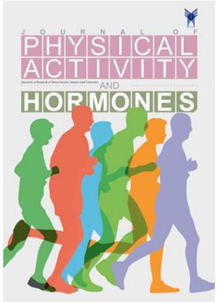
Journal of Physical Activity and Hormones
(J Physic Act Horm)
Journal HomePage: *https://sanad.iau.ir/journal/jpah/*



Comparison of small-sided games and sprint training program on the testosterone, cortisol, blood cell count, and physical fitness indices in teenage soccer players

Mona Sebghati Shiraz[1], Ramin Shabani [2*], Mojtaba Mohammadi [3]

[1] MA, Exercise Physiology, Rasht Branch, Islamic Azad University, Rasht, Iran.
[2] Professor in Exercise Physiology, Rasht Branch, Islamic Azad University, Rasht, Iran.
[3] MA Candidate in Exercise Physiology, Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran.

Keywords
Sprint training, Small-sided games, Testosterone, Cortisol, Systemic Immune-Inflammation Index, Physical fitness.

Correspondence
Tel.: +98 911 232 4796;
E-mail address: Ramin.Shabani@iau.ac.ir

Received: Sep 2023; **Revised:** Oct 2023; **Accepted:** Dec 2023.

DOI: https://doi.org/10.71878/jpah.2024.1104206

Abstract

Introduction: The purpose of this study was to comparison of small-sided games (SSG) and sprints on testosterone, cortisol, blood cell count, and physical fitness indices in teenage soccer players.

Material & Methods: In this Quasi-experimental study, thirty-six teenage athletes (13.55±0.53) were randomly divided into control (CG), SSG, and sprint groups (SG). The subjects in the SG underwent 45-minute short bursts of sprinting. The SSG group exercise program 45 minutes consisted of 8×3 minutes with 3 minutes of active recovery between sets and was performed on a small Football pitch without a goalkeeper. In contrast, the control group continued their usual routine activities for 4 weeks (3days/week). Basal levels of K-TEST, RSA, and YO-YO tests, as well as blood indices of testosterone, cortisol, and blood cells, were measured before commencement and after 4 weeks of training.

Results: The results indicate that sprint training led to a significant increase in testosterone, testosterone to cortisol ratio (T/C ratio), RBC, and WBC compared to the control group and a significant decrease in cortisol and agility performance. SSG also caused a significant increase in testosterone, T/C ratio, RBC, WBC, Systemic Immune-Inflammation Index (SII), and aerobic performance, with a significant decrease in cortisol and agility performance. Additionally, in the control group, cortisol showed a significant increase, and the T/C ratio was significantly decreased ($p<0.05$).

Conclusion: The present study revealed that both sprint and SSG training individually can have desirable effects on testosterone, cortisol, T/C ratio, WBC, RBC, and agility tests. Sprint and SSG were found to be effective for these factors. The SSG training program increases WBC, SII, and aerobic performance.

1. Introduction

Soccer is one of the most popular and complex sports, and players need high levels of physical, technical, and tactical factors for success. Training on small-sided games (SSG), which utilize smaller dimensions compared to traditional fields and have different rules, is considered an enjoyable and effective training method for improving physical fitness and tactical skills in football. With their high intensity, these exercises can closely resemble the conditions of real football competitions. These advantages make SSGs a popular and engaging training approach for most football coaches(1). During a football match, players are required to perform straight-line sprints, changes of direction, jumps, rotations, and other repetitive actions. Among these movements, straight-line sprints are introduced as the most common. According to the analysis of goal-scoring player movements in football games, it is evident that straight-line sprints and agility constitute 51% of all movements (2). Under the influence of exercise intensity, exercise characteristics, age, and initial fitness level, exercise can have positive or negative effects on growth, metabolism, enzymes, and blood cells (3). Players utilize short-duration, high-intensity sprints (less than 10 seconds) and various activities such as one-on-one duels, change of direction, jumps, accelerations, decelerations, and rotations during the game. The players' ability to execute such rapid activities is essential for optimizing success in a match (4). It should be noted that physical fitness along with precise execution of specific football skills is an essential aspect of this sport (5, 6). In addition, at the professional level, about 80% of speed changes and 30% of movements at high speeds (over 2.25 kilometers per hour) occur during the game. It has been observed that approximately 83% of goals scored in a top-tier league involve at least one powerful movement, with the primary one being a direct sprint (7).

