Original Article

Investigation of time-motion characteristics of work load and physiological load in different regimes of small-sided games in soccer

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ABSTRACT

The aim of this study was to examine the work-load and physiological-load on the players of continuous and intermittent small-sided games (SSGs) in terms of time-motion. Twelve soccer players (age: 20.75 ± 1.60 years; body mass: 72.17 ± 5.20 kg; height: 179.42 ± 5.96 cm) participated in the research voluntarily. SSGs were played in two regimens, continuous (SSGc) and intermittent (SSGi). Wearable GPS device was used to measure the work-load and physiological-load of the players during the SSGs. Five different intensity zones were determined according to the maximal heart rate (HRmax) percentage of the players. Time, HR, running distance and running speed of the players were recorded separately for five zones during SSGs. Comparative analysis was performed between both SSGs. Players' average HR (p = .002) and player load (p = .037) indicators were significantly higher in SSGi than SSGc during the game. There was no significant difference between SSGi and SSGc in total running distance, sprint distance and maximal speed (p > .05). The most crucial finding of the study is that zone-5 activity duration was found to be significantly higher than SSGc in SSGi (p = .023). During SSGc, it was observed that the physiological responses of the players spent time in zone-4, which is the submaximal level, rather than in zone-5, which is the high-intensity activity level. As a result, a higher physiological load at maximal intensity occurred in SSGi compared to SSGc on players. SSGi created a more fluctuating heart rate. While both methods created a physiological load at a sub-maximal density on players, SSGi created a more intense anaerobic load level.
Keywords: Performance analysis, Soccer, Running, Speed, Games, Heart rate, Distance.

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INTRODUCTION

Small-sided games (SSGs) in soccer are seen as an alternative to traditional training exercises without the ball (Hill-Haas, Coutts, et al., 2009). SSGs include features such as the duration and method of the game, the size of the field, the number of players, and the change of rules. These practices create an interval training effect on players (Impellizzeri et al., 2006). SSGs are more advantageous in terms of motivating the players due to their technical, tactical and physical practices (Reilly et al., 2009) and their application with a ball, and making the training time more efficient (Hoff & Helgerud, 2004).

Diversification of SSGs causes players to use different energy metabolisms while providing the improvement of that characteristic. It is difficult to hide in the flow of the game in SSGs, so all players have to combine defence and offense, so their transition from defence to offense and offense to defence will be rapid. Quick transition times will positively affect maximum participation and physiological development (Rampinini, Impellizzeri, et al., 2007).

In SSGs, adjustments can be made in line with the performance parameters that the trainer wants to improve in players thanks to variations such as the number of players, the size of the field, the loading-rest time, the rules of the game, motivation, limitations of playing with the ball, and the method of reaching the goal (Bangsbo, 1994). Since this diversity in SSGs directly concerns the training effect on players, the effectiveness of these games should be well understood in planning the training process (Aguiar et al., 2012; Hill-Haas, Coutts, et al., 2009).

Some previous studies investigated how selected variables (size of the game field, number of players, additional player in the attacking team and coach support) affect the intensity of SSG training (Kelly & Drust, 2009; Owen et al., 2004; Praça et al., 2015; Rampinini, Impellizzeri, et al., 2007; Williams & Owen, 2007). It was emphasized that game field size changes increase players' HR, blood lactic acid (LA), and rating of perceived exertion (RPE) average (Aroso et al., 2004; Little & Williams, 2007; Rampinini, Impellizzeri, et al., 2007) and when game field size remains constant and the number of players increases, the HR decreases (Owen et al., 2004; Williams & Owen, 2007).

Interval training creates a higher intensity physiological load on athletes than continuous training (respectively: 80-95% VO2max; 50-80% VO2max) (Perry et al., 2008; Tuimil et al., 2011). In the previous study comparing intermittent and continuous SSGs, higher HR and % HRmax were found in 3vs3 games than 2vs2 and 4vs4 games, while higher LA responses were reported in 2vs2 games (Köklü, 2012). In another study, no significant difference was found between the total running distance, walking, jogging or running at medium speed during intermittent and continuous SSGs. Besides, high speed running distances were found to be higher in intermittent than continuous (Hill-Haas, Rowsell, et al., 2009).

