Physiological adaptations in small-side games combined with speed-endurance training: analyzing heart rate and rate of perceived exertion

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Abstract

Background and Study Aim	Monitoring physiological responses during training is crucial for understanding how athletes adapt to various exercise intensities. However, the specific effects of combining Small-Sided Game (SSG) and Speed-Endurance Training (SET) on these parameters require the search for more effective solutions. This study aims to determine the effect of combined SSG and SET on heart rate (HR) and rate of perceived exertion (RPE).
Material and Methods	This quantitative research employed an experimental method with a weekly pretest-posttest design. The study population consisted of eighty-two members of the Unesa Soccer Student Activity Unit. A sample of eighteen individuals was selected through simple random sampling. The sample had the following characteristics: age 20±0.69 years, weight 65±9.54 kg, height 165.22±4.31 cm, and BMI 22.82±1.92. Data were collected using the Polar H-10 device, and RPE interviews were conducted ten minutes after each training session. Data analysis was performed using paired sample t-tests and Wilcoxon tests.
Results	The results showed a significant difference in HR for pair 1 ($p = 0.037$), but no significant differences for pair 2 ($p = 0.058$) or pair 3 ($p = 0.076$). However, the results for RPE indicated significant differences in pair 1 ($p = 0.001$), pair 2 ($p = 0.004$), and pair 3 ($p = 0.002$). The combination of SSG and SET led to an increase in HR during the first and second weeks. In the third week, HR decreased. RPE increased from the first to the second week. It then stabilized in the third and fourth weeks, indicating a consistent level of effort. The decrease in HR during the third week, despite the same effort level, suggests that the athletes successfully adapted to the training program.
Conclusions	The combination of SSG and SET demonstrates potential as an effective training method for improving both physiological performance and adaptation in athletes. These findings offer valuable insights into how athletes respond to structured training programs, providing a foundation for future research and practical applications in sports training. The results contribute to a deeper understanding of the role that specific training combinations play in athlete development and recovery.
Keywords:	small-sided game, speed-endurance training, heart rate, rate of perceived exertion, physiological response.

Introduction

Optimal athletic performance relies on athletes' ability to adapt to varying training intensities. Therefore, monitoring physiological responses is key to evaluating these adaptations. Developing training strategies that enhance athletes' physical adaptation and overall performance is of great importance in this context. This is particularly relevant to football, where performance depends on physical fitness, psychological factors, technical skills, and team tactics [1, 2]. The development of modern soccer requires players to possess optimal physical and technical abilities. Soccer is characterized by high-intensity activities, such as sprinting, rapid changes of direction, and jumping, necessitating training that mirrors the competitive physical demands of the game [3]. Modern soccer matches also involve more passing, ball dribbling, and crossing, reflecting a significant increase in match intensity [4, 5]. Therefore, soccer players require a high level of fitness to meet the physical demands of the game.

To prepare players for optimal performance during matches and reduce the risk of injury, training loads are often recorded and monitored [6, 7, 8]. By monitoring heart rate data during matches, coaches can more accurately adjust training programs for individual players, supporting their physical development and readiness. This approach ensures that training loads and recovery are optimally

managed, leading to the best possible results [9, 10].

According to previous research, training monitoring involves the systematic collection of data reflecting the volume, intensity, and content of training, serving as an effective tool for controlling training [11]. This aligns with findings that training monitoring is essential for minimizing injury risk, assessing fatigue and recovery needs, and preventing negative training adaptations [12]. In addition to monitoring physical development, measuring training load and recording training outcomes are crucial. It is vital to assess the physical demands placed on each player, such as distance covered, acceleration, and physiological responses like heart rate or rate of perceived exertion. Therefore, systematic and accurate monitoring is necessary to support the physical development of soccer players.