Testosterone (T) and cortisol (C) are two hormones that play a crucial role in daily physiological functions, especially when exercise-related stress occurs. It has been emphasized that the physiological response to a specific exercise bout is considered an integral part of training, and a precise assessment can empower exercisers to confidently prescribe exercises with predictable outcomes within a specific timeframe (8). These factors can lead to physiological disturbances and disrupt the relative homeostasis of muscles, endocrine glands, and the body's immune system. Maintaining the body's homeostasis is a key point in the health of athletes, regulated by various factors, including anabolic and catabolic hormones (such as cortisol and testosterone) (9). Testosterone is recognized as the most important androgen hormone in the blood. Almost 99% of total testosterone is bound to globulins and albumins associated with sex hormones. free testosterone (FT) can have anabolic effects, and increase strength, muscle mass, or bone density (10). In the period of adolescence, the primary function of the hypothalamus-pituitary-gonad axis is to regulate the levels of testosterone and the functioning of the sex glands (11). Cortisol plays a significant role in anti-inflammatory processes, gluconeogenesis, and glycogenolysis. It also increases blood glucose concentration. Moreover, it is considered a catabolic hormone due to its inhibition of amino acid absorption by muscles and reduction in protein synthesis (12).

In improving athletes' performance, hematological and biochemical factors play a vital role. However, research indicates that the effects of acute and chronic exercise stimuli on hematological parameters, including hemoglobin (Hb), red blood cells (RBC), and hematocrit (Ht), may vary. It appears that after a period of football training, especially during the preparation phase, an increase in these blood parameters is observed. Hb, RBC, and Ht are directly related to the aerobic capacity of the relevant players. Additionally, in response to the injuries incurred during the football season, neutrophils, monocytes, and eosinophils play a fundamental role in the inflammatory response through the phagocytosis process. Furthermore, lymphocytes and basophils also have a crucial role in the immune system and in combating acute viral and bacterial infections (13).

Research examining the impact of SSG on the performance of football players has shown that SSG exercises may have a greater influence on the technical skills and agility of players (14). In 2023, Selmi et al reached results indicating that the combination of aerobic and speed exercises with specific football drills is a safe and effective training method. This approach not only has a positive impact on physical readiness but is also effective in enhancing confidence and coping with anxiety among male football players (15). Balbasi et al. showed that high-intensity interval training can increase maximum aerobic and anaerobic power in adolescent futsal players(16). Winker and colleagues (2022), through a controlled randomized trial, investigated the impact of exercise on inflammatory markers and the Systemic Immune-Inflammation Index (SII) in children with cancer. The study revealed a significant reduction in SII after exercise compared to the control group. These findings may suggest a positive implication of exercise on inflammatory parameters and immune systems in this group of pediatric patients (17). Furthermore, Zork and colleagues (2022) did not observe significant differences in testosterone and cortisol changes among endurance training, strength training, and no-exercise groups after performing interval speed exercises. This is likely indicative of insufficient exercise volume (18). The findings of Chmura and colleagues' research in 2019 suggested that likely, increasing rest intervals in 1 × 1 Small-Sided Games (SSG) exercises for 30 seconds may lead to a reduction in catabolic reactions and, consequently, decrease the risk of excessive training in young football players (10).

Based on the presented research, SSG and speed exercises demonstrated different outcomes in terms of testosterone, cortisol levels, and blood cell counts. Therefore, due to the existing discrepancies among studies and the limited number of such investigations for adolescents, we have decided to assess the impact of SSG and a speed training program on testosterone, cortisol, blood cell counts, and physical readiness in youth.

2. Materials and methods

Thirty-six trained teenagers volunteered to participate in this study after obtaining consent from their parents. Participants were asked to complete a personal health and medical history questionnaire, and each of them had at least 12 months of exercise experience before the study. Thereafter, the subjects were divided into SSG group (n=12) Sprint group (n=12), and control group (n=12) randomly.

