

Unveiling anaerobic soccer training: comparing its effects with small-sided games on youth performance enhancement

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Abstract

Background and Study Aim Soccer is a high-intensity sport that requires players to maintain optimal physical performance over an extended period. This has led to the development of various training methods to enhance both aerobic and anaerobic energy systems. Small-Sided Games (SSG) is a popular training method in soccer, as it improves both technical skills and fitness. However, its effectiveness in developing anaerobic capacity still requires further investigation. Therefore, this study aims to compare the effects of Anaerobic Soccer Training (AnST) and SSG on aerobic and anaerobic performance in young soccer players.

Material and Methods A randomized trial was conducted on 25 male soccer players (AnST: n = 16; SSG: n = 9) aged 18 to 21 years. The average (mean ± SD) values were: age 19 ± 0.65 years, body weight 61.88 ± 5.28 kg, height 167 ± 5.50 cm, and body mass index (BMI) 21.84 ± 2.01. The intervention lasted six weeks. Aerobic capacity was assessed using a 2400-meter run test. Anaerobic performance was evaluated through average power, minimum power, peak power, and fatigue index. Statistical analysis included paired t-tests and percentage change calculations.

Results The findings indicate that both AnST and SSG significantly improved aerobic performance. The AnST group showed a greater relative increase ($\Delta\% = 7.23\%$) compared to the SSG group ($\Delta\% = 5.06\%$). For anaerobic performance, AnST produced a significant increase in average power ($\Delta\% = 16.80\%$, $p < 0.001$) and minimum power ($\Delta\% = 28.60\%$, $p < 0.001$). Changes in peak power and fatigue index were not statistically significant.

Conclusions Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) are both effective in improving aerobic and anaerobic capacities in young soccer players. AnST demonstrated greater gains, likely due to its higher training intensity.

Keywords: anaerobic soccer training, small-sided games, aerobic capacity, anaerobic performance, soccer training.

Introduction

Modern soccer demands high levels of physical performance due to its fast-paced and dynamic nature. Players are required to repeatedly perform high-intensity efforts, including sprints, rapid accelerations, and quick recovery between actions. This places a substantial burden on both aerobic and anaerobic energy systems. In this context, it becomes essential to examine the available training strategies to better understand their practical applications and impact on physical performance. However, questions remain regarding the extent to which different approaches address both aerobic and anaerobic demands, especially in youth athletes.

Anaerobic Soccer Training (AnST) is an innovative training method developed to enhance physical performance, particularly the anaerobic components of soccer players. This method

emphasizes a holistic approach by combining short-distance sprints with Small-Sided Games (SSG). It has the potential to produce more sport-specific physical adaptations compared to conventional methods. The primary advantage of AnST lies in its ability to simulate real-game scenarios. In these situations, players are often required to perform short sprints before engaging in complex game actions. Previous studies have shown that AnST effectively improves players' anaerobic capacity [1].

On the other hand, SSG has become a widely adopted training method for enhancing the physical capacities of soccer players [2]. Several studies have demonstrated its effectiveness in improving aerobic performance by integrating tactical elements and technical skills. It also requires high levels of concentration during ball possession [3]. Although SSG increases player involvement and the frequency of ball touches, some studies suggest that the training intensity is often insufficient to optimally develop the speed and explosive power required in high-intensity matches [4, 5].

From a physical demand perspective, soccer is a high-intensity sport that requires players to maintain optimal performance over an extended duration [6, 7]. Previous research has shown that elite players cover an average distance of 10 to 13 km during a 90-minute match [8, 9]. Furthermore, match activities include 23% high metabolic load distance, 11% high-intensity accelerations and decelerations, and 6% maximal sprints [10]. Therefore, effective training methods are essential for improving both aerobic and anaerobic capacity to support performance at a high level. Additionally, the evolution of modern game strategies demands greater physical capacity from players to cope with the increasingly fast and dynamic tempo of play. Structured and evidence-based training approaches are thus critical for player success.

As the physical demands in soccer continue to increase, the need for more integrative and game-based training approaches is becoming increasingly urgent [11]. Many coaches still rely on traditional methods that separate physical, technical, and tactical components. However, these approaches often fail to reflect actual match conditions. Training that does not align with game demands may hinder player development and limit the transfer of fitness and skills to real-match situations. As a result, more integrative and game-based training methods are gaining attention among coaches and sports scientists as more effective strategies for enhancing player performance.