During the competition preparation phase, gradual increases in training load have been shown to reduce injury risk and maintain or even enhance performance throughout the season [8, 13, 14, 15]. However, training loads are often not systematically recorded or monitored, leading to discrepancies between the prescribed loads and each player's physical capacity in the program design. In addition to focusing on physical, technical, and tactical improvements, coaches must also design training programs that meet the team's needs within a relatively short timeframe. To address this challenge, an innovative approach is proposed by combining two different training models, Small-Sided Games (SSG) [16] and Speed-Endurance Training (SET) [17], to analyze the effectiveness of this combination in soccer team training.

Another study showed that SSG, which involve playing in small groups on a smaller field, have become a focus of research aimed at improving technical skills and physical performance across various sports [16]. At a basic level, this training method allows players to enhance their technical and tactical skills in smaller game situations, improve player interactions, and accelerate decision-making [18, 19]. Meanwhile, SET is defined as high-intensity interval training that leads to maximum oxygen uptake (VO2 Max) [17, 20].

Other studies focus on the development of training models that combine SSG with HIIT methods, which have recently gained increasing use in professional soccer clubs [21, 22]. The combination of these two training models, which enhance physical, technical, and tactical abilities, has a positive impact on team development. Both HIIT and SSG offer similar benefits for soccer-specific performance variables and endurance, with minimal impact on neuromuscular performance [3].

In this context, SSG have been introduced as a specific alternative to running-based high-intensity interval training, providing simultaneous improvements in technical skills, tactical abilities, and overall fitness levels in soccer players [21, 23]. Despite the positive effects of this combined training approach, previous studies have mainly focused on monitoring and recording physical abilities, with limited attention given to how physiological responses, such as heart rate (HR) and rate of perceived exertion (RPE), are influenced during such training. Therefore, it is crucial to investigate the impact of combining SSG and SET on HR and RPE responses. This study hypothesizes that the combination of SSG and SET will significantly enhance soccer players' physiological responses, particularly HR and RPE, over a four-week training period.

Materials and Methods

Participants

The study was conducted with 18 active soccer players from the Student Soccer Unit of Universitas Negeri Surabaya, selected from a population of 82 using random sampling. The participants had an average age of 20 ± 0.69 years, an average weight of 65 ± 9.54 kg, an average height of 165.22 ± 4.31 cm, and a BMI of 22.82 ± 1.92.

Research Design

An experimental method with a pretest-posttest design was used. The research was conducted over four weeks, with three sessions per week. The design of the study is presented in Figure 1.

Figure 1 shows that in the first week of the study, a baseline test was conducted at the end of the week to gather initial data from the participants. After
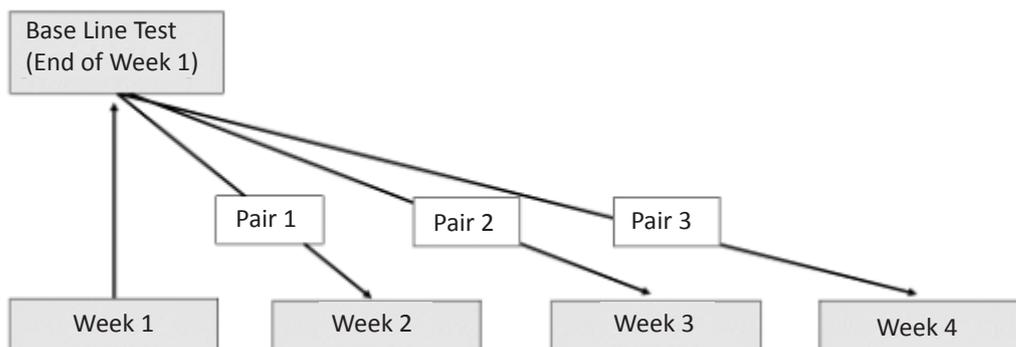