While there are studies in the literature that can provide sufficient insight into the physiological load on the total game time of both methods, there are a limited number of studies (Hill-Haas, Rowsell, et al., 2009; Nagy et al., 2020) comparing the time spent in the percentages of HRmax during games. Therefore, trainers need to know the level and duration of physiological load the players are exposed to during SSGs that coaches frequently use.

This study aimed to investigate the differences between continuous small-sided game (SSGc) and intermittent small-sided game (SSGi) methods in terms of time spent by players in HR zones created according to HRmax percentages.

METHODS

Participants

Twelve soccer male players (mean ± SD, age: 20.75 ± 1.60 years, height: 179.42 ± 5.96 cm, body mass: 72.17 ± 5.20 kg, HRmax: 188.08 ± 4.44 bpm) participated in this study voluntarily. The subjects consist of university students with 9.83 ± 1.52 years of experience and play in the same soccer team. The study was planned during the season of participants in which they do their regular weekly training and play official games. This study was approved by the local Investigation Review Committee of the Faculty of Sport Sciences of Mugla Sitki Kocman University (Document No/Date: 54825672-605.00.00.00-79/23.01.2018) and was consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki. The subjects were fully informed about the procedures to be used and the experimental risk.

Study design

The maximal heart rate value reached during the Yo-Yo Intermittent Recovery Tests can be used as the maximal heart rate value of athletes (Krustrup et al., 2003). Maximal heart beats of the subjects were measured on a different test day with the Yo-Yo Intermittent Recovery Test Level 1 (YYIRT-1). On the test day, first the resting heart rate of the subjects were recorded. In recording the resting heart rate, subjects waited for 5 minutes while sitting, and then the lowest number of heart rate in the next 5 minutes was recorded as resting heart rate. YYIRT-1 was implemented until exhaustion level and the maximal heart rate (HRmax) values were recorded and used in calculating the HRmax calculations. While creating heart rate zones, the target heart rate interval was calculated with the Karvonen formula:

Karvonen equation: HRtarget = [(HRmax-HRrest)*intensity%]+HRrest (Karvonen et al., 1957).

Different intensity zones were created in previous studies in classifying the external intensity of training according to the HRmax percentage (Hill-Haas, Rowsell, et al., 2009; Köklü et al., 2012; Nagy et al., 2020; Scott et al., 2013). In our study, the time that the players spent in the percentile of the maximal heart rate during games were classified as 5 zones. 1st zone (<60% of HRmax), 2nd zone (60-74% of HRmax), 3rd zone (75-84% of HRmax), 4th zone (85-94% of HRmax), 5th zone (94>% of HRmax).

Small-sided games

Field measurements used in SSGs were determined by reviewing previous studies (Brandes et al., 2012). The field dimensions for 3vs3 small-sided games played on the Olympic artificial turf field were 34*26 m. During the SSGs, spare balls were always kept on the side of the field so that the game was not interrupted. Before the games, the athletes were in-formed about the rules and asked to show maximal performance. Both SSGs were implemented on different days and with 2 days apart. After 15 minutes of warm-up, games started. Intermittent (interval) SSGi was implemented on the first test day. 3 repetitions*4 minutes of game and 2 minutes rest between reps. In load: rest, the 1:1/2 principle was adopted. On the second test day, the continuous small-sided game (SSGc) was played for 12 minutes without a break.

Data collection

In order to measure the heart rate, running distance, running speed, player load (PL) and the time spent in the heart rate areas during games, a real-time recording wearable chest band with a three-axis 400Hz accelerometer and a global positioning (10 Hz GPS) device (Playertek GPS Catapult Group International Ltd. was used. GPS and accelerometer technologies are reliable devices to measure the training intensity of football players in field-based training (Nicolella et al., 2018; Scott et al., 2013). The PL metric uses the accelerometer data to calculate the load or the activity level of the player. Research has shown that PL is a valid and reliable measure and can provide important insights into player activity (Christina, 2022; Nicolella et al., 2018). According to the players' individual data (ID, age, body height, HRmax, HRrest, etc.) and HRmax percentiles, 5 intensity zones were uploaded to the software that is integrated into the GPS device. The data were obtained by transferring the recorded data by the GPS device during the SSGs to this software.

