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Original Scientific Article

Anaerobic Soccer Training Model: Enhancing Soccer Players' Performance through a Combination of Repeated Sprints and 4 vs 4 Games

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. The Anaerobic Soccer Training (AnST) model was designed to increase variation in soccer training programs by implementing a game-based approach to matching characteristics. This study aimed to evaluate the effectiveness of the training model in improving soccer players' anaerobic abilities.

Materials and methods. The research method used was the ADDIE model consisting of five integrated phases: Analysis, Design, Development, Implementation, and Evaluation. Eighty-two soccer players from the UNESA male student activity unit were involved in this study, with 20 samples taken using random sampling techniques. Sample characteristics included the following data: age 20.05 ± 0.69 years, height 165.85 ± 5.00 cm, weight 62.08 ± 6.82 kg, and BMI 22.54 ± 1.98. The intervention was carried out over a four-week period, with a frequency of three times a week. The Aiken's V test was used to analyze the assessment data from three expert judgments, followed by percentage analysis for content validity. The normality test was conducted using the Shapiro-Wilk test, while the mean difference was analyzed using the paired sample t-test.

Results. The results showed that in variables for peak power (.001), mean power (.000), fatigue index (.013), Lactate Week (LW) 1-2 (.020) and LW1-3 (.038), notable differences with significance values below 0.05 were observed. In contrast, LW1-4 (.631) did not demonstrate significant differences. Overall, the development of the AnST model successfully improved the anaerobic ability of players, as evidenced by an increase in peak power, mean power, and a decrease in the fatigue index.

Conclusions. These findings indicate that this training model is effective in enhancing the anaerobic performance in soccer players.

Keywords: anaerobic, soccer training, repeat sprint, small sided games.

Introduction

Soccer requires high physical ability with moderate to high-speed running movements in a ninety-minute match duration, with match intensity reaching 90 % of the maximum heart rate (Mendez-Villanueva et al., 2013; Rebelo et al., 2014). When viewed from the perspective of using its energy system, McArdle et al. (2014) concluded that players need 10 % energy through the phosphocreatine system, 70 % anaerobic glycolysis, and 20 % aerobic glycolysis. In addition, based on previous research, players cover a distance of up to 13 km in the match and perform sprinting, acceleration, deceleration, and changes of direction interspersed with short recovery periods (Beato & Jamil, 2018). A soccer player performs a sprint action at a speed of >19.7 km/h for 645.71 meters

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(Wehbe et al., 2014), 19.8-25.2 km/h for 771 meters (Carling et al., 2016), 21.1-24.0 km/h for 518.25 meters (Miñano-Espin et al., 2017), and 19.8-25.1 km/h for 617.72 meters (Modric et al., 2019). The number of running frequencies in one match is 33 times (Chmura et al., 2017) and 31 times (Miñano-Espin et al., 2017). If we look at the data, soccer requires very complex training with a dominant need for anaerobic glycolysis. The irony on the field is that coaches tend not to pay attention to these needs, resulting in less-than-optimal performance due to the lack of information on specific physical training models applied to soccer. Based on previous research, popular anaerobic training studies include High-Intensity Interval Training (HIIT) (Faude et al., 2013), Speed Endurance Training (SET) (Iaia et al., 2015), and Repeat Sprint Training (RST) (Beato et al., 2019). Although these exercises are practical in increasing players' anaerobic abilities, in their implementation, there is no information that these exercises are by the needs of the game, especially in terms of the frequency and distance of sprints in one match. In addition, physical training must also involve elements of technique and tactics (Clemente et al., 2022); this is in line with previous systematic review studies, which concluded that a holistic approach positively impacts training (Kusuma et al., 2024). According to Izquierdo et al. (2023), coaches should ideally develop a training program that suits the needs of the competition.

The solution that can be adopted is to develop the Anaerobic Soccer Training (AnST) model. The development adopts the theory of Speed Endurance Training Maintenance (SET-M) Long Intervals with an intensity of 50-80 %, duration of 15-90 seconds, ratio of 1:1-1:3, and repetitions of 6-12 (Hostrup & Bangsbo, 2023). This approach combines elements of high-intensity speed training with elements of technique and tactics in the match, in line with research (M. Oliva-Lozano et al., 2023), which found that repeated sprint ability is needed in soccer games. In more detail, the load refers to the need for repeated sprints in the match, namely the average total running distance (> 19.7 km/h) = 638.17 m. The training intensity used in this exercise is classified as high intensity using the anaerobic lactate acid energy system. Several studies have identified that soccer players require energy from various sources, including the phosphocreatine system, anaerobic glycolysis, and aerobic glycolysis (Coratella et al., 2016; Hill-Haas et al., 2011; McArdle et al., 2014; Wong et al., 2012). In addition, the importance of repeated sprinting ability and high running frequency during matches has been emphasized in previous literature. In addition, physical training such as HIIT, SET, and RST have been studied and proven effective in improving the physical abilities of soccer players. However, they have not fully met the needs of matches, especially in terms of sprint frequency and distance.

