Effect of the Fatigue on the Physical Performance in Different Small-Sided Games in Elite Football Players

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Abstract

Calderón Pellegrino, G, Paredes-Hernández, V, Sánchez-Sánchez, J, García-Unanue, J, and Gallardo, L. Effect of the fatigue on the physical performance in different small-sided games in elite football players. *J Strength Cond Res* 34(8): 2338–2346, 2020—Football players need to be able to perform high-intensity efforts of short duration with brief recovery periods. The aim of this study was to analyze the influence of the pitch dimension on high-intensity actions and the effect of a repeated sprint ability (RSA) test on the physical performance in different 4-against-4 (4v4) small-sided games (SSG) dimensions. Sixteen U-18 elite football players performed an RSA test between two 4v4 SSGs (pre and post) to induce fatigue and compare physical data. Speed, sprint number, accelerations, sprint distance, total distance covered, and total distance covered of the players at different intensities were evaluated in 3 different SSGs (125, 150, 250, and 300 m²). Results revealed a significant detriment of physical performance in the 125-m² SSG after RSA, mostly in number of sprints (−6.56; confidence interval [CI] 95%: −10.13 to −3.00; effect size [ES]: 1.13 $p < 0.001$), accelerations (−2.69; CI 95%: −5.13 to −0.24; ES: 0.68; $p = 0.032$), and sprint distance (−65.44 m; CI 95%: −103.73 to −27.16; ES: 1.20; $p = 0.001$). In bigger SSGs (250 and 300 m²), higher distance at high intensity was covered and Vmax, V_{mean}, and sprint distance were greater. In summary, accelerations, sprint number, and fatigue were higher in smaller pitches, and higher velocities were reached in bigger SSGs. Football players should be aware that changes in pitch size can modify the physical performance on high-intensity actions in SSGs.

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Introduction

Football is considered an unpredictable sport composed by technical, physical, tactical, and cognitive parameters that occur in dynamic situations that are constantly changing (23). A top-class player performs intermittent work and 150–250 brief intense actions (between 2 and 6 seconds and the intensity is maximal or submaximal) during a game (2). In terms of energy production, the high-intensity exercise periods are important (2). Match analysis studies have demonstrated that football requires participants to repeatedly produce maximal or near maximal actions of short duration with brief recovery periods (36).

Physical performance in football during training and competition has been studied intensively in male participants (6,7,23,31,34,38) These authors have analyzed physical parameters such as sprint, power, total distance covered at different intensities, and distances covered with and without ball. More specifically, fatigue has been also well analyzed in the scientific literature (16,22,23,26,34). Physiologically, various factors such as dehydration, hyperthermia, glycogen depletion, and accumulation of potassium in the muscle interstitium have been proposed as candidate fatigue mechanisms (2). Numerous investigations suggest that physical and technical parameters decrease due to fatigue in football (16,22,30,31,34,38), and it seems to occur mostly after short-term intense periods in both halves, in the initial phase of the second half and toward the end of the game (25).

According to technical aspects, previous studies has shown that players decrease their involvements with the ball, number of short passes, and successful short passes between the first and second halves of matches (31). Similarly, after brief periods of higher speed running, there was a reduction in measures of both physical and technical performance. Moreover, Lyons et al. (22) indicate that high-intensity localized muscle fatigue had a detrimental effect on the different aspects of the football-passing test such as performance scores, passing errors, and total errors. It has been reported that the amount of sprinting, high-intensity running and distance covered was reduced in the final 15-minute period of elite football matches compared with the opening 15-minute period (1,3,23). Another study made by Mohr et al. (24), where the players performed a sprint test before as well as after each half, the ability to sprint repeatedly was unchanged at the end of the first half, but after the half-time break sprint performance had deteriorated. By contrast, Carling and Dupont (6) analyzed total distance, high-speed distance, and distance with ball as physical parameter. These data were registered in 3 consecutive games in 7 days during 15-minute periods, and no significant differences were found in the results. Analysis of all skill-related performance revealed no significant differences between match halves or 15-minute intervals for any of the variables. Reasons could be psychological or tactical, as explained Weston et al. (38), that the decline of physical performance in second half is not always due to fatigue as a main reason, but it could be due to tactical decisions from the coach. Dupont et al. (10) reported that the result may have an influence on the fatigue. Winner team must protect the result keeping the ball, and the loser team must press and run at a high intensity to take the ball and try to score. This study showed that physical aspects such as distance covered at high intensity depend on the physical level of the player, but also on the result, the situation of the game, and the technical and tactical level of both teams. Teams with higher technical and tactical level can cover less distance at high intensity than the opponent.