Analysis of existing research shows that both Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) offer valuable contributions to the physical development of soccer players. The authors propose that combining short sprints with game-based drills, as in the AnST model, may lead to more specific adaptations relevant to match demands. However, unresolved issues remain, particularly concerning the optimal balance between training intensity and technical-tactical integration. These challenges highlight the need for continued investigation and the development of new approaches to maximize training effectiveness in youth soccer. Therefore, this study aims to compare the effects of Anaerobic Soccer Training (AnST) and SSG on aerobic and anaerobic performance in young soccer players.

Materials and Methods

Participants

This study involved 28 male soccer players who were recruited based on specific eligibility criteria. Participants were healthy individuals aged between 18 and 21 years. Their average characteristics were as follows (mean \pm SD): age 19 ± 0.65 years, body weight 61.88 ± 5.28 kg, height 167 ± 5.50 cm, and body mass index (BMI) 21.84 ± 2.01 . All players had

at least two years of playing experience and trained a minimum of four times per week. Individuals recovering from injury or illness were excluded. Initially, 16 players were assigned to the Anaerobic Soccer Training (AnST) group and 12 to the Small-Sided Games (SSG) group, based on the study design and training requirements. However, four players were unable to continue due to injury or illness. In accordance with the approved research ethics, these individuals were allowed to withdraw. As a result, the final sample consisted of 16 participants in the AnST group and 9 in the SSG group. Any player who developed a sudden illness and missed two consecutive training sessions was also considered withdrawn.

Research Design

This study employed an experimental two-group pretest-posttest design. Players were randomly assigned to one of two intervention groups: Anaerobic Soccer Training (AnST) or Small-Sided Games (SSG). The intervention period lasted six weeks, with training sessions conducted three times per week. Before and after the intervention, all participants underwent testing to assess anaerobic and aerobic capacity. Anaerobic performance was evaluated using the Running-Based Anaerobic Sprint Test (RAST), while aerobic capacity was measured with a 2400-meter run test. During training sessions, physiological intensity was monitored using Polar H-10 heart rate sensors to ensure that all exercises were performed within the intended intensity zones.

Protocol Test

The Running-Based Anaerobic Sprint Test (RAST) was used to assess the players' anaerobic capacity [13]. At the beginning of the test, players were instructed to perform maximal sprints toward designated points at opposite ends. Each player completed six maximal 35-meter sprints, with a 10-second recovery period between each sprint. Sprint times were recorded for each attempt and used to calculate key performance parameters, including peak power (W), minimum power (W), average power (W), and fatigue index (%).

The 2400-meter run test was employed to evaluate aerobic endurance capacity. This test is widely recognized for its practicality and validity in estimating maximal oxygen uptake (VO_{2max}) based on submaximal to maximal running performance. It was conducted on a standardized 400-meter athletic track under consistent environmental conditions. Ambient temperature and surface type were recorded prior to testing to ensure external validity and reproducibility. Before the test, all players completed a structured warm-up consisting of five minutes of light jogging. After the warm-up, they were instructed to position themselves behind the designated starting line. At the signal, players

were required to run 2400 meters in the shortest time possible. The structure of the Anaerobic Soccer Training (AnST) protocol, including sprint repetitions and Small-Sided Games integration, is illustrated in Figure 1.



Figure 1. AnST Training

AnST combines the Speed Endurance Training (SET) approach with Small-Sided Games (SSG) using a 1:1 work-to-rest ratio. The SSG area is set at 20 × 20 meters, with each player required to complete repeated sprints over distances of 5 meters, 10 meters, and 15 meters before engaging in the SSG. Each sprint repetition covers a total distance of 60 meters, with an estimated time of approximately 2–3 seconds for the 5-meter shuttle, 4–5 seconds for the 10-meter shuttle, and 6–7 seconds for the 15-meter shuttle. The entire 60-meter sprint is completed in about 15 seconds. At the start of each session, players complete a 60-meter sprint, immediately followed by a 1-minute SSG focused on ball control. After the sprint-SSG combination, players undergo a rest period equal to the total previous training duration, approximately 1 minute and 15 seconds (1 minute SSG + 15 seconds sprint), maintaining a 1:1 training-to-recovery ratio. This session is repeated 10 times, making the total training duration approximately 25 minutes. The structure and flow of the AnST session are illustrated in Figure 2.

