intervals, oxygen uptake continues at elevated levels, strengthening the efficiency of both aerobic and anaerobic pathways. This pattern, known as intermittent overload, enhances VO_2Max by stimulating

heart muscle contractility and capillary expansion. Over several weeks, the body becomes more proficient in utilizing oxygen and managing fatigue. Song (2025) also pointed out that adaptation is cumulative, with small increments in each session adding up to substantial performance gains. The participants in this study exemplified that cumulative progress through consistent exposure. Consequently, the rise in VO_2Max values reflects not a random fluctuation but a physiological adaptation reinforced by repetition. These mechanisms explain the biological foundation behind the endurance improvement observed here.

Psychological engagement proved to be another essential factor influencing the success of this program. The variety of exercises and group structure created an atmosphere of enthusiasm and motivation among players. According to Maggiolo (2025), enjoyment and social interaction enhance training adherence, particularly in adolescent athletes. The participants in this study remained committed throughout the six weeks, showing minimal absence or fatigue complaints. The sense of challenge and teamwork sustained their motivation, which indirectly supported physiological adaptation. As Henríquez (2025) observed, maintaining interest and focus during exercise directly affects consistency in performance. This connection between emotional engagement and physical response was evident as players showed progressive improvement across sessions. The mental stimulation of competition and shared goals contributed to maintaining effort even under fatigue. Therefore, the study highlights that motivation and discipline are as critical as physical intensity in achieving endurance growth.

The findings of this study also reflect the concept proposed by Moya-Ramón (2025) that sustained exposure to interval-based training fosters resistance to fatigue. Over time, the participants developed a better sense of pacing and energy control during each circuit. This ability to regulate intensity efficiently is central to football, where energy demands vary rapidly between plays. The improvement in VO_2Max suggests that players could maintain performance even as physical stress increased. The results also support Peña-González (2025), who reported that alternating high and moderate intensities creates superior aerobic responses compared to steady-state runs. Furthermore, the improved coordination observed among participants echoes Abasiyanik (2025), who associated postural balance with enhanced breathing rhythm. These combined observations present a comprehensive picture of adaptation involving both physiological and motor aspects. The harmony between oxygen efficiency, energy management, and movement control exemplifies how circuit sprint-based training improves overall functional endurance.

This study carries valuable implications for physical education and youth athletic programs. Sun (2025) emphasized that measurable improvement should be a central goal of school-based training, and this study demonstrated exactly that. The program achieved consistent endurance enhancement within realistic educational constraints. Moreover, Chu (2025) stressed that holistic development—combining physical fitness, focus, and teamwork—is essential for adolescent athletes. The cooperative nature of circuit training encouraged group support and discipline throughout implementation. Fang (2025) also proposed that repeated, moderate stress leads to sustainable adaptation, a principle that aligns with the gradual progress observed in this study. The method's simplicity makes it replicable in diverse educational settings. It also offers a framework that promotes self-regulation and resilience among students. As such, circuit sprint-based training is not only effective scientifically but also pedagogically beneficial. It demonstrates how evidence-based approaches can strengthen both performance and character.

In conclusion, the results of this study align with and extend the collective insights of Sun (2025), Chu (2025), Fang (2025), Yao (2025), Song (2025), Maggiolo (2025), Henríquez (2025), Moya-Ramón (2025), Peña-González (2025), and Abasiyanik (2025). Together, their research highlights that endurance improvement arises from structured repetition, balanced intensity, and biomechanical efficiency. The circuit sprint-based approach used here embodies those principles while adapting them for practical, school-level implementation. The significant rise in VO_2Max confirms that meaningful progress can be achieved through simple yet disciplined conditioning. This program not only enhanced physical performance but also promoted motivation, teamwork, and persistence among young athletes. The results affirm that success in endurance training depends on methodical design rather than advanced technology. Therefore, this study contributes both theoretical and practical value to the field of youth sports science. It presents circuit sprint-based training as a realistic and effective model for enhancing endurance in adolescent football players.

CONCLUSIONS

The present study shows that circuit sprint-based training can serve as an effective and realistic approach to developing endurance in young football players. After six weeks of consistent and structured practice, participants displayed a noticeable improvement in their VO_2Max, reflecting better oxygen utilization and overall cardiovascular efficiency. This progress illustrates that meaningful performance gains can be achieved even with simple methods when training is planned with discipline and clear progression. The balance between sprint effort and controlled recovery allowed players to train intensively while avoiding excessive fatigue, creating a sustainable path for endurance enhancement. Beyond measurable physical outcomes, the sessions also encouraged focus, teamwork, and motivation among the athletes, forming habits that support long-term development. The findings emphasize that success in conditioning does not rely on expensive facilities or advanced tools, but rather on thoughtful program design and consistent participation. In essence, circuit sprint-based training offers a practical and holistic model that strengthens both physical capacity and character in school-based football environments.

AUTHOR'S CONTRIBUTION

Amin Setiawan designed and implemented the research, conducted data collection, performed data analysis, and prepared the manuscript draft. Danardono, S.Pd., M.Pd. supervised the entire research process, provided academic advice and constructive feedback, and reviewed the manuscript critically to ensure its scientific accuracy and coherence. Both contributed to improving the methodological approach and refining the presentation of the study results.

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