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Reproducibility of Physical Performance during Small- and Large-sided Games in Elite Soccer in Short Period: Practical Applications and Limits

Alexandre Dellal[1-3*], **Karim Chamari**[4], **Florian Payet**[3], **Léo Djaoui**[2] **and Del P Wong**[5,6]

[1]*FIFA Medical Center of Excellence, Centre Orthopédique Santy, Lyon, France*

[2]*Centre de Recherche et d'Innovation Sur le Sport (CRIS), Université de Lyon 1, France*

[3]*Laboratoire LAMHESS (EA 6309), Université de Nice Sophia Antipolis, Nice, France*

[4]*Athlete Health and Performance Research Centre, Aspetar, Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar*

[5]*Sports and Recreation Research Centre, Technological and Higher Education Institute of Hong Kong (THEi), Hong Kong, China*

[6]*Human Performance Laboratory, Technological and Higher Education Institute of Hong Kong (THEi), Hong Kong, China*

[*]**Corresponding author**: Dellal Alexandre, OGC Nice (soccer), parc des sports Charles Erhmann, 177 Route de Grenoble, 06200 Nice, France, Tel: 00.33.630.515.311; E-mail: alexandredellal@gmail.com

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Abstract

The aim of the present study was to examine the reproducibility of the physical activity during different sided games in elite soccer players during different training sessions. Twenty elite soccer players belonging to a French first league team (age: 24.3 ± 3.2 years; height: 178.1 ± 4.2 cm; body mass: 76.9 ± 4.3 kg) participated in different small and large-sided games (SSG: i.e. 5 vs. 5, 6 vs. 6, 7 vs. 7; and LSG: i.e. 8 vs. 8, 9 vs. 9 and 10 vs. 10 with and without goalkeepers) repeated at 2 different sessions within a competitive season. Peak speed reached (V_{max}), heart rate (HR) responses and the total distance covered (TDC) at walking (0-6 $km.h^{-1}$), very-light (>6-10 $km.h^{-1}$), light (>10-16 $km.h^{-1}$), moderate (>16-23 $km.h^{-1}$), and high (>23 $km.h^{-1}$) intensities were measured and analyzed using global positional system (GPS) during all SSG and LSG. No statistical significant differences of V_{max}, HR response, TDC, and TDC at high and moderate intensities for all sided games played between 2 different sessions were found. Moreover, the inter-individual coefficients of variation of HR during all SSG were lower than 8.6% with no statistical significant differences when SSG and LSG were repeated at 2 different sessions. In conclusion, the physical performance and especially the high intensities activities of elite soccer players present good reproducibility when different types of SSG were applied in 2 different sessions in the same period, even if the rules and formats were being manipulated allowing coaches to use it with a target time-motion characteristic and an equivalent workload week after week.

Keywords: Exercise response; Football; High-intensity running; Motion analysis; GPS

Introduction

Nowadays, small-sided games (SSG) are widely used and considered as a modern training method in professional, amateurs and young soccer players due to its ability to solicit all the players' capacities that are similar in an official game (mental, physical, technical and tactical capacities) [1-3]. Numerous studies showed that SSGs needs a great attention in order to well control the physiological impact and physical performance while the incidence of rules and formats' manipulation is well documented. The latter characteristics influence the physical activity, the physiological responses and the technical performance of players within SSGs [1,2]. In this context, it was demonstrated that specific changes in the number of ball touches authorized per individual possession [4], the pitch size [5,6], the number of players [7,8], the duration of the exercise [1,9,10], the coach encouragements [11], and/or the presence of goalkeepers [12,13] affected players activity. Moreover, the training regimens, the age and the playing level of the players also influenced the workload, the technical actions and the time-motion characteristics within SSGs [13,14]. However, what about the reproducibility of the activities when coaches use SSG in same condition among different proximal training sessions?

Although the effect of the manipulation of games rules and training regimens is well known, it appears that several limiting factors need to be further examined in order to improve the use and the workload control of SSG by coaches. Among these, the reproducibility of SSGs regarding the time-motion characteristics and the physiological impacts require more attention. During the same training session, [6,14] have shown that the repetition of several bouts of SSG (2 vs. 2, 3 vs. 3 and 4 vs. 4) induces a decrease in the technical and physical performance and higher cardiovascular load from the 1st to the 3rd and the 4th bouts repetition of SSG. Specifically, they observed an increase in the number of ball loss, the blood lactate concentration, the rating of perceived exertion (RPE) and the heart rate (HR) response, and a decrease in the number of duels, percentage of the successful passes and very-high intensity running [14,15] showed no difference of the HR responses, tackle, interception, turn, shoot and header during 3 successive bouts of 3 vs. 3 with goalkeepers (4 min of recovery in-between) performed during the same training session. Nevertheless, they confirmed the results of other studies Kelly et al., Dellal et al. [6,14] showing that RPE and percentage of successful passes decreased from the 1st to the 3rd bouts period.

Results from these previous investigations are not always in agreement probably due to the difference of game rules (presence of goalkeeper, duration and number of bouts period, recovery duration) or the pitch size, which has been shown to directly affect players'

performance within SSGs. In this sense, Hill-Haas et al. [3] showed that smaller games formats (2 vs. 2) presents better reproducibility than larger format (4 vs. 4) but with especially poor scores reproducibility concerning total distance covered >18 $km.h^{-1}$ and blood lactate concentration. Similarly, Rampinini et al. [11] have showed that the reproducibility appeared to be better when the intensity of SSG is higher (i.e., 3 vs. 3>6 vs. 6). They added that the intra-participant variability for heart rate, RPE and blood concentration were considered as limits. In this context, although Rampinini et al. [11] and Hill-Haas et al. [3] analyzes the reproducibility of SSGs from the technical and physiological points of view, there is a lack of knowledge about the reproducibility of physical performance within SSGs. Therefore, the aim of the present study was to investigate the reproducibility of the physical activity from the same SSG played in the same conditions throughout different sessions in real training setting in the same period of the season. This investigation may help to better individualize physical training according to physiological and physical target determined by the technical staff and to plan integrated training schedule.

Materials and Methods

Subjects

Twenty professional soccer players from the same French League-1 team (age: 24.3 ± 3.2 years; height: 178.1 ± 4.2 cm; body mass: 76.9 ± 4.3 kg) took part in this study. Only players who participated in complete training duration and with no recent injury (>6 weeks) were used for analysis. The study was conducted according to the Declaration of Helsinki and the local university ethics committee approved the study protocol before the commencement of the assessments.

Study design

All the SSG and LSG were performed during the 2013-2014 season (from September to November) in the same training conditions (grass field) and environmental conditions (temperature: 15-24°C, and relative humidity: 52-70.0%) at the same time of the day (10 h-12 h) to avoid any effect of circadian rhythms [16]. The analysis concerned the reproducibility of the physical activity (peak speed and total distance covered