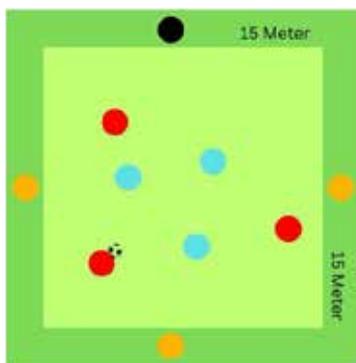


Figure 2. SSG Training

The three vs. three plus four neutral players Small-Sided Game (SSG) training enhances players' technical skills, tactical understanding, and physical capacity. In this drill, players are divided into three groups distinguished by color: red players (Group A), blue players (Group B), and orange players (Group C). The red and blue groups begin the game

in a three vs. three format within a 15 × 15 meter area. Three neutral players from the orange group remain outside the playing area to support attacking plays. Additionally, a coach wearing black acts as a neutral player outside the field but does not take part in the rotation. Each game session lasts 2.5 minutes and is performed at high intensity. After each round, the roles rotate: the red group becomes neutral players, while the blue group plays against the orange group in the same format. This cycle continues until all players have actively participated in 10 sets. The total duration of the training session is approximately 25 minutes.

Statistical Analysis

Descriptive statistics were used to summarize the characteristics of the participants. The normality of data distribution was assessed using the Shapiro–Wilk test. Paired t-tests were performed to evaluate within-group differences between pre- and post-test results. Independent sample t-tests were used to assess between-group differences in the effects of the AnST and SSG interventions. Levene’s test was applied to verify the assumption of homogeneity of variance. All results were reported with 95% confidence intervals (CI) to enhance the precision of the parameter estimates. Statistical analyses were conducted using R software (R Core Team, Vienna, Austria) within the RStudio integrated development environment (Posit Software, PBC, Boston, MA). Data visualization was performed using the ggplot2 package [12]. Additionally, the percentage change ($\Delta\%$) from pre- to post-test was calculated using the formula: $((\text{post} - \text{pre}) / \text{pre}) \times 100$.

Results

The baseline characteristics of the participants in the Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) groups are summarized in Table 1. These data provide an overview of the comparability of the groups prior to the intervention.

Table 1. Characteristics of research subjects (n = 25)

Characteristics	AnST (n = 16)	SSG (n = 9)	P-Value
Age (years)	19 ± 0.61	19 ± 0.72	0.517
Body Weight (kg)	61.37 ± 4.44	62.77 ± 6.74	0.536
Body Height (cm)	166 ± 5.30	168 ± 5.80	0.289
Body Mass Index (kg/m ²)	22 ± 2.03	21.5 ± 2.06	0.607

The comparison of demographic and anthropometric data between the two groups revealed no statistically significant differences. This indicates that both groups were comparable at baseline in terms of age, body composition, and physical dimensions. The absence of significant variation supports the internal validity of the study and ensures that observed training effects can be

attributed to the interventions rather than pre-existing differences.

The normality of the data was assessed using the Shapiro–Wilk test. The detailed results for each variable in both groups, before and after the intervention, are presented in Table 2. The results presented in Table 2 show that in the AnST group, all variables in both the pre-test and post-test conditions had significance values greater than 0.05, confirming that the data were normally distributed. In contrast, in the SSG group, most variables also met the normality assumption. However, the fatigue index in the post-intervention condition had a significance value of $p = 0.047$, indicating that the data for this variable were not normally distributed.

To verify the assumption of homogeneity of variances between groups, Levene’s test was conducted for all measured variables. The detailed results are presented in Table 3. The results of the homogeneity test using Levene’s test, as shown in Table 3, indicate that all variables had significance values greater than 0.05: Aerobic test ($p = 0.311$), Mean Power ($p = 0.319$), Peak Power ($p = 0.477$), Minimum Power ($p = 0.196$), and Fatigue Index ($p = 0.206$). These results confirm that the assumption of homogeneity of variances between the AnST and SSG groups was satisfied, supporting the validity of subsequent independent t-test analyses.