Figure 1. Research Design

collecting the baseline data, participants underwent the treatment during the following weeks. In the second week, the first t-test was conducted to compare baseline results with the outcomes from the second week's treatment. This test aimed to assess changes occurring after two weeks of treatment. In the third week, the second t-test was conducted to compare baseline results with the outcomes from the third week's treatment, aiming to identify changes occurring after three weeks. In the fourth week, the third t-test was conducted to compare baseline results with the outcomes from the fourth week's treatment, evaluating changes occurring after four weeks. The data included the percentage of heart rate per minute (BPM) for the sample during the combination of SSG and SET, as well as RPE for each week of training. Data collection instruments included a heart rate monitor and interviews. The Polar H10 heart rate monitor was used to measure the players' heart rates during training sessions. Additionally, interviews were conducted to obtain players' subjective views on their effort during training, using an RPE scale of 1-10.

Training Program

The training program design is illustrated in Figure 2, which demonstrates the combination of SSG with SET, including player positioning, sprinting distances, and repetition patterns.

The combination of SSG with SET begins with the Blue and Red players positioned in Area 2 (Figure 2a), then they sprint 20 meters through Area 3 towards Area 1 (Figure 2b). In Area 1, they play for 18 seconds, with the Blue players tasked with attacking and the Red players defending. Afterward, they return to Area 2 by sprinting 20 meters (Figure 2c) and play again for 18 seconds, this time switching roles—Red players attack, and Blue players defend (Figure 2d). Next, the players sprint 20 meters back to SSG 1 and repeat the game pattern. Each repetition involves a total of 4 sprints, with each sprint covering 20 meters, so the total sprint distance per repetition is 80 meters, and the total SSG playtime is 72 seconds (18 seconds x 4). During one training session, the players perform 8 repetitions, which means the total sprint distance covered is 640 meters (80 meters x 8 repetitions), and the total SSG playtime is 576 seconds (72 seconds x 8 repetitions). The interval between activities is 1:2, ensuring a balance between work intensity and rest. The training involved three groups alternating between SSG and SET. When one group was engaged in SSG with SET, the other two groups performed recovery by passing the ball outside the training area. During recovery, players remained active by passing the ball to each other on the sidelines to keep their heart rate within the training zone. This approach not only improves physical fitness but also maintains high training intensity and ensures positive player adaptation.

Statistical Analysis

The means and standard deviations of the data in this study are presented. Tests for normality were conducted as part of the prerequisites. The Shapiro-Wilk test was used to assess whether the data followed a normal distribution. Paired sample t-tests and Wilcoxon tests were employed to analyze the differences between the pretest and posttest results. Statistical significance was set at $p<0.05$.

Results

Table 1 presents the descriptive statistics for HR from 18 subjects over four weeks. In Week 1 (baseline), the average HR was 88.56 with a standard deviation of 5.19. In Week 2, the average HR increased to 90.22 with a standard deviation of 4.07. In Week 3, the average HR was 89.78 with a standard deviation of 5.26, and in Week 4, the average HR was 89.72 with a standard deviation of 5.38.

Table 2 presents the descriptive statistics for RPE from 18 subjects over four weeks. In Week 1 (baseline), RPE values ranged from 8.00 to 9.00, with an average of 8.06 and a standard deviation of 0.24. In Week 2, RPE values ranged from 9.00 to 10.00, with an average of 9.06 and a standard deviation of 0.24. In Week 3, RPE values ranged from 8.00 to 10.00, with an average of 8.61 and a standard deviation of 0.61. Finally, in Week 4, RPE values ranged from 8.00 to 9.00, with an average of 8.61 and a standard deviation of 0.50. The RPE data indicates that the average perceived effort of the

Figure 2. Training Program

subjects slightly increased from Week 1 to Week 2, then stabilized in Weeks 3 and 4.

Based on Table 3, the normality test results show that the heart rate (HR) percentages for Weeks 1-4 have a significance value (sig > 0.05), indicating that the data are normally distributed. Therefore, a paired sample t-test was conducted. Conversely, the normality test results for RPE for Weeks 1-4 show a significance value (sig < 0.05), indicating that the data are not normally distributed. Consequently, the Wilcoxon test was conducted.