Football needs a combination of movement at different velocities, and it requires participants to repeatedly produce maximal or near maximal actions of short duration with brief recovery periods. For these reasons, football should include aerobic and anaerobic training. Repeated sprint ability (RSA)-based exercises are characterized by several sprints altered with brief recovery periods that occur during real matches (11). Various studies have shown that sprint training consisting of maximal or near-maximal short-term efforts (5–30 seconds) can produce improvements in the ability to repeat several sets of anaerobic exercise (5). Many kinds of RSA test have been used in previous studies. In particular, Rampinini et al. (30) used an RSA protocol in his study and explained that 5 minutes of high-intensity activity is sufficient to highlight a decline in physical performance, probably as a consequence of the acute effect of fatigue (23) and the most demanding phase experienced by a player during a match consisted of 11 consecutive high-intensity running periods with a high-intensity:low-intensity ratio of 1:3 (40).

From a practical standpoint, the faster an athlete can accelerate, the greater the chance for success, for instance, evading the opponent or getting possession of the ball. This kind of specific football efforts (short, at high intensity and intermittent) has been well used in many scientific studies, and it is considered an indicator of physical performance in football (30,37) and an appropriate training exercise (11).

Previous studies have confirmed that small-sided games (SSGs) are commonly used by coaches during training, players of different ages, and skill levels in team sports such as football. Hill-Haas, et al. (17) suggested that SSGs assist teaching players, improve training specialization and quality through the embodiment of "real" game conditions, and imitate the physical, tactical, and technical characteristics of the competition in football. Moreover, Grant, et al. (14) found that technical demands were higher, and players were involved in more game activities with the ball in 8 players-against-8 (8v8) SSGs than 11 players-against-11 (11v11) games, and that in 8v8 games, players spent less time standing. Similarly, many studies found a higher ball possession and touches per player during the same time in SSGs than large-sided games (more than 8 players in each team) (27). Furthermore, Pill and Elliot (28) suggest that there is a significantly more offensive scoring plays and goal scoring opportunities by using the SSG version. Regarding the pitch size, Hodgson, et al. (19) explained that SSGs played on medium (40 × 30 m) and large (50 × 40 m) pitches had a greater physical demand than on small (30 × 20 m) pitches, with significantly more distance covered. The small pitch imposed a greater technical demand on players (more passes, shots, and tackles) compared with medium and large pitches. The benefits are not only technical, but also psychological because these types of training drills result in more enjoyment (21). Physically, SSGs are very useful to improve cardiorespiratory fitness (11,33), and most studies report an increase in mean heart rate (HR), blood lactate, and rating of perceived exertion (RPE) as pitch size is increased because of an increase in the effective playing area per player (8,30). Radziminski, et al. (29) found that in young football players, SSG training was more effective in improving the maximal oxygen uptake ($\dot{V}O_2max$) than an interval training protocol. These reasons are why physical trainers prefer SSG and conditioned games. However, there has been no study investigating the influence of the fatigue caused by the RSA protocol on a 4-against-4 (4v4) SSG, especially on high-intensity actions. Consequently, the aim of our study was to analyze the influence of the pitch dimension on high-intensity actions and the effect of an RSA test on the physical performance in different 4v4 SSGs dimensions in an U18 Spanish professional football team.

Methods

Experimental Approach to the Problem

They participated in 4 training sessions weekly, in addition to one competitive match per week during the season. They played on a regular-sized football field (60 × 100 m) with the same rules of eleven-a-side football. To avoid potential imbalances between the 2 teams, and to ensure their equivalence, the selection of players was made subjectively by the coaches. Goalkeepers were excluded from the study, although they participated in the exercises.