The results of the aerobic capacity assessment before and after the intervention are illustrated

in Figure 3. This figure compares the mean values within each group using paired t-tests. In the AnST group, the pre-test result was 47.52 ± 5.12 , while the post-test result increased to 50.80 ± 4.32 . The percentage change was 7.23%, with a confidence interval (CI) of -2.516 to -0.941 and a p-value < 0.001 , indicating a statistically significant improvement. In the SSG group, the pre-test result was 49.23 ± 3.41 , and the post-test was 51.63 ± 2.94 . The percentage change was 5.06%, with a CI of -1.726 to -0.132 and a p-value = 0.022, also showing a significant increase.

The effects of the intervention on anaerobic performance in the AnST group are presented in Figure 4. This figure displays changes in power output and fatigue index based on pre- and post-test measurements. Mean power increased significantly from 402.304 ± 78.819 W to 468.001 ± 95.948 W, reflecting a relative improvement of $\Delta\% = 16.80\%$ (CI: -1.876 to -0.564, $p < 0.001$). Minimum power also showed a significant increase, rising from 299.885 ± 81.286 W to 385.619 ± 86.664 W, with a relative improvement of $\Delta\% = 28.60\%$ (CI: -2.202 to -0.760, $p < 0.001$). In contrast, peak power rose from 522.676 ± 101.433 W to 567.102 ± 114.543 W, but this change ($\Delta\% = 8.50\%$) was not statistically significant (CI: -0.991 to 0.047, $p = 0.075$). The fatigue index slightly decreased from 6.412 ± 1.889 to 5.536 ± 1.693 , showing a reduction of $\Delta\% = -13.67\%$, though this change was also not statistically significant (CI: -0.147 to 0.867, $p = 0.164$).

Table 2. Normality test of aerobic and anaerobic performance

Group	Variable	df	Shapiro-Wilk			
			Pre		Post	
			Statistic	Sig.	Statistic	Sig.
AnST	Aerobic Test	16	0.957	0.607	0.956	0.586
	Mean power	16	0.935	0.293	0.970	0.839
	Peak power	16	0.921	0.173	0.966	0.769
	Min power	16	0.959	0.649	0.920	0.168
	Fatigue index	16	0.951	0.499	0.954	0.553
SSG	Aerobic Test	9	0.861	0.098	0.872	0.128
	Mean power	9	0.960	0.795	0.949	0.676
	Peak power	9	0.955	0.744	0.949	0.683
	Min power	9	0.964	0.842	0.876	0.142
	Fatigue index	9	0.912	0.328	0.832	0.047

Table 3. Homogeneity Test of Aerobic and Anaerobic Performance

Variable	Levene Statistic	df	Sig.
Aerobic test	1.074	23	0.311
Mean power	0.214	23	0.319
Peak Power	0.523	23	0.477
Min Power	1.769	23	0.196
Fatigue Index	0.071	23	0.206