Sprint group training program was carried out three days a week for four weeks, with participants engaging in one-hour sessions per week. Each session began with a 10-minute warm-up involving jogging and sprint drills, followed by a 45-minute main session. The main session included 8×15m partner-resisted sprints, 8×20m straight sprints, and 8×20m change-of-direction sprints with 60° and 90° turns. The session concluded with a relay race featuring 90° turns, with each participant completing eight races, resulting in a total of 32 short sprints. Sprint durations ranged from three to six seconds, followed by 60 to 90 seconds of recovery.

Participants were instructed to execute the sprints at maximal speed, emphasizing high-intensity efforts throughout the program (19).

SSG group training plan starts with a 10-minute general warm-up, followed by a 45-minute Small-Sided Games (SSG) session for 4 weeks (3 days/week). This SSG structure involves 8 sets lasting 3 minutes each, with 3 minutes of active recovery between sets, aiming to simulate half of a realistic soccer game. The training is conducted without goalkeepers, allowing for free ball touches. The field size is 20 m×25 m, and the main objective is to maintain ball possession. Coaches can give instructions using standardized methods, and participants are permitted to consume water as needed during the training (3).

The control group maintained their usual regimen, involving 60 minutes of aerobic exercise with a moderate intensity level, equivalent to 60 to 70 percent of their maximum heart rate. The maximum heart rate (MHR) for each participant was determined using the formula "MHR= 220 - age." The exercise session commenced with a 10-minute warm-up, consisting of slow running and stretching exercises. Following the warm-up, participants engaged in 40 minutes of primary aerobic activities, including brisk walking, light jogging, stretching, and aerobic exercises. Subsequently, a 5-minute cool down was performed. This exercise routine was repeated three times weekly over four weeks (**Error! Reference source not found.**).

It is necessary to point out that the training performed in each group may have similar characteristics in terms of tactical and technical aspects.

Table 1. *Exercise Planning for Three Groups*

Aspect	Sprint	SSG	Control
Frequency	Three days a week	Three days a week	Three days a week
Duration	4 weeks	4 weeks	4 weeks
Session Length	1 hour	1 hour	1 hour
Warm-up	10 minutes (jogging, sprint drills)	10 minutes (general warm-up)	10 minutes (slow running, stretching)
Main Session	45 minutes	45 minutes	40 minutes (aerobic activities)
Type of training	8×15m partner-resisted sprints 8×20m straight sprints 8×20m change-of-direction (60° and 90°) 8×relay race (90° turns)	8×3minutes Simulating a realistic soccer game	40minutes of aerobic activities (60-70% MHR)
Recovery	60 to 90 seconds	3 minutes	N/A (Cool down included)

2.1. Biochemical Analysis

Blood samples were gathered 24 hours before the initiation of the training program under standard conditions. Similarly, samples were obtained 24 hours after the conclusion of the last intervention session. Throughout each phase, a laboratory specialist collected blood from the left antecubital vein while participants were at rest and seated, with the sampling occurring between 7 and 8 in the morning.

For CBC tests, K2 EDTA laboratory tubes containing 200μl of sodium citrate anticoagulant solution were used, and the blood sample volume was 2ml. For testosterone and cortisol assays, in each phase, blood samples were taken from the left antecubital vein by the laboratory specialist in a resting and seated position and a volume of 5 ml of blood was collected. After obtaining the blood samples, they were sent to the laboratory in containers with ice for the measurement of testosterone, cortisol, and blood cell counts. The levels of cortisol and testosterone were measured by existing commercial ELISA kits (Abcam Co. Boston, MA, US). Additionally, to assess the testosterone-to-cortisol ratio, the values of testosterone were divided by cortisol for each participant. For the evaluation of the systemic immune-inflammatory index (SII), the formula SII = P × N/L was utilized. SII for healthy individuals at rest is 453×10^9. An increase in the SII value indicates the presence of inflammation after exercise (20).