Subjects

Sixteen U18 players from a professional Spanish football team academy were chosen to participate in this study (mean ± *SD*; age 16.9 ± 0.32 years). All the players of the team were selected for the study, and the experimental design was included in the training sessions. All the players and their parents were notified of the research design and its requirements, as well as the potential benefits and risks, and all of them provided formal consent before the start. Parental consent was obtained, and an informed consent was signed by all subjects. The research was approved by the Institutional Review Board of The University of Castilla-La-Mancha (Toledo-Spain) based on the latest version of the Declaration of Helsinki.

Procedures

Before the beginning of the study, all players were familiarized with the exercises used in the study. Specifically, subjects performed, in 2 separated sessions, the warm-up, the 4v4 SSG (pre), the first half of the RSA exercise (5 bouts), and the other 4v4 SSG (post). All these exercises were well known for the players because they were used to do it during the season in their club. Sixteen players were separated in 2 groups of 8 (group 1 and 2) that were at the same time separated in 2 teams of 4 players each one. In total, there were 4 teams of 4 players (team A, B, C, and D). Teams A and B belongs to the group 1 and teams C and D belongs to group 2 (Figure 1). After this control period of 2 sessions in the same week, the study started the next week, and it was executed by the group 1 every Tuesday and the group 2 every Wednesday. These days were chosen to ensure that players would not be tired or overload because of the game in the weekend. After a 12-minute warming-up period, which included 4-minute jogging, 2-minute stretching and joint mobility, 2-minute activation, coordination, and speed with ladders, and 4-minute ball passing by couples, a 8-minute 4v4 SSG (pre), RSA exercise to induce fatigue, and then another 8-minute 4v4 SSG (post) were executed. Each team made this protocol 4 times during 4 weeks (1 session per week), and the 4v4 SSG dimensions were different in each session. The different field dimensions were randomly assigned in a counterbalanced order. The total duration of the session was approximately 1 hour and 30 minutes.

4-Against-4 Small-Sided Game. All the teams performed 8 SSGs at 4 different dimensions during 8-minute nonstop each game: 125, 150, 250, and 300 m^2. Two games with the same dimensions were performed in each session, before (pre) and after (post) the RSA exercise to examine the effect of the fatigue on physical performance during these SSGs. A consistent verbal encouragement was used to maintain a high work rate. Physical parameters were also measured using a portable global positioning system (GPS) unit (GPSports SPI High Performance Unit, GPSport, Canberra, Australia), held by a special vest, worn at the top of the players back. After each training session, data were collected using a software (Team AMS, GPSport, Canberra, Australia) that connected each GPS devices for downloading participant coordinate data. Validity and reliability of these instruments have already been provided by the manufacturers and have been subjected to independent verification (4).

Movement Patterns—External Load. The GPSs attached to the players provided information about the total distance covered during the game (DT), the maximum speed (Vmax), average speed (V_{mean}), sprint number, sprint distance, and accelerations in pre and post RSA test in each SSG's different dimensions. The distance covered in each 1 of the 6 locomotor categories was provided with the following speed ranges: standing (0–0.5 $km \cdot h^{-1}$), walking (0.5–7 $km \cdot h^{-1}$), easy running (7–14 $km \cdot h^{-1}$), fast running (14–18 $km \cdot h^{-1}$), high-speed running (18–21 $km \cdot h^{-1}$), and sprinting (>21 $km \cdot h^{-1}$). The actions above 18 $km \cdot h^{-1}$ (high-speed running and sprinting) were grouped and defined as high-intensity running. In the same way, the GPS devices registered the maximum acceleration peaks and the number of accelerations of the players in different ranges of intensity: 1.2–2.5 (zone 1), 2.5–3.5 (zone 2), and >3.5 $m \cdot s^{-2}$ (zone 3).