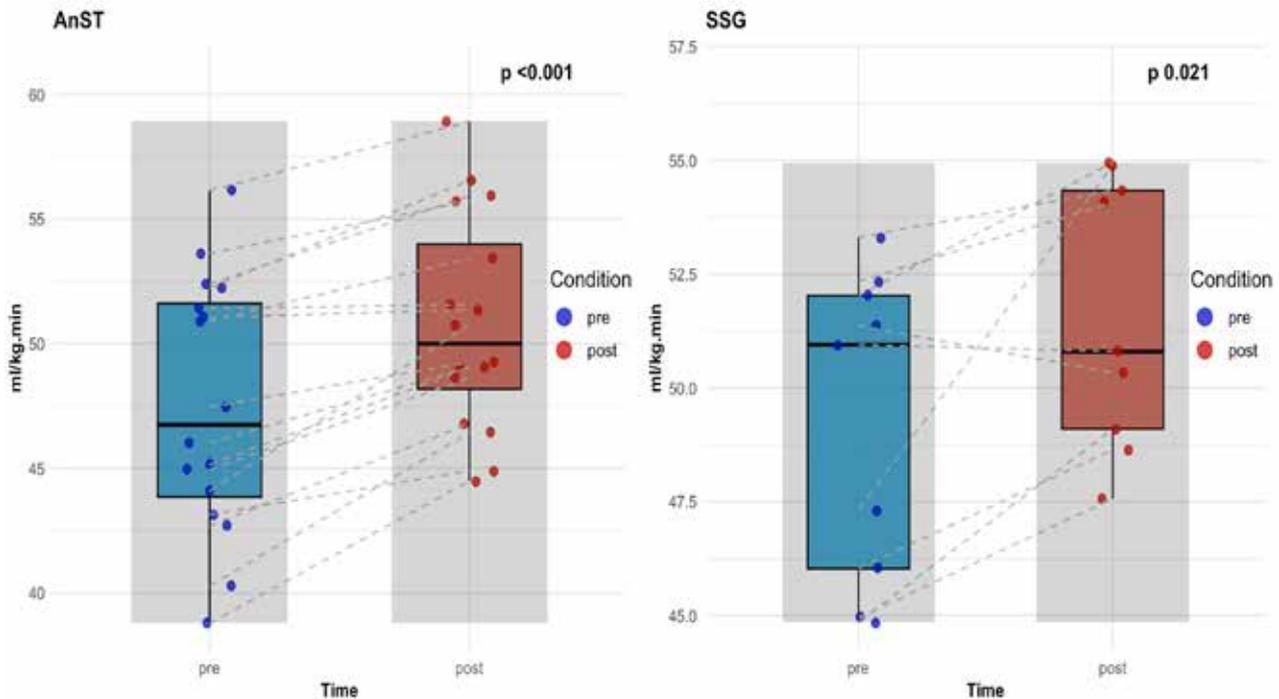


Figure 3. Result Paired t-test in aerobic test

The effects of the intervention on anaerobic performance in the SSG group are illustrated in Figure 5. This figure presents pre- and post-test results for key power-related indicators and fatigue index. Mean power significantly increased from 441.023 ± 51.295 W to 511.672 ± 87.225 W, representing a relative improvement of $\Delta\% = 16.14\%$ (CI: -1.842 to 0.196, $p = 0.014$). Minimum power also improved significantly, rising from 329.103 ± 82.822 W to 385.873 ± 58.652 W, with a relative increase of $\Delta\% = 17.24\%$ (CI: -1.641 to 0.083, $p = 0.030$).

In contrast, peak power showed a slight, non-significant increase from 526.934 ± 75.354 W to 561.232 ± 87.175 W, with a change of $\Delta\% = 6.51\%$ (CI: -1.322 to 0.115, $p = 0.100$). The fatigue index, evaluated using the Wilcoxon test, also increased slightly from 5.757 ± 1.762 to 6.312 ± 1.411 , but the difference ($\Delta\% = 9.64\%$) was not statistically significant (CI: -0.812 to 0.326, $p = 0.211$).

The comparison of aerobic performance between the AnST and SSG groups was conducted using an independent t-test. The detailed results are presented in Table 4. Table 4 shows that there was no significant difference in aerobic capacity between the two groups ($p = 0.612$). The effect size was -0.214, and the confidence interval ranged from -1.030 to 0.607, which includes zero. These findings confirm the absence of a statistically meaningful difference in aerobic outcomes between the intervention groups.

A comparative analysis of anaerobic performance between the AnST and SSG groups was performed using independent t-tests and the Mann-Whitney test. The results are summarized in Table 5. As shown in Table 5, there were no significant

differences in anaerobic power parameters between the groups, with all p-values exceeding 0.05. The Mann-Whitney test applied to the fatigue index also revealed no significant difference, with a p-value of 0.207. These findings indicate that, despite within-group improvements, the between-group differences in anaerobic outcomes were not statistically significant.

Discussion

This study was designed to compare the effects of Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) on aerobic and anaerobic capacities in young male soccer players over a six-week period. The findings show that both training methods led to significant improvements in aerobic capacity. However, the improvement was more pronounced in the AnST group (7.23%) compared to the SSG group (5.06%). These results are consistent with previous research suggesting that sprint-based training protocols are more effective than game-based methods in enhancing maximal oxygen uptake [14]. The greater aerobic gains observed in the AnST group may be attributed to the repeated high-intensity efforts combined with short recovery intervals [15]. This type of stimulus is known to promote oxidative adaptations and improve the efficiency of the aerobic energy system [16]. Consequently, the AnST protocol appears to better reflect the physical demands of modern soccer, which requires players to recover quickly and maintain high performance across repeated efforts.