2.2. Measurement

To calculate the Body Mass Index (BMI), the formula weight divided by the square of height in meters was used. After measuring the height and weight (Seca Stable Stadiometer Measurement 700, Germany), of the participants, the obtained values were substituted into the formula, and their BMI was calculated and recorded.

2.3. Physical fitness tests

RSA: This test was used to determine the repeated sprint ability of players. The RSA test consisted of 6 repetitions of maximal 15*2 meters shuttles with a standing inactive recovery of 14 seconds. Three seconds before the start of each sprint, participants were instructed to assume the ready position and wait for the start signal. The participant initiated the sprint from the starting position, and the time was recorded by a stopwatch (**Error! Reference source not found.**) (21).

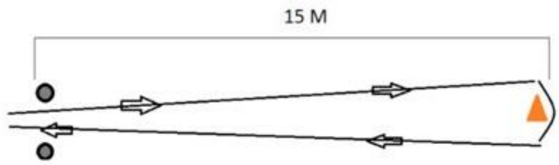


Fig. 1. *RSA*

K-TEST: The K-TEST was utilized to assess speed and agility. This test was conducted in an open field on a grass surface. Running paths were marked with cones, with distances between cones 2-1 and 5-1 (4.5 meters) and distances between cones 2-3 and 5-4 (3 meters). Participants started individually from a designated point, and the time was recorded using a stopwatch with precision. Each player made three attempts with a 10-minute recovery, and the best time was recorded(**Error! Reference source not found.**) (21).

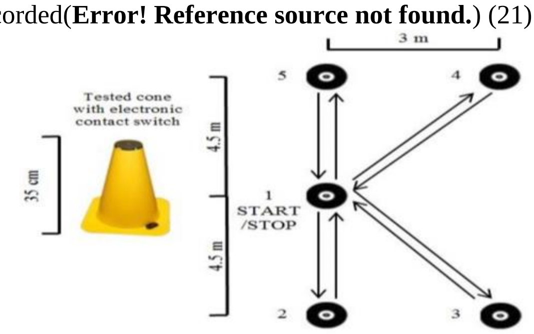


Fig. 2. *K-TEST*

YOYO-TEST: Participants' aerobic performance was assessed using the Yo-Yo Intermittent Level 2 test, which included two 20-meter shuttle runs performed at increasing speeds controlled by a beep sound. Then, a 10-second active recovery (involving a 5×2-meter run) was performed after each shuttle run. The test was concluded when participants could not start the run-on time for the second time, and the distance covered was recorded as the final result. This test was conducted in an open field on a grass surface, and running paths were marked with cones (21).

It is worth mentioning that all measurements of physical fitness indicators were conducted on-site during the exercise sessions and at the same hours, both as pre-tests and post-tests.

2.4. Statistical Analysis

In this study, the Shapiro-Wilk test was used to examine the normal distribution of the data. To investigate the research hypotheses, paired t-tests, analysis of covariance (ANCOVA), and Bonferroni post hoc tests were employed. The analyses were conducted using SPSS version 28, and significance levels less than 0.05 ($p<0.05$) were considered statistically significant.

3. Results

The sample comprised 36 patients, distributed equally among three groups. The personal characteristics of the subjects are presented in Table 1. The groups exhibited similarity in the measured variables at the initiation of the study.

Table 1. *Anthropometric parameters of participants (mean ± SD) of the subjects*

Variables \ Group	Control	Sprint	SSG
Age	13.91 ± 0.28	13.66 ± 0.65	13.08 ± 0.66
Height (cm)	162.16 ± 7.35	169.08 ± 5.50	158.83 ± 5.11
Body mass (kg) Pre-test	52.00 ± 6.55	50.33 ± 4.09	50.08 ± 9.29
Body mass (kg) Post-test	52.33 ± 6.81	49.83 ± 3.92	49.66 ± 8.86
BMI (kg/m2) Pre-test	19.44 ±2.79	19.65 ± 1.51	19.74 ± 2.76
BMI (kg/m2) Post-test	19.55 ± 2.81	19.45 ± 1.40	19.58 ± 2.63

The alterations in biochemical and physical fitness parameters among the participants in the three groups are detailed in Table .