To address the gap between existing training models and the specific match needs in soccer, this study attempts to develop a new model called Anaerobic Soccer Training (AnST). One of the unique features of the AnST model is its more specific approach to the needs of repeated sprinting in soccer matches, which is reflected in training loads such as the total average running distance at high speed, the number of sprints, and the duration of sprints without leaving out the technical and tactical components. Thus, the AnST model offers a more focused and relevant solution to improve the physical abilities of soccer players according to match requirements.

Materials and Methods

Study Participants

82 UNESA male student soccer players comprised the population in this study, and 20 players were taken as samples. The sample was taken using a random sampling technique. The characteristics of the sample were 20.05 ± 0.69 years old, 165.85 ± 5.00 cm tall, 62.08 ± 6.82 kg in weight, and 22.54 ± 1.98 in BMI. This trial was implemented for four weeks with a frequency of three times a week.

Study Organization

This study uses the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) Method (Branch, 2009). The analysis stage is marked by identifying problems in the field, where a lack of a holistic soccer training program combines technical, physical, and tactical elements. In the Design stage, researchers began to design training called AnST. This training combines the SET-M Long Interval concept with tactical training elements. In the Development stage, researchers conducted a Focus Group Discussion (FGD) to test the validity of the design with the objectives to be achieved and obtain input from expert judgment. The validity test involves three expert judgments: soccer, physical, and game experts. This stage aims to ensure that the product being developed meets the objectives and is based on the characteristics of soccer before being tested. In the implementation stage, researchers conducted a trial where the trial was carried out with a sample size of 20 people. The last stage is evaluation, which is carried out to improve certain elements, adjust the intensity of training, add variations, or make other changes based on feedback and evaluation results. The test instrument used at this stage is RAST to determine anaerobic ability—a questionnaire to test the validity of the product. In addition, heart rate and lactate monitoring instruments can be used from a physiological perspective.

Statistical Analysis

Validity test analysis in developing the AnST model uses quantitative descriptive analysis. The Aiken'V test is used to analyze the assessment data of three expert judgments. After the content validity test is declared valid, the assessment data of three expert judgments are analyzed using percentages to determine the feasibility of the product being developed. The normality test in this study uses the Shapiro-Wilk test, while the average difference test uses the paired sample t-test.

Training Program

This AnST exercise uses the Speed Endurance Training and Game (SSG) approach with a 1:1 interval. The SSG area is 20x20 meters, and each player will sprint back and forth with a distance of 5 meters, 10 meters, and 15 meters before starting the SSG. The total sprint taken in one repetition is 60 meters, with an estimated time for a 5-meter back-and-forth sprint of around 2-3 seconds, a 10-meter back-and-

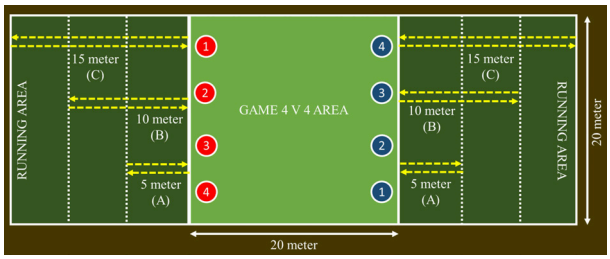

Fig. 1. ASnT method

forth of around 4-5 seconds, and a 15-meter back-and-forth of around 6-7 seconds. Thus, the total time for a 60-meter sprint is around 15 seconds.

To start the exercise, players sprint back and forth with a total distance of 60 meters. After the sprint, players will immediately play SSG for 1 minute, focusing on ball control. After completing the sprint and SSG session, players rest for the same duration as the total sprint and SSG time, which is around 1 minute 15 seconds (1 minute SSG + 15 seconds sprint), so the training and rest interval is 1:1. This session is repeated 10 times so that in one training session, the total training time (including sprint, SSG, and recovery) is around 25 minutes. This training aims to improve anaerobic endurance, with an average heart rate target of >80 % of HR Max during sprints and SSG in the high-intensity zone. The total sprints performed by each player in 1 training session are 600 meters, designed to encourage players to reach maximum speed and improve their recovery ability between intense activities.