Given that the HR data showed a normal distribution, the paired t-test was used, while the Wilcoxon test was applied for the non-normally distributed RPE data (Table 4).

According to Table 4, the results of the paired samples t-test show a significance level (sig. 2-tailed) of 0.037 for Pair 1, 0.058 for Pair 2, and 0.076 for Pair 3. With a significance threshold of 5% (0.05), among the three HR comparisons, only HR in Pair 1 is significant (0.037 < 0.05), while HR in Pair 2 (0.058 > 0.05) and HR in Pair 3 (0.076 > 0.05) are not significant.

According to Table 5, the results of the non-parametric Wilcoxon test show a significance level (sig. 2-tailed) of 0.000 (<0.05) for Pair 1, 0.004 (<0.05) for Pair 2, and 0.002 (<0.05) for Pair 3. With a significance threshold of 0.05, the results indicate that all pairs are statistically significant.

Table 1. Descriptive Statistics for Average HR

Week	N	Minimum	Maximum	Mean	Std. Deviation
Week 1 (baseline)	18	81.00	97.00	88.56	5.19
Week 2	18	83.00	96.00	90.22	4.07
Week 3	18	80.00	98.00	89.78	5.26
Week 4	18	79.00	98.00	89.72	5.38
Valid N (listwise)	18				

Note: Data are presented as mean±SD.

Table 2. Descriptive Statistics for RPE

Week	N	Minimum	Maximum	Mean	Std. Deviation
Week 1 (baseline)	18	8.00	9.00	8.06	0.24
Week 2	18	9.00	10.00	9.06	0.24
Week 3	18	8.00	10.00	8.61	0.61
Week 4	18	8.00	9.00	8.61	0.50
Valid N (listwise)	18				

Note: Data are presented as mean±SD.

Table 3. Normality Test Results for HR.

Week		Shapiro-Wilk		
		Statistic	Df	Sig.
HR Result	HR Week 1	.942	18	.318
	HR Week 2	.940	18	.288
	HR Week 3	.942	18	.311
	HR Week 4	.945	18	.350
RPE Result	RPE Week 1	.253	18	.000
	RPE Week 2	.253	18	.000
	RPE Week 3	.741	18	.000
	RPE Week 4	.624	18	.000

Table 4. Results of Paired Samples T-Test

Pair	T	df	Significance (2-tailed)
Pair 1: HR Baseline - HR Week 2	-2.263	17	.037*
Pair 2: HR Baseline - HR Week 3	-2.028	17	.058
Pair 3: HR Baseline - HR Week 4	-1.891	17	.076

Note: Percentage of change between pre- and post-training performance. *Significant difference, p < 0.05.

Table 5. Results of Wilcoxon Test

Pair	Z	Significance (2-tailed)
Pair 1: RPE Baseline – RPE Week 2	-4.243[b]	.000*
Pair 2: RPE Baseline – RPE Week 3	-2.887[b]	.004*
Pair 3: RPE Baseline – RPE Week 4	-3.162[b]	.002*

Note: [b]- Based on negative ranks; Percentage of change between pre- and post-training performance. *Significant difference, $p < 0.05$.

Discussion

The objective of this study was to evaluate the effect of combining SSG and SET on physiological responses, specifically HR and RPE. The results reveal an interesting pattern in physiological responses and perceived exertion over the 4-week training period. In the first week, the increase in maximal HR in zones 4 and 5 during training indicates that the workload was sufficiently high, triggering an increase in heart rate as the body responded to meet oxygen demands. The continued increase in HR during the second week suggests that the body was still in the adaptation phase to the given training load. In the third week, although HR remained higher than in the first week, the increase was not significant, indicating that the players' bodies had begun to physiologically adapt to the training intensity. The decrease in average HR in the fourth week may reflect improved heart efficiency in pumping blood, a positive sign of adaptation from the training. This finding aligns with previous research [11], which also showed that during the first and second weeks, the average HR Max (maximum heart rate) of players was in high training zones 4 and 5, indicating very high work intensity during training.