Repeated Sprint Ability Test. Subjects performed 10 consecutive 40-m high-intensity shuttle running phases with a 180° direction change every 20 m after an audio signal. There were 25-second recovery phase between each bout to obtain

WEEK 1		WEEK 2		WEEK 3		WEEK 4	
TUESDAY	**WEDNESDAY**	**TUESDAY**	**WEDNESDAY**	**TUESDAY**	**WEDNESDAY**	**TUESDAY**	**WEDNESDAY**
GROUP 1	GROUP 2	GROUP 1	GROUP 2	GROUP 1	GROUP 2	GROUP 1	GROUP 2
TEAM A VS TEAM B	TEAM C VS TEAM D	TEAM A VS TEAM B	TEAM C VS TEAM D	TEAM A VS TEAM B	TEAM C VS TEAM D	TEAM A VS TEAM B	TEAM C VS TEAM D
(n=4) (n=4)	(n=4) (n=4)	(n=4) (n=4)	(n=4) (n=4)	(n=4) (n=4)	(n=4) (n=4)	(n=4) (n=4)	(n=4) (n=4)
Pitch Area: 300 m^2	**Pitch Area:** 125 m^2	**Pitch Area:** 125 m^2	**Pitch Area:** 300 m^2	**Pitch Area:** 150 m^2	**Pitch Area:** 250 m^2	**Pitch Area:** 250 m^2	**Pitch Area:** 150 m^2

Figure 1. Distribution of the players, teams, groups, and small-sided games according to counterbalanced order.