The study also found that both AnST and SSG effectively improved repeated sprint ability, as shown by significant increases in mean and

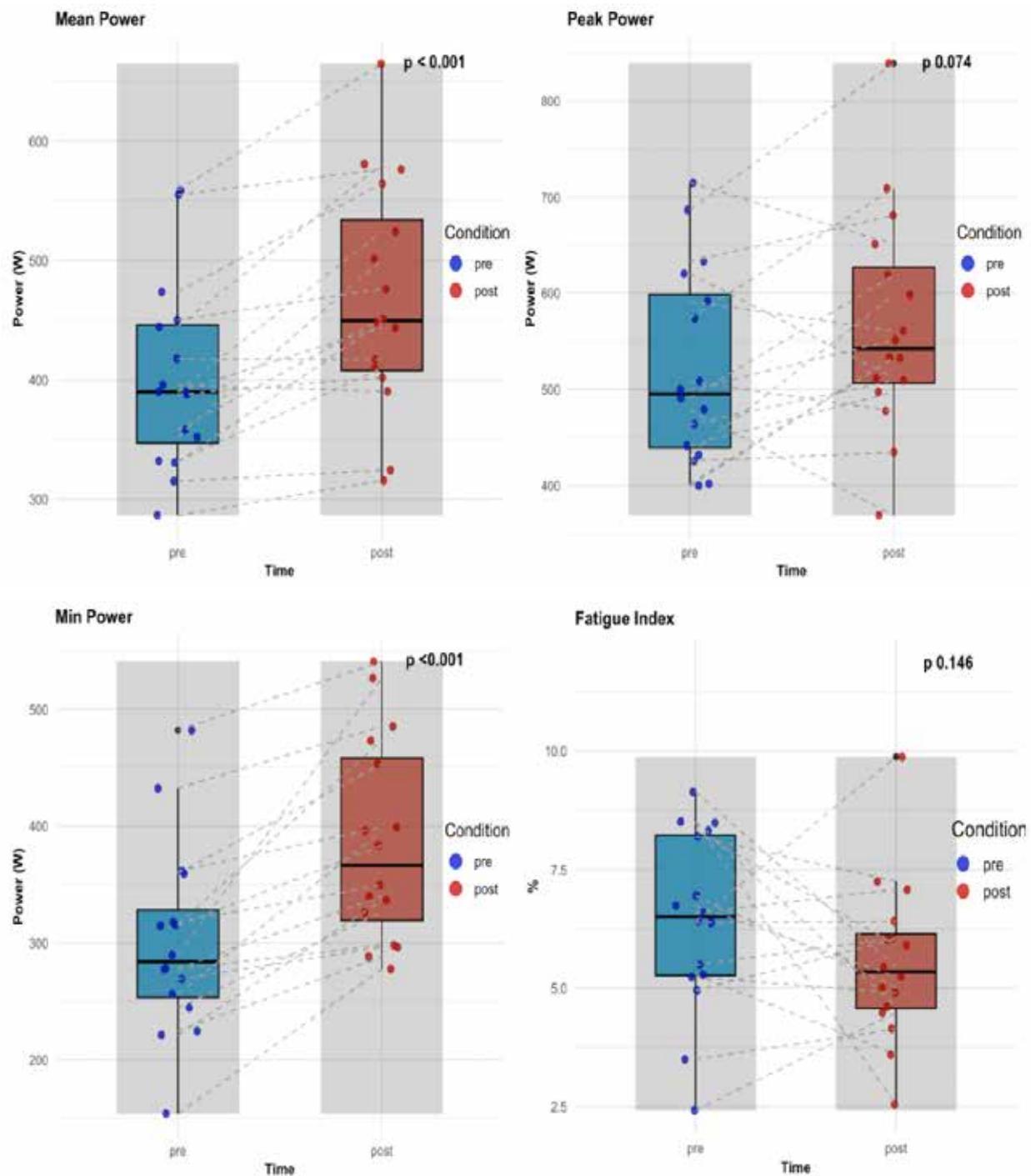


Figure 4. Result in anaerobic test AnST Group

minimum power. These improvements suggest that both training methods enhance the body's ability to sustain power output during repeated high-intensity efforts. However, the comparative analysis indicated that the AnST protocol led to more favorable adaptations than the SSG protocol. This outcome is likely due to the high-intensity interval nature of AnST, which includes short work periods and limited recovery time [17, 18]. Such conditions generate substantial metabolic stress, which in turn promotes improvements in anaerobic efficiency [19]. This interpretation is supported by findings

from Arslan et al. [20], who demonstrated that high-intensity training enhances neuromuscular and metabolic efficiency more rapidly and significantly than training at moderate or low intensities.