Results

Table 1. Expert Judgement (EJ) Questionnaire Results

No	Question items	EJ1	EJ2	EJ3
1	To what extent does the training design in the product provide enough variety to maintain user interest and motivation?	4	4	3
2	Does the training design integrate aerobic and anaerobic aspects in a balanced way?	4	5	5
3	Does the training design integrate technical aspects of soccer in a balanced way?	5	4	5
4	Is there a clear progression in training design from beginner to advanced level?	5	5	4
5	Does the product provide clear and easy-to-understand instructions for users?	5	5	4
6	Will the product have an impact on users' aerobic ability?	5	4	4
7	Will the product have an impact on users' anaerobic ability?	5	5	4
8	Will the product impact users' technical ability to play soccer?	4	4	5
9	Will the product have a positive effect on users' mood?	4	3	5
10	Does the product have clear guidance and warnings regarding safe training practices and injury prevention?	5	5	4
	Total	46	44	43

Table 1 above shows the questionnaire results filled out by three expert judgments. Before the percentage analysis, the questionnaire data entered the content validity test stage. The content validation test using Aiken' V can be seen in the table below:

Table 2. Aiken' V Test Results

No	Question Items	Results EJ3	Description
1	Item 1	0.666666667	Medium
2	Item 2	0.916666667	High
3	Item 3	0.916666667	High
4	Item 4	0.916666667	High
5	Item 5	0.916666667	High
6	Item 6	0.833333333	High
7	Item 7	0.916666667	High
8	Item 8	0.833333333	High
9	Item 9	0.75	High
10	Item 10	0.916666667	Medium
Mean		0.858333333	High

Table 2 shows the evaluation results of 10 questions by three assessors, with average scores ranging from 0 to 1 and categorized into "Medium" or "High." Overall, the average score of all items is 0.86, which falls into the "High" category, indicating that the assessors rated the majority of questions very well. The next stage is a percentage test based on the results of the expert judgment assessment. This analysis aims to test the feasibility of the product being developed.

Table 3. Product Feasibility Percentage Test

No	EJ1	EJ2	EJ3	Total	Percentage	Description
1	46	44	43	133	0.886666667	Feasible

Based on Table 3, the total score from the three assessors is 133, with a feasibility percentage of 88.67%, which is categorized as "Feasible." The next stage is implementation or trial. This stage uses an experimental method for four weeks of treatment.

Table 4. Heart Rate Monitoring

Variable	Week 1	Week 2	Week 3	Week 4
Average HR	82.92 ± 2.64	83.58 ± 3.48	85.00 ± 4.41	84.92 ± 4.80
Maximum HR	95.50 ± 4.48	95.83 ± 4.37	95.17 ± 5.06	95.25 ± 5.08

Data are presented as mean ± SD

Table 4 shows that the heart rate data showed some changes during the four weeks of training. The average heart rate increased from 82.92 % HrMax in the first week to 85.00 % HrMax in the third week before decreasing slightly to 84.92 % HrMax in the fourth week. Meanwhile, the maximum heart rate remained stable, with an average value of around 95 % HrMax.

Table 5 shows the results of lactate monitoring from 20 samples over four weeks. The mean lactate increased from a baseline of 1.59 mmol/L to a peak in the third week

Table 5. Lactate Monitoring

Statistic	Baseline	Week 1	Week 2	Week 3	Week 4
Mean	1.59	6.91	6.47	7.56	4.08
Standard Deviasi	0.51	3.54	2.50	3.59	1.74

of 7.56 mmol/L before decreasing to 4.08 mmol/L in the fourth week. This pattern indicates a significant increase in lactate during the training period, followed by a decrease towards the end of the training period, which could indicate the body's adaptation to intense training.