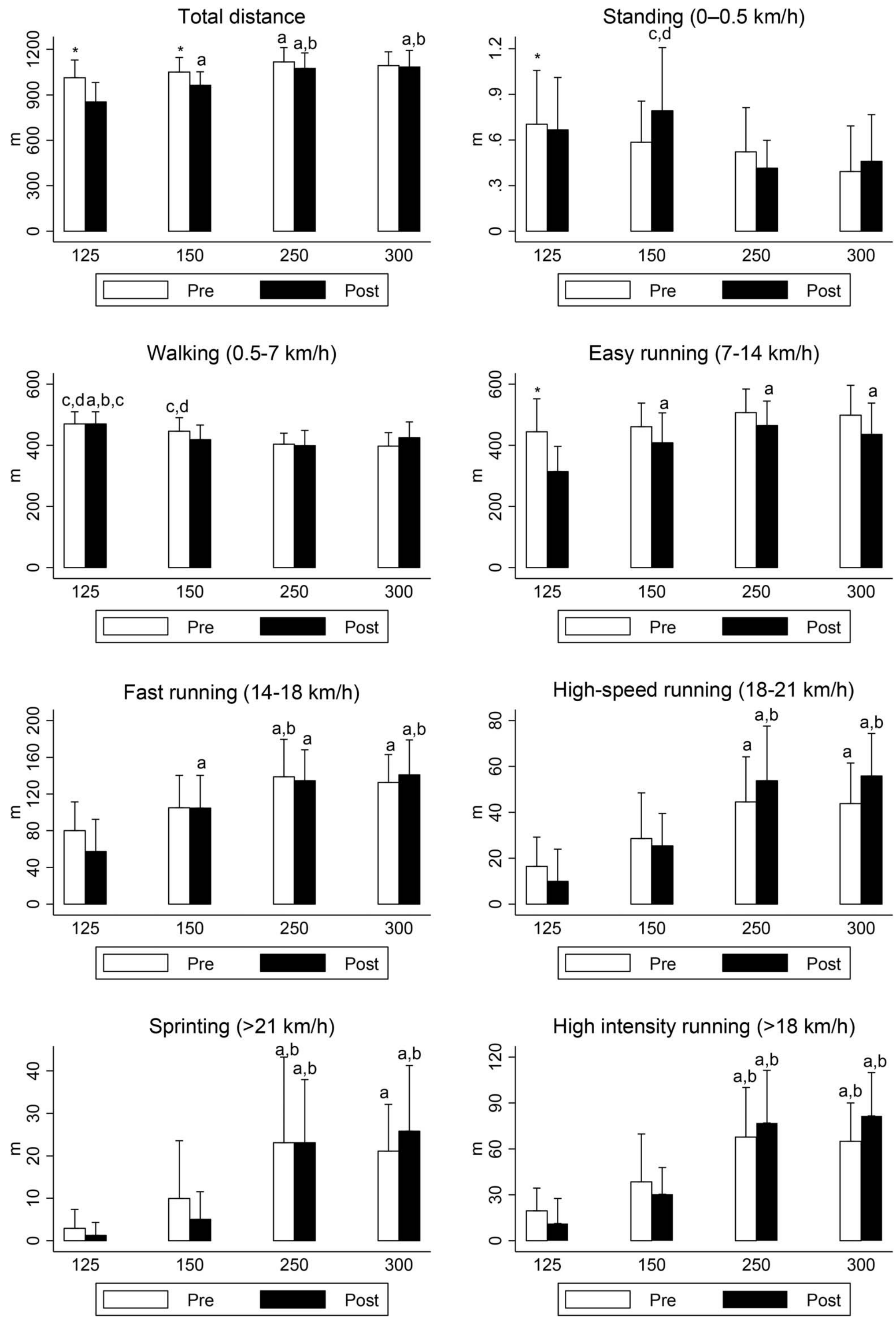

Figure 2. Activity profile during small-sided games in 4 different spaces (125, 150, 250, and 300 m^2), expressed as the distance covered in different locomotor categories including standing (0–2 $km \cdot h^{-1}$; st), walking (2–7 $km \cdot h^{-1}$; W), easy running (7–13 $km \cdot h^{-1}$; ER), fast running (13–18 $km \cdot h^{-1}$; FR), high-speed running (18–21 $km \cdot h^{-1}$; HSR), and sprinting (21 $km \cdot h^{-1}$; sp). *Differences between pre and post; [a]differences vs. 125; [b]differences vs. 150; [c]: differences vs. 250; [d]differences vs. 300; $p < 0.05$.

Table 1. High-intensity actions during small-sided games (SSGs) in 4 different spaces (125, 150, 250, and 300 m^2).

	Pre				Post			
	125 m^2	150 m^2	250 m^2	300 m^2	125 m^2	150 m^2	250 m^2	300 m^2
Vmax ($km \cdot h^{-1}$)	21.22 ± 1.76‖	22.73 ± 1.78	24.14 ± 2.17*	24.58 ± 1.84*†	19.40 ± 1.97	21.84 ± 1.60*	23.50 ± 1.23*	24.43 ± 1.68*†
V_{mean} ($km \cdot h^{-1}$)	5.76 ± 0.53‖	6.62 ± 0.70*	7.29 ± 0.66*†	7.22 ± 0.60*‖	5.07 ± 0.56	6.44 ± 0.67*	7.04 ± 0.62*§	6.34 ± 0.90*
Sprint number (*n*)	21.50 ± 6.43‖	23.44 ± 4.70§	21.81 ± 5.60‖	18.00 ± 4.26	14.94 ± 5.18	20.75 ± 4.58*	18.13 ± 4.62	17.44 ± 5.03
Acc. zone 2 (2.5–3.5 $m \cdot s^{-2}$)	10.88 ± 4.21‖	13.75 ± 4.06§	11.13 ± 3.28	9.19 ± 2.71	8.19 ± 3.66	11.38 ± 3.20	9.50 ± 3.60	8.69 ± 2.96
Acc. zone 3 (>3.5 $m \cdot s^{-2}$)	1.31 ± 1.25	1.19 ± 1.05	1.38 ± 0.89	1.31 ± 1.08	0.63 ± 1.09	1.13 ± 0.96	1.06 ± 1.12	1.19 ± 1.11
Sprint distance (*m*)	187.89 ± 58.50‖	204.61 ± 49.29	250.51 ± 51.29*	199.79 ± 46.49	122.45 ± 50.45	196.77 ± 52.88*	220.71 ± 65.35*	222.54 ± 60.62*

*Differences vs. 125.
†Differences vs. 150.
§Differences vs. 300.
‖Differences pre vs. post in each SSG; $p < 0.05$.

a high-intensity:low-intensity ratio of 1:3, and the total duration of this exercise was 5 minutes. Five seconds before the start of each sprint, subjects assumed the ready position and waited for the start signal. This exercise was executed by all players between two 4v4 SSGs (pre and post), and the main goal was to induce fatigue in these players to analyze their performance in the following 4v4 to compare physical data in fresh and fatigue situation.