Statistical analysis

The descriptive statistics of the players and the data recorded during the SSGs are given as mean and standard deviation (mean ± SD). An independent samples t-test was completed to determine the differences between the SSGs variables. The level of statistical significance was accepted as .05. Finally, the effect size (Cohen's d) was also assessed (small <0.5; moderate 0.50-0.79; large ≥0.80) (Cohen, 1988).

RESULTS

The results of the study showed a significant difference between SSGc and SSGi in players' mean heart rate (HR) and player load (PL) parameters (HR: 183.61 ± 7.62; 188.50 ± 4.57 bpm, *p* = .002; PL: 24.66 ± 8.54; 28.29 ± 5.68 arbitrary units (au), p = .037; respectively). A higher mean HR and PL were obtained in SSGi. There was no significant difference between SSGs (SSGc; SSGi, respectively): total running distance (460.89 ± 59.32; 475.42 ± 50.21m.; *p* = .266), distance travelled per minute (94.04 ± 43,28; 109.38 ± 31.93 m.min^{-1}; *p* = .092), sprint distance (9.69 ± 9.88; 11.12 ± 14.02 m; *p* = .617) and maximal speed (20.26 ± 2.45; 20.03 ± 2.85 km.h^{-1}; *p* = .708), (Table 1).

Table 1. Performance and HR (mean ± SD) Comparison Analysis in SSGs.

	SSGc	SSGi	t	*p*	ES.
HR (bpm)	183.61±7.62	188.50±4.57	-3.30**	.002	0.78 large
Total running distance (m)	460.89±59.32	475.42±50.21	-1.12	.266	0.26 small
Distance (min.m)	94.04±43.28	109.38±31.93	-1.71	.092	0.40 small
Sprint distance (m)	9.69±9.88	11.12±14.02	0.50	.617	0.11 small
Maximal velocity (km.h)	20.26±2.45	20.03±2.88	0.38	.708	0.08 small
Player Load (au)	24.66±8.54	28.29±5.68	-2.12*	.037	0.50 medium

*Note. SSGc = Continuous small sided games, SSGi = Intermittent small sided games, HR = Heart rate, ES = Effect size- Cohen's d, *p < .05, **p < .01.*

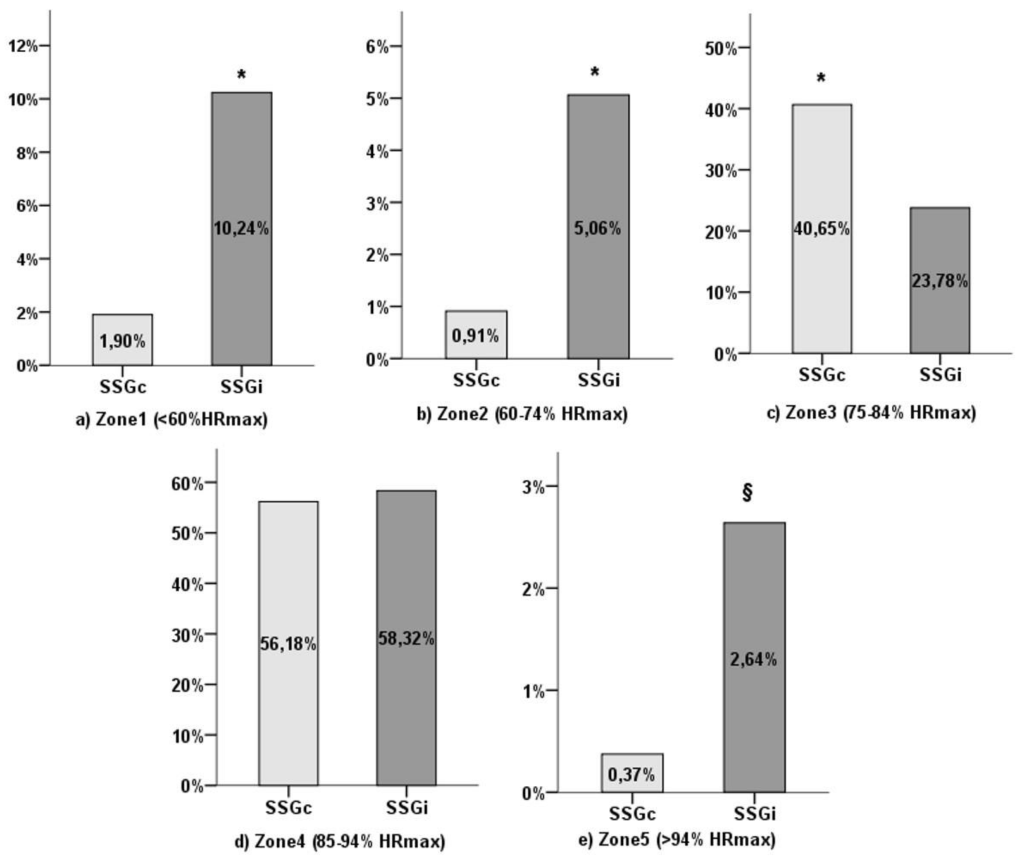
Table 2. Comparison of The Time of Players Spent in HR Zones During SSGc and SSGi (mean ± SD).