Table 3. *Changes in biochemical and physical fitness indices were assessed in both experimental and control groups before and after the test using the collected samples*

Variable	group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Paired t-test (sig)	ANCOVA
Testosterone (ng/dl)	SSG	3.36 ± 0.60	3.99 ± 0.74	0.03*	0.003*
	Sprint	3.97 ± 1.10	4.61 ± 1.09	0.031*	
	Control	3.43 ± 0.38	3.36 ± 0.40	0.315	
Cortisol (µg/dl)	SSG	10.11 ± 1.83	9/38 ± 1.31	0.026*	0.003*
	Sprint	10.91 ± 0.79	10/16 ± 0.52	0.027*	
	Control	9.48 ± 0.64	10/05 ± 0.75	0.033*	
Testosterone/Cortisol (µg/dl)	SSG	0.34 ± 0.11	0.44 ± 0.13	0.029*	0.001*
	Sprint	0.36 ± 0.09	0.45 ± 0.08	0.001*	
	Control	0.36 ± 0.04	0.33 ± 0.04	0.036*	
WBC (µl)	SSG	5.82 ± 1.06	7.12 ± 1.11	0.010*	0.2484
	Sprint	5.61 ± 0.70	6.54 ± 1.14	0.071	
	Control	6.19 ± 0.60	5.97 ± 0.76	0.15	
RBC (µl)	SSG	4.59 ± 0.27	4.82 ± 0.13	0.014*	0.01*
	Sprint	5.07 ± 0.47	5.25 ± 0.52	0.041*	
	Control	4.72 ± 0.14	4.69 ± 0.17	0.709	
Platelet (µl)	SSG	241.75 ± 43.09	238.58 ± 38.74	0.813	0.197
	Sprint	251.08 ± 18.86	268.91 ± 38.32	0.174	
	Control	254.66 ± 47.90	240.583 ± 49.14	0.068	
SII ($\times 10^9$L)	SSG	460.90 ± 101.18	422.16 ± 64.56	0.040*	0.078
	Sprint	524.01 ± 98.61	576.08 ± 115.71	0.218	
	Control	449.08 ± 90.77	450.93 ± 93.99	0.881	
Anaerobic performance	SSG	0.95 ± 0.02	0.95 ± 0.01	0.517	0.119
	Sprint	0.94 ± 0.28	0.94 ± 0/27	0.913	
	Control	0.94 ± 0.02	0.94 ± 0/02	0.156	
Agility performance	SSG	13.59 ± 0.70	13.06 ± 0.83	0.003*	0.05
	Sprint	13.40 ± 0.96	13.15 ± 1.00	0.007*	
	Control	13.67 ± 0.64	13.58 ± 0.81	0.503	
Aerobic performance	SSG	356.66 ± 109.82	377.50 ± 112.80	0.023*	0.085
	Sprint	350.00 ± 114.89	356.66 ± 112.89	0.744	
	Control	314.16 ± 88.05	290.00 ± 49.14	0.105	

The results of the table indicate that Sprint training and SSG led to a significant increase in testosterone compared to the control group (*$p<0.05$), while the control group did not show a significant difference in testosterone levels ($p>0.05$).

Sprint training and SSG resulted in a significant decrease in cortisol levels ($p<0.05$), whereas in the control group, cortisol showed a significant increase ($p<0.05$).

The testosterone-to-cortisol ratio significantly increased in the sprint training and SSG groups ($p<0.05$), while the control group exhibited a significant decrease in the ratio ($p<0.05$).

Sprint training and SSG led to a significant increase in white blood cells, with this increase being significant in the SSG group ($p<0.05$). In the control group, there was no significant difference between pre and post-test ($p>0.05$).

Sprint training and SSG resulted in a significant increase in red blood cells ($p<0.05$), while no significant difference was observed in the control group ($p>0.05$).

There was no significant difference in platelet levels among sprint training, SSG, and control groups ($p>0.05$).

In the SSG group, a significant difference in the systemic immune inflammation index was observed between pre and post-tests ($p<0.05$). However, there was no significant difference in the sprint and control groups ($p>0.05$).

No significant difference in anaerobic performance was found among sprint training, SSG, and control groups ($p>0.05$).