Statistical Analyses

Data are presented as mean ± *SD*. Two-way analysis of variance and Bonferroni post hoc test was used to analyze the differences between different SSG and pre-post test. Confidence interval of the differences (CI of 95%) was included, and effect size (ES) was calculated to identify the magnitude of changes (ES; Cohen's *d*). The ES was evaluated after the next criteria: 0–0.2 = trivial, 0.2–0.5 = small, 0.5–0.8 = moderate, and >0.8 = large (9). SPSS 21.0 was used for the data analysis and the level of significance was established at $p \leq 0.05$.

Results

The analysis of the RSA effect on the SSG physical performance revealed a significant reduction of the total distance covered in the 125 m² (−160.13 m; CI 95%: −233.52 to −87.00; ES: 1.32; $p < 0.001$) as well as in the 150-m² field (−88.33 m; CI 95%: −161.46 to −15.13; ES: 0.95; $p = 0.018$; Figure 2). The distance covered in different speed ranges evidenced a lower distance in zone 3 (7–14 $km \cdot h^{-1}$) after RSA test in 125 m² (−129.98 m; CI 95%: −193.49 to −66.46; ES: 1.38; $p < 0.001$).

On the other hand, compared with the SSGs played on a 125-m² field, our results indicated that the players covered higher total distances in 150-m² field SSG (+108.98 m; CI 95%: 90.91–208.07; ES: 1.01; $p = 0.023$), 250 m² (+221.50 m; CI 95%: 122.42– 320.58; ES: 1.94; $p < 0.001$), and 300 m² (+229.67 m; CI 95%: 130.59 to 328.75; ES: 1.93; $p < 0.001$) after the RSA test. Focusing on high-intensity actions (zones 5 and 6), SSGs played in 250- and 300-m² field presented higher distances covered comparing with SSGs played in 125 and 150 m² before ([250 vs. 125: +48.27 m; CI 95%: 23.54–73.00; ES: 2.03]; [250 vs. 150: +29.13 m; CI 95%: 4.40–53.86; ES: 0.92]; [300 vs. 125: +45.51 m; CI 95%: 20.78–70.25; ES: 2.27]; [300 vs. 150: +26.38 m; CI 95%: 1.65–51.11; ES: 0.94]) and after ([250 vs. 125: +65.62 m; CI 95%: 40.88–90.35; ES: 2.58]; [250 vs. 150: +46.43 m; CI 95%: 21.70–71.16; ES: 1.79]; [300 vs. 125: +70.34 m; CI 95%: 45.61–95.07; ES: 3.15]; [300 vs. 150: +51.16 m; CI 95%: 26.42–75.89; ES: 2.24]) the RSA test (Figure 2).

Table 1 shows that Vmax (−1.81 $km \cdot h^{-1}$; CI 95%: −3.05 to −0.57; ES: 0.97; $p = 0.005$), V_{mean} (−0.69 $km \cdot h^{-1}$; CI 95%: −1.16 to −0.23; ES: 1.26; $p = 0.004$), number of sprints (−6.56; CI 95%: −10.13 to −3.00; ES: 1.13 $p < 0.001$), accelerations zone 2 (−2.69; CI 95%: −5.13 to −0.24; ES: 0.68; $p = 0.032$), and sprint distance (−65.44 m; CI 95%: −103.73 to −27.16; ES: 1.20; $p = 0.001$) significantly decreased in 125-m² SSGs after the RSA test. Only in 300-m² SSG, our data found a significantly reduction in V_{mean} (−0.88 $km \cdot h^{-1}$; CI 95%: −1.35 to −0.42; ES: 1.17; $p < 0.001$) and number of sprints in 250 m² (−3.69; CI 95%: −7.52 to −0.12; ES: 0.72; $p = 0.043$) after the RSA. According to the comparison between the different SSGs, it has been reported a lower Vmax, V_{mean}, and sprint distance in 125-m² field comparing with 150 m² (ES_{Vmax}: 1.37; ES_{Vmean}: 2.22; $ES_{SprintDistance}$: 1.44), 250 m² (ES_{Vmax}: 2.56; ES_{Vmean}: 3.34; $ES_{SprintDistance}$: 1.70), and 300 m² (ES_{Vmax}: 2.76; ES_{Vmean}: 1.73; $ES_{SprintDistance}$: 1.80), especially after the RSA test.