Zones	Time Spent at Zones (sec.)		t	p	ES
	SSGc	SSGi			
Zone 1 (<60%HRmax)	0.04±0.09	0.20±0.43	-2.27**	.026	0.52 medium
Zone 2 (60-74% HRmax)	0.08±0.12	0.41±0.27	-6.77**	.000	1.58 large
Zone 3 (75-84% HRmax)	1.63±0.98	0.95±0.68	3.39**	.001	0.81 large
Zone 4 (85-94% HRmax)	2.25±1.00	2.33±0.87	-0.39	.699	0.09 small
Zone 5 (>94% HRmax)	0.02±0.05	0.11±0.23	-2.32*	.023	0.54 medium

*Note. SSGc = Continuous small sided games, SSGi = Intermittent small sided games, %Hrmax = Percentage of maximum heart rate, ES = Effect size- Cohen's d, *p < .05, **p < .01.*

A significant difference was found between SSGc and SSGi in the averages of the time the players spent in the first, second, third and fifth zones during SSGs (t = -2.27; *p* = .026, t = -6.77; *p* = .000, t = 3.39; *p* = .001; t = -2.32, *p* = .023, respectively). The time that players spent in the first two zones and the fifth zone in SSGi was significantly higher than in SSGc. In the third zone, SSGc was found to be significantly higher. The difference between the two methods was not significant in terms of the mean time spent in the fourth HR zone (t = -0.39; *p* =.699). The time spent on the 4th zone (85-94% HRmax) was found to be the highest in both methods (Table 2).

The percentile distribution of the time that players spent in HR zones in SSGs with 12 minutes active time is clearly seen in Figure 1. The percentage of zone5 (>94% of HRmax) in SSGi was significantly higher than SSGc (respectively: 2.64%; 0.37%, $p < .05$). The percentage of zone4 (85-94% of HRmax) in SSGi was not significantly different from SSGc (respectively: 58.30%; 56.17%, $p > .05$). In both games, the most time was spent in zone4. In Zone3 (75-84% of HRmax), SSGc was significantly higher than SSGi (respectively: 40.65%; 23.77%, $p < .01$). In zone2 (60-74% of HRmax) and in zone1 (<60% of HRmax), players spent more time in SSGi (10.23%; 5.06% respectively) compared to SSGc (1.90%; 0.91% respectively).



*Note. *p < .01, § < .05 significant difference between SSGs in Fig. a-b-c-e. a) SSGi > SSGc in zone1, b) SSGi > SSGc in zone2, c)SSGc > SSGi in zone3, e)SSGi > SSGc in zone5.*

Figure 1. Percentages of time spent in HR zones in SSGc and SSGi.