Conversely, the SSG group also demonstrated improvements in mean and minimum power, although these gains were slightly lower than those observed in the AnST group. This indicates that game-based training can still contribute to meaningful performance adaptations. SSG drills focus on technical and tactical execution within small, constrained spaces, which indirectly activate

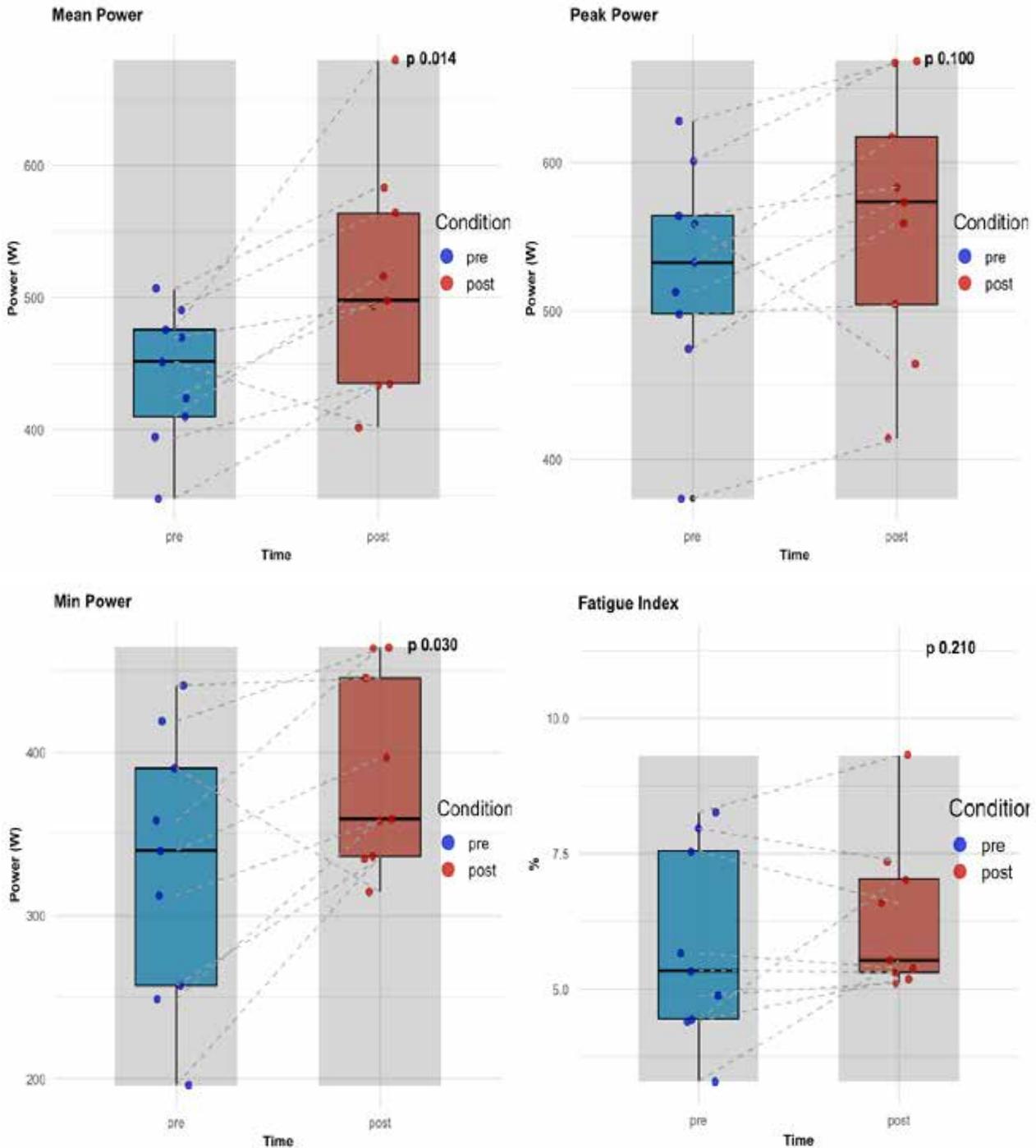


Figure 5. Result in Anaerobic test SSG group

the aerobic and, to a lesser extent, anaerobic energy systems. This activation primarily occurs through explosive actions such as short sprints and rapid directional changes [21, 22]. These findings align with previous research suggesting that SSG delivers a balanced combination of physiological and technical stimuli within a single training framework [23]. However, due to its greater emphasis on aerobic demands and relatively longer recovery periods between high-intensity actions [24], the resulting adaptations in anaerobic capacity may be suboptimal [25]. This explains why the

improvements observed in the SSG group, while present, were not as pronounced as those resulting from the AnST protocol. Moreover, the absence of significant changes in peak power in both groups indicates that, although mean and minimum power improved, the ability to generate maximal explosive force did not. Peak power reflects the capacity of muscles to produce force over a very short time frame, and the lack of targeted stimulus in either training model may account for this outcome [26].

Interestingly, the study revealed contrasting responses in the fatigue index between the two

Table 4. Independent t-test in Aerobic

Variable	df	P-Value	Effect Size	95% CI effect size	
				Lower	Upper
Aerobic	23	0.612	-0.214	-1.030	0.607

Table 5. Comparative Analysis of Physical Parameter Means Using Independent t-Test and Mann-Whitney Test

Variable	df	P-Value	Effect Size	95% CI effect size	
				Lower	Upper
Mean power	23	0.271	-0.470	-1.292	0.363
Peak Power	23	0.895	0.055	-0.762	0.872
Min Power	23	0.994	-0.003	-0.820	0.813
Fatigue Index	23	0.207†	-0.319	-0.671	0.149

Note: †: Mann-Whitney test

groups. The AnST group exhibited a slight, although non-significant, decrease in fatigue index. This suggests that high-intensity training may be more effective in enhancing the body's ability to adapt to physical stress under repeated high-intensity conditions. Such adaptation is often linked to physiological improvements in fatigue resistance following intense efforts [28]. Supporting this, Jiménez et al. [29] found that sprint training with limited recovery improves the body's capacity to manage fatigue caused by lactate accumulation, allowing athletes to sustain performance across repeated