Discussion

The aim of our study was to analyze the influence of an RSA test on the physical performance in high-intensity actions in different 4v4 SSGs dimensions (125, 150, 250, and 300 m²). The other aim was to analyze the influence of the pitch dimension on the same physical actions during these different 4v4 SSGs. These results suggest that only in the smallest SSG (125 m²), significant differences in physical parameters were found after the RSA test, probably due to the smaller space that demand higher intensity for the players to keep the ball, and this high intensity is not possible to keep it after the RSA. Specifically, a significant detrimental of Vmax, Vmean, number of sprints, accelerations in zone 2, and sprint distance were observed in the 125-m² SSG after RSA. Furthermore, compared with the data of the smallest SSGs (125 and 150 m²), our findings indicated that in the biggest SSGs (250 and 300 m²) almost 25% more distance at high intensity was covered but, in contrast, the number of sprints was significantly lower. Similarly, Vmax, V_{mean}, and sprint distance were greater, especially compared with the 125-m² SSG due to not space enough to perform high-speed actions, but increasing shorter running movements. However, a higher space allows to perform higher speed efforts. In this way, our results revealed a higher external load in higher spaces.

Small-sided games are a common practice in team-sport games (12,18,35) and are often researched. However, no studies have examined the relationship between the fatigue induced by an RSA test and the physical performance during a 4v4 SSG. The findings suggest that, by altering the pitch size and keeping the same number of players, physical performance in high-intensity actions (sprint distance, maximal speed, and average speed) changed significantly. Based on the results of this study, it seems logical for coaches to consider using bigger spaces with the same number of players in games to increase physical performance, mostly the high-intensity actions. These results are in line with data reported previously by other authors who showed that higher intensity was found during the larger pitch dimensions. These results confirm that the increase in pitch dimensions with a constant number of players (4v4) may increase the physiological demands of SSG (HR, La-, and RPE) (8,15,39).

Casamichana and Castellano (8) demonstrated that increasing pitch dimensions allows increases in physiological responses (HR and RPE) during 5v5 SSG with 3 pitch sizes. Moreover, Williams and Owen (39) found an increase in HR with the increase of the pitch area during 3v3 SSG. From these studies, it is possible to deduce that the increase of physiological parameters by increasing the pitch size could be accompanied by higher physical demands, as happen in the results of our study in the biggest dimensions (250 and 300 m^2). On the other hand, and focusing on physical performance that is the main goal of our investigation, Hodgson et al. (19) reported that changing pitch size affects both the physical and technical demands of SSGs. These results are similarly found in our study, which showed that the lowest sprint distance, accelerations in zone 3, V_{mean} and Vmax were found in the smallest dimension (125 and 150 m^2) comparing with the bigger pitch sizes (250 and 300 m^2). Small pitch sizes are characterized by a reduced physical demand and an increased technical demand in comparison with large pitches. These data have important implications for coaches and practitioners using SSGs as a conditioning stimulus in football. In this study from Hodgson, players covered more total distance, and more distance during acceleration and deceleration ranges on medium and large pitch sizes. Also, the total distance, distances covered at high speed ($>14.4\ km\cdot h^{-1}$) and high power ($>20W\cdot kg^{-1}$) as well as the average metabolic power, absolute maximum speed, acceleration, and deceleration were greater when the pitch area increased (13).