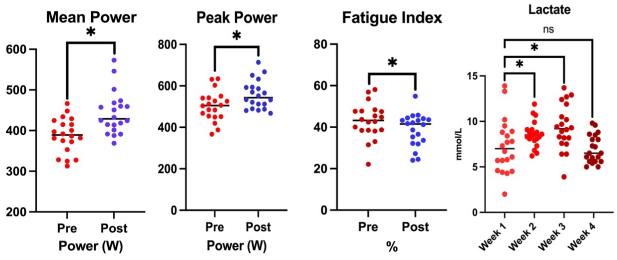

Fig. 2. Anaerobic and Physiological Performance Data Description

Figure 2 above presents the peak power (watt), mean power (watt), and fatigue index (FI) values before and after the anaerobic exercise program for 20 samples. The average peak power before exercise was 502.10 W and increased to 557.21 W after exercise, with standard deviations of 72.08 and 68.82, respectively. Mean power showed an average before exercise of 388.28 W and increased to 443.01 W after exercise, with standard deviations of 43.11 and 52.33.

Table 6. Normality Test of Anaerobic and Physiological Performance

Variable	Shapiro-Wilk		
	Statistic	Df	Sig.
Peak Power	.964	20	.622
Mean Power	.965	20	.645
Fatigue Index	.942	20	.267
Lactate Week 1 (LW1)	.952	20	.398
Lactate Week 2 (LW2)	.953	20	.422
Lactate Week 3 (LW3)	.971	20	.783
Lactate Week 4 (LW4)	.922	20	.102

The fatigue index showed an average before exercise of 42.97 and after exercise 38.68, with standard deviations of 8.58 and 7.91, respectively. These results indicate that the anaerobic exercise program has succeeded in increasing peak power and mean power and significantly reducing the fatigue index in the samples observed.

The normality test conducted using the Shapiro-Wilk test showed that all variables in the study were normally distributed with a significance value of Sig. > 0.05. Furthermore, the test continued to the hypothesis testing stage.

Table 7 shows the differences between the AnST pretest and posttest. The variables peak power, mean power, fatigue index, LW1-2, and LW1-3 showed significant differences with significance values below 0.05. While LW1-4 did not show significant differences

Discussion

This study shows that AnST has a significant impact on improving the anaerobic performance of soccer players. AnST is a combination of SET training and a soccer game approach. In training, players perform repeated sprints at high speed and then play 4 vs 4 in a 20-meter x 20-meter area interspersed with active recovery with a 1:1 interval ratio. Regarding energy use, the AnST approach applies a combination of anaerobic energy systems (ATP-PCr and glycolytic) and oxidative. When doing repeated Sprints with a total distance of 60 meters using the anaerobic system, then shifting to a 4 vs. 4 game, the energy systems contributing are anaerobic and aerobic and end with a short recovery involving the oxidative system. The AnST program includes 10 repetitions of 60-meter sprints, categorized as long-distance sprint training. Rey et al. (2024) concluded that short-distance sprint training (SST) and long-distance sprint training (LST) are both effective in improving specific soccer performance, but LST provides a more significant increase; this supports the findings of AnST, which also includes the LST category. Therefore, the AnST program can be considered an optimal approach to improve the physical capacity of soccer players.

Previous studies have shown that repeated sprint training with active recovery has been shown to improve anaerobic capacity when compared to endurance training (Sökmen et al., 2018); this further strengthens the position of AnST as an effective training tool for improving anaerobic capacity. AnST training involves a combination of repeated high-intensity sprints and short rest breaks, which aim to develop muscle

Table 7. Paired Sample T-Test Anaerobic and Physiological

Variable	Paired Differences				df	Sig. (2-tailed)
	Mean	Std. Deviation	95 % Confidence Interval of the Difference			
			Lower	Upper		
Peak Power	-55.11	63.17	-84.68	-25.54	19	.001*
Mean Power	-54.74	43.07	-74.90	-34.58	19	.000*
Fatigue Index	4.29	6.97	1.03	7.55	19	.013*
LW1-LW2	-1.35	2.36	-2.44	-2.53	19	.020*
LW1-LW3	-2.08	4.16	-4.03	-.13	19	.030*
LW1-LW4	.32	2.93	-1.05	1.69	19	.631

Data are presented as mean ± SD; (*): Significant at pretest ($p < 0.05$)

endurance and anaerobic capacity (Garciá-Pinillos et al., 2017; Rosenblat et al., 2020). This training method is essential for soccer players because they often have to sprint during matches, followed by a short recovery phase before the next sprint. With AnST training, players can be more effective in maintaining speed performance, increasing physical endurance, and reducing the risk of fatigue in the final phase of the match.