DISCUSSION AND CONCLUSIONS

The small-sided games cause a significant increase in the players' HR. During the SSGs, the players had a physiological load close to the average HRmax value (188.08 ± 4.44 bpm). When the SSGs methods were compared, it was seen that the mean HR of the players were different during the SSGi and SSGc. In both methods, the average HR values of the players during the 12-minute active game approached the maximal values, but the mean SSGi HR was significantly higher than the SSGc.

Although previous studies have reported average HR in a soccer match in the range of 160-170 bpm (Bangsbo, 1994; Rampinini, Coutts, et al., 2007), it can be said that this average is quite variable in different parts of the match. It has been reported that the mean HR of players in SSGs is higher than in the match, and the mean HRmax is range of 87-90% in 3vs3 SSGs (Katis & Kellis, 2009; Little & Williams, 2006; Rampinini, Impellizzeri, et al., 2007).

In addition to HR outputs, another important indicator of external training intensity is player load (PL). PL is an important metric that reveals the intensity of the player's activity (Casamichana et al., 2013; Casamichana & Castellano, 2015). Previous studies reported that were high correlations between PL and rating of perceived exertion (RPE), heart rate (HR) and blood-lactate (BLa) levels (Casamichana et al., 2013; Montgomery et al., 2010). In the present study, the mean player load indicator recorded during SSGi was significantly higher than the SSGc which indicates that the training intensity was higher in SSGi.

In the present study, the fact that the time spent in zone5 where the maximal intensity occurs is significantly higher in the SSGi method compared to the SSGc indicates that the players are exposed to a higher physiological load in the interval method. Additionally, zone4 where submaximal load occurs was the region where the most time was spent in both games. According to the time spent in other zones, it can be said that the interval method creates a more fluctuating physiological load while the continuous method creates a more stable physiological load.

Hill-Haas, et al. (2009) reported a significant difference between the total distance travelled, the number of sprints, HRmax, and internal load parameters during the continuous and intermittent SSGs in young football players (Hill-Haas, Rowsell, et al., 2009). Contrary to present study' results, they found no significant difference between both games in the time spent in zones determined by HRmax percentage. Nagy, et al. (2020) examined the load/rest relationship of SSGs according to % HRmax zones and compared the 3 different SSGs in terms of time spent in intensity zones according to the load-rest ratio (1:2, 1:1 and 1:1/2). The players spent 49.12% of the total time in the zone of maximal intensity (zone 90-100% of HRmax) and 32.93% in the submaximal zone in SSG (1:1/2). They reported that this creates a significantly high physiological load on the players compared to other games (SSG (loading:rest): SSG (1:2), SSG (1:1). Therefore, they emphasized that SSGs are important in terms of loading:rest relationship, and training should be planned in accordance with the current situation and goals of the players by considering the repetition times, number of sets and rest periods.

Players perform differently in matches according to their categories and the difficulty level of the tournament. It is known that the required performance level is higher in upper categories and upper tournament matches. Therefore, previous studies have emphasized the importance of adjusting the intensity level of the training of the players according to the competition levels of the teams (Freire et al., 2022). SSGs can be seen as a very important way for players to prepare for the necessary needs at football matches.

In conclusions, both game methods create submaximal physiological load and workload on the players. In SSGs, the average HR achieved by players in total time is higher in SSGi, which indicates that this game method creates a higher intensity load. When examined in detailed, the players spent at maximal and sub-maximal zones about 56% in SSGc and about 61% in SSGi of the total time. Another important outcome is that physiological load having a more fluctuating trend and at the same time increasing to maximal intensities is an important characteristic of SSGi. SSGc created a more stable and steadier physiological load. In short, coaches should prefer SSGi when planning training focused on increasing anaerobic capacity and creating match-specific load.

AUTHOR CONTRIBUTIONS

Conceptualization - O.M. and A.K.; Methodology - O.M. and A.K.; Formal analysis - O.M. and A.K.; Data curation - O.M. and A.K.; Writing–original draft preparation - O.M. and A.K.; Writing–review and editing - O.M. and A.K.

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No potential conflict of interest was reported by the authors.

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