This indicates that the players were in optimal condition to improve their cardiovascular fitness and aerobic capacity. On the other hand, the RPE increased from the first week to the second week, reflecting that the players perceived a higher intensity and training load, which is expected during the initial adaptation phase to a new training program. In the third and fourth weeks, RPE remained stable, indicating that the players exerted relatively the same effort from week 1 to week 4.

The results of the study demonstrate that the combination of two training models, SSG and SET, positively influences players' physiological capabilities. These findings align with previous research [3, 24], which showed that combining these two training models is effective in consistently maintaining high work intensity throughout the training period, a key factor for fitness development and performance optimization in soccer. In the context of our research, the combined training of SSG and SET aims to create a holistic approach to soccer player development. By integrating technical, tactical, speed, and endurance elements, this training provides a balanced physiological impact while developing competitive soccer skills. Players undergoing this combined training are expected to perform optimally in matches and better manage both physical and mental challenges.

The combination of SSG and SET training has a wide-ranging physiological effect on soccer players. SSG incorporates technical and tactical drills that enhance players' coordination and creativity in small-sided scenarios, while SET emphasizes the development of speed and endurance. This integrated approach improves both aerobic and anaerobic capacity in players [25].

In the context of our research, the combination of SSG and SET simultaneously involves both aerobic and anaerobic activities. SSG training can increase players' aerobic capacity through continuous play, while SET training improves anaerobic endurance through short sprints and speed training. Heart rate optimization and cardiovascular system improvement occur through the integration of these two methods, which comprehensively stimulate the cardiovascular system. High-intensity SSG increases heart rate and blood flow, while SET enhances the cardiovascular system's ability to efficiently deliver oxygen and nutrients to muscles. Maximum speed and sprinting ability are also developed through SET training, and when combined with SSG, this approach helps players simultaneously enhance their maximum speed and sprinting ability. Short sprints in SET build muscle strength that supports speed, while SSG game situations improve players' reactions and sharpness in dynamic game conditions. High-speed endurance development also occurs when the combination of SSG and SET allows players to experience game situations that test their endurance at high speeds, providing significant benefits when they need to maintain intensity and performance quality during high-pressure matches.

This study demonstrates that the combination of SSG and SET positively affects soccer players' physiological responses, specifically HR and RPE. These findings are consistent with previous research, which has shown that this training combination increases overall training intensity, as reflected by elevated HR and higher RPE ratings [3, 11, 16]. The results of this study have important practical implications for designing training programs for soccer players. Combining SSG with SET can be an effective strategy to improve players' physical

conditioning and endurance, which can enhance their performance in actual matches. This study confirms that the combination of SSG and SET is a holistic soccer training model that has a positive impact on players.

One limitation of this study is the relatively small sample size of 18 participants, which may limit the generalizability of the findings to a broader population of soccer players. Additionally, the study was conducted over a four-week period, which is a relatively short timeframe for assessing the long-term effects of training. Future research could focus on a longer training cycle and a larger sample size to provide more accurate conclusions.

Conclusions

The combination of Small-Sided Games (SSG) and Speed-Endurance Training (SET) represents a comprehensive training approach that integrates both physiological and tactical development in soccer players. This approach has the potential to enhance players' overall fitness, technical abilities, and adaptability to high-intensity match conditions. By addressing both aerobic and anaerobic demands, this combined training model can be effectively incorporated into soccer training programs to improve long-term performance.

Future research could explore the effects of extended training periods beyond four weeks to determine long-term adaptations and performance improvements. Additionally, investigating the application of this training approach across different age groups, skill levels, and competitive environments could provide valuable insights into its versatility. Further studies may also focus on optimizing the balance between SSG and SET for specific training objectives, such as injury prevention or recovery strategies.

Conflict of interest

The authors have not received any support or endorsement from any organization for the submitted work.

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