Significant results related to physiological responses, especially heart rate (HR), were obtained during the four-week AnST program. Throughout the time, the training zone consistently reached high intensity in each session. This finding is in line with previous studies examining the combination of SSG and running training, which recorded HR of 88.9 ± 2.5 % of HRmax in a 3-sided model and 86.8 ± 4.0 % of HRmax in a 4-sided model (Köklü et al., 2020). Previous studies have also found comparable results, showing that HR remains in the high-intensity category (Brandes & Elvers, 2017; Halouani et al., 2017). Previous findings also suggest that high-intensity interval training can improve aerobic and anaerobic performance in soccer players (Arazi et al., 2017; Fang et al., 2021). AnST training has been shown to consistently produce high levels of cardiovascular activity, with participants' HR always in the intense zone. This condition can be interpreted as a physiological response due to the high training intensity. In addition to HR, interestingly, this study also highlights the lactate levels that arise due to high-intensity training. In the first three weeks of AnST, lactate levels were significantly increased after the training session. The increased lactate concentration is believed to originate from the glycolytic flow rate (Piero et al., 2018). High-intensity interval training induces more significant glycolytic activity, with a short time resulting in high lactic acid, and this activity beneficially contributes to producing higher levels of ATP (Stöggl & Björklund, 2017). To reduce high lactate, the role of short recovery in AnST is crucial during repeated sprint sessions and 4 vs 4 games. During short rest periods, the oxidative system plays a role in oxidizing lactate, removing accumulated inorganic phosphate (Pi), and re-synthesizing phosphocreatine (PCr) (Turner & Stewart, 2013). These results are in line with previous studies examining the combined response of SSG with running training, which resulted in LA – 9.6 ± 1.9 mmol·L^{-1} in a 3-sided model and 8.2 ± 1.79 mmol·L^{-1} in a 4-sided model (Köklü et al., 2020). Previous studies also obtained similar results, namely high lactate levels (Chmura et al., 2023).

Conclusions

Overall, the development of an anaerobic soccer training model can improve anaerobic ability, and this training is proven to be by the physiological demands of anaerobic training, namely training that produces a high heart rate and high lactate tolerance.

Conflict of interest

No conflict of interest was reported by the authors.

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Модель анаеробного тренування у футболі: Підвищення результативності футболістів шляхом поєднання методу повторних спринтерських забігів та ігор за схемою 4 на 4

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Реферат. Стаття: 8 с., 7 табл., 2 рис., 34 джерела.

Мета дослідження. Модель анаеробного тренування у футболі (Anaerobic Soccer Training, AnST) була розроблена для підвищення варіативності тренувальних програм за рахунок впровадження ігрового підходу до відповідності характеристик. Це дослідження мало на меті оцінити ефективність тренувальної моделі з точки зору покращення показників анаеробних здібностей футболістів.

Матеріали та методи. В якості методу дослідження застосовано модель ADDIE (Analysis, Design, Development, Implementation, and Evaluation), що включає п'ять інтегрованих етапів: аналіз, дизайн, розробка, впровадження та оцінка. У дослідженні взяли участь 82 футболісти з чоловічого студентського осередку університету UNESA, 20 з яких були відібрані за методом рандомізації. Характеристики вибірки включали такі показники: вік 20,05 ± 0,69 років, зріст 165,85 ± 5,00 см, вага 62,08 ± 6,82 кг, IMT 22,54 ± 1,98. Інтервенція проводилась впродовж чотиритижневого періоду, з частотою тричі на тиждень. З метою аналізу даних оцінок, отриманих від трьох експертних висновків, використовувався V-критерій Ейкена, з подальшим відсотковим аналізом для перевірки валідності змісту. Перевірка нормальності розподілу проводилась з використанням критерію Шапіро-Уілка, а середня різниця була проаналізована за допомогою t-критерію для парних вибірок.

Результати. За результатами дослідження встановлено, що у змінних максимальної потужності (.001), середньої потужності (.000), індексу втоми (.013), показників рівня лактату впродовж тижня (LW) 1-2 (.020) та LW1-3 (.038) спостерігалися суттєві відмінності зі значеннями рівня значущості нижче 0.05. Натомість, показник LW1-4 (.631) не продемонстрував достовірних відмінностей. Загалом, розробка моделі анаеробного тренування у футболі сприяла покращенню анаеробних здібностей гравців, про що свідчить підвищення показників максимальної потужності, середньої потужності та зниження рівня індексу втоми.

Висновки. Отримані дані вказують на ефективність застосування зазначеної моделі тренувань в контексті поліпшення показників анаеробної продуктивності футболістів.

Ключові слова: анаеробний, тренування з футболу, повторний спринт, ігри неповними складами команд.

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