The agility performance time significantly decreased in the sprint training and SSG groups ($p<0.05$), while no significant change was observed in the control group ($p>0.05$).

SSG led to a significant increase in the aerobic performance test results ($p<0.05$), with no significant difference observed in the sprint training and control groups ($p>0.05$).

4. Discussion

SSG are smaller, organized formats of football implemented in training sessions. They primarily combine physiological exercises and specific in-game situations, such as numerical superiority in attack or defense, designed based on the needs and focus of the training session. Speed is a crucial factor in a wide range of sports activities and, in many cases, can define performance success. This study aimed to compare the effects of two training programs, small-sided games (SSG) and speed training, on the levels of testosterone, cortisol, blood cells and selected physical readiness indices in adolescent football players.

Significant increases were observed in the levels of testosterone, cortisol, and the testosterone-to-cortisol ratio in participants with both sprint training and SSG. Significant increases in white blood cell counts and the SII were noted with SSG. However, Results showed that the increase in platelet levels and anaerobic performance was not statistically significant in participants with sprint training. A significant decrease in agility performance time was observed in participants with both sprint training and SSG. A significant increase in the aerobic performance test distance was observed in participants with SSG, while no statistically significant increase was observed in sprint training.

To increase testosterone levels, it is recommended that an individual increase the intensity and duration of their exercise. Although the impact of regular exercise on testosterone levels is generally less clear, the intensity and duration of exercise also play a crucial role in this matter. In some cases, runners may have lower testosterone levels compared to non-exercisers, according to some reports. Testosterone enhances protein synthesis. However, it has been reported that during prolonged endurance exercise, the concentration of this hormone decreases (22). The findings of this study regarding the impact of SSG exercises on testosterone are consistent with the research by Madadi and Shadmehri (2021) (23). On the other hand, a study conducted by Mitrotasios and colleagues (2021), which aimed to investigate hormonal changes resulting from SSG, showed inconsistent results (24). Additionally, in the research by Andrzejewski et al. (2021) conducted on an under-19 football team over six months with four measurements, the analysis of total and free testosterone revealed no significant differences between the measurements (25). Furthermore, the results of this study regarding the effect of speed exercises on testosterone align with the research by Muscella and colleagues (2019) but are inconsistent with the study by Zurek and colleagues (2022), which demonstrated no significant differences in testosterone changes (8, 18). Differences in the variations of testosterone levels in past research may be due to various factors such as the type of exercise, the number and duration of sessions, the duration of the training period, sample size, and statistical issues. The mechanisms for the increase in resting testosterone levels after exercise are not well-defined. However, researchers have mentioned mechanisms such as increased production and secretion of this hormone in the testes, testosterone secretion due to vasodilation and increased blood flow to the testicles, the impact of heart rate or direct lactate stimulation on testosterone secretion, as well as the increased in sympathetic activity resulting from exercise (26).

The results of this study regarding the impact of SSG exercises on cortisol are consistent with the research by Muscella and colleagues (2019) and Andrzejewski et al. (2021). However, they are incongruent with the studies conducted by Madadi and Shadmehri (2019) and Mitrotasios et al. (2021), where cortisol increased after a training session (8, 23-25). The increase in plasma cortisol levels after acute exercise with more than 60% VO2 max and also after intense resistance training may be justified by differences in the hypothalamus-pituitary-adrenal axis response to exercise with varying durations and intensities. Research has also demonstrated that participation in short-term and high-intensity physical activities leads to a significant increase in cortisol levels in sedentary individuals as well as athletes (18). Furthermore, the findings of this study regarding the impact of speed training on cortisol levels are consistent with the research by Vitale et al. (2020), which observed a significant reduction in cortisol among participants during a 4-week endurance speed training program (27). Additionally, Zurek et al. (2022) did not find a significant difference in cortisol changes among endurance, strength, and non-exercise groups following interval speed training, which contradicts the results of this study. Studies have demonstrated that engaging in short-term and high-intensity exercise leads to a noticeable increase in cortisol levels in sedentary individuals and athletes, providing further justification for the observed discrepancy in cortisol level increases in this study (18). Contradictions that exist may be related to various factors, including the type of exercise and the conditions of athletes (professional or amateur). Cortisol, as the main glucocorticoid produced by the adrenal glands, is a vital hormone that controls the increase in gluconeogenesis and the elevation of blood glucose levels to deal with stressful situations. The release of cortisol is influenced by various factors, including environmental changes, dietary habits, physiological pressures, and training conditions (28). It appears that increasing exercise intensity leads to a decrease in performance due to a reduction in the secretion of catecholamines and sympathetic activity. It has been reported that the increase in cortisol secretion is dependent on the exercise intensity, and engaging in high-intensity exercise causes an elevation in its secretion (29). These changes are likely dependent on the intensity of exercise, age, and training status of the subjects. In any case, further research is needed, and conclusions cannot be confidently drawn from a single study.

In the field of sports physiology, the testosterone-to-cortisol ratio is utilized to analyze the balance between anabolic and catabolic processes. Since testosterone demonstrates anabolic effects, while cortisol increases catabolic effects, the testosterone-to-cortisol ratio serves as a crucial indicator in evaluating the acute and chronic effects of exercise, both in strength and endurance training (30). This study contradicts the findings by Mitrotasios et al. (2021), where the testosterone-to-cortisol ratio significantly decreased after intervention sessions of SSG (24). Moreover, the research by Andrzejewski et al. (2021), assessing the testosterone-to-cortisol ratio in a youth football team under 19 years old, revealed an increase in the total and free testosterone-to-cortisol ratio after six months, aligning with the results of this study (25). Brini et al. (2020) conducted a 12-week training program for a professional basketball player, focusing on changes in speed direction. They observed a significant reduction in the testosterone-to-cortisol ratio after 12 weeks of group training, particularly evident in the speed training group, suggesting that these discrepancies may be attributed to the type of exercise and differences in sports disciplines (31). Therefore, given the limited research in this area and conflicting results, further investigations are warranted.

The findings of this study regarding the overall increase in white blood cells and the correlation with the rise in red blood cells and blood platelets were consistent with the results of the research conducted by Mitrotasios et al. (2021). The observed decrease was attributed to intravascular hemolysis, which occurs due to mechanical rupture when red blood cells pass through capillaries in contracting muscles. This process is mainly a consequence of intense, rapid, and compressive exercises impacting red blood cells during training. Additionally, the noted reduction in hematocrit post-exercise was associated with an increase in the destruction of red blood cells, their number, size, and the hydration status of players. However, studies have indicated that red blood cells may increase after an extended training period, potentially justifying the findings of this research. Nevertheless, further research is needed. The roles of platelets and endothelial function in thrombotic events, where thrombosis (an increased number of circulating platelets) occurs following intense exercise, play a vital role (24).

The results of this study were inconsistent with the findings of Amiri and Taghian (2020) and Larsen et al. (2017), which focused on the impact of SSG on physical readiness factors (14, 32). The results of this study are in line with the research by Hulka and Sterniste (2021), where significant improvements were observed in the agility performance examination (21). Therefore, the K-TEST, used to assess speed and agility, indicates the influence of SSG exercises on enhancing the speed and agility of football players. The significant differences observed in our study may be attributed to the intensity of the exercises or the technical and tactical levels of the players. Additionally, the age group of the athletes could also have an influential impact on the test results (21).

As a limitation of the study, it should be noted that the results only reflect trends in teenage categories and may not be extrapolated to other age groups. Additionally, the biological age of participants was not simultaneously taken into account. Future research should determine the age limit from which it is appropriate to apply the training intervention.

5. Conclusion

This study demonstrated that sprint training and SSG exercises individually can have favorable effects on testosterone, cortisol, T/C ratio, white blood cells, red blood cells, and also agility performance, it was determined that both sprint training and SSG exercises can be effective for these factors. The SSG exercise program alone was able to yield greater in increasing WBC SII, and aerobic performance.

6. Acknowledgment

The authors gratefully acknowledge all of the subjects who cooperated in this investigation.

Conflict of interests: No conflict of interests amongst authors.

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