From the literature, RSA can be summarized as crucial fitness for team-sport athletes. Studies have shown that the main features of team sports are high-intensity sprints of short distances usually, coupled with brief recovery during each exercise bout (20). The use of the RSA protocol during our investigation to induce fatigue in players has been based on the intermittent nature of football (1,6,11,32), and the determinant importance of high-intensity actions (sprint, accelerations, and decelerations) during the game. In addition, it was designed to reflect the high-intensity demands of the competition. This protocol could be considered an effective training strategy for inducing aerobic- and football-specific training adaptations (11), and to reduce the player physical capacities to induce fatigue (23). According to the players' fatigue, physical parameters decreased significantly after the RSA test, mostly in the smallest field (125 m^2). These findings are in line with the study of Rampinini et al. (30) that found a negative effect on short-passing ability after the same RSA protocol that was used in our study. It could be possible to extrapolate the detrimental effect of the match-related fatigue on technical aspects to physical aspects too. Thus, this notion suggests that the fatigue accumulated during the match has a detrimental effect on physical aspects. In football, player's physical performance is reduced in the second half as demonstrated by the decrease in sprinting and high-intensity activity compared with the first half. Furthermore, the detrimental effect of match-related fatigue is particularly evident toward the end of a game (23). This is supported further by previous studies reporting a greater distance covered in the first than the second half both for players (1,3,32). Thus, the training of top-class players should focus on improving their ability to perform intense exercise and to recover rapidly from periods of high-intensity exercise. Various factors such as dehydration, hyperthermia, glycogen depletion, and accumulation of potassium in the muscle interstitium have been proposed as candidate mechanisms to fatigue (2). It is possible that similar physiological mechanisms causing deterioration in physical performance may alter technical aspects too. Indeed, the players' physical performance was reduced after a period with a large amount of high-intensity exercise during match play and toward the end of the match. In addition, the distance covered at high intensity significantly decreases immediately after 5-minute intervals of high-intensity activity (23). In line with this notion is the observation that the physical parameters (speed, sprint, and accelerations) of the players in our study were reduced after the 5-minute RSA protocol. More specifically, this author found that the distance covered by top-class players when sprinting was 43% less in the last 15 minutes than in the first 15 minutes of the game, and the number of sprints was 25% less. This finding is directly related with our results that showed a 35% detriment of sprint distance and 31% less number of sprints after the RSA test. Moreover, after these short bout test, we found that Vmax, V_{mean}, and accelerations in zone 2 were almost 10, 12, and 25%, respectively, lower in the 125 m^2-post-RSA game.

In summary, the main finding of this study was that the RSA test has a detrimental effect on physical aspects related with high-intensity actions in an SSG mostly in the smallest field (125 m^2). Moreover, this study suggests that changing the pitch size in a 4vs4 SSG and keeping the same number of players, physical intensity can be manipulated. In smaller pitches (125 and 150 m^2), the intensity increases mostly in accelerations and sprinting activity; and in bigger pitches (250 and 300 m^2), higher velocities are reached (V_{mean} and Vmax) in U-18 elite football players.

This study has some limitations because the current volume of systematic research in fatigue and SSGs is small, and, consequently, definitive conclusions are difficult to form. The importance of acceleration movements in football is an area that warrants further research, both in training and match play situations. If these movements characterize fatigue in football, then the ability of players to repeat acceleration efforts over the course of a 90-minute game is an important ability to train; our data would indicate that SSGs might be an efficacious method to achieve this (19). Future research is required to further develop our understanding of the fatigue stimulus caused by an RSA test and the influence on SSGs. Another important area of future research is the influence of the fatigue induced by an RSA protocol on technical and tactical aspects during SSGs.

Practical Applications

This study is the first to investigate the influence of the fatigue caused by the RSA protocol on a 4v4 SSG, especially on high-intensity actions. The results of this investigation show that it is possible to use different pitch sizes to modify the physical intensity, and that mainly, in the smallest SSG (125 m^2) significant differences were found after the RSA test. From a practical perspective, coaches can modify the playing area of small-sided training games to increase the physical parameters (e.g., speed, sprint number, accelerations, sprint distance, total distance covered, and total distance covered of the players at different intensities) according to the training purposes. Finally, the results of this study provide new information about the incidence of repeated sprint actions on the physical performance in SSGs, especially in smaller size fields (125 m^2) and the effectiveness of using SSGs as a high-intensity training stimulus for soccer. Moreover, it is demonstrated that the SSG pitch size has a direct influence on the conditional aspects. In bigger spaces, high-speed actions are reached, and in shorter ones, a higher number of accelerations and short-duration actions are required. This new information may be useful for prescribing soccer-specific conditioning programs for elite youth soccer players.

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