bouts. In contrast, the SSG group showed an increase in the fatigue index. This may be the result of suboptimal load distribution that fails to sufficiently stimulate the anaerobic system [30]. Without a strong anaerobic stimulus, neuromuscular adaptations may remain limited. As a result, players in the SSG group might have experienced greater fatigue, possibly due to inadequate exposure to prolonged or repeated high-intensity efforts.

Limitations

This study has several limitations that should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of the findings. Second, unequal group sizes due to participant dropout may have introduced imbalance, despite random allocation. Third, the intervention period was limited to six weeks; longer training durations may result in different adaptation patterns. Finally, the study did not incorporate biochemical or neuromuscular measurements. Future research should include such parameters to provide a more comprehensive understanding of the physiological mechanisms underlying performance improvements.

In summary, both Anaerobic Soccer Training

(AnST) and Small-Sided Games (SSG) proved effective in enhancing aerobic and anaerobic performance in young soccer players. However, AnST produced more substantial improvements, particularly in repeated sprint ability and aerobic capacity, likely due to its higher training intensity and structured intervals. While SSG remains a valuable and practical method for integrated skill and fitness development, it may be less effective in targeting peak anaerobic performance. These findings support the strategic application of training modalities based on desired performance outcomes and highlight the potential of high-intensity models such as AnST in modern soccer conditioning.

Conclusions

This study concludes that both Anaerobic Soccer Training (AnST) and Small-Sided Games (SSG) are effective in improving aerobic and anaerobic capacities in young soccer players over a six-week training period. However, AnST led to greater percentage improvements, particularly in VO₂max, mean power, and minimum power. These results are likely attributable to the higher intensity and structured intervals of the AnST protocol, which provide a stronger physiological training stimulus. The findings offer practical implications for coaches and practitioners, suggesting that AnST may be a more effective approach when the primary goal is to enhance high-intensity performance capacities in youth soccer training.

Conflict of interest

The authors declare no conflict of interest. They did not receive any financial support, sponsorship, or endorsement from any organization related to the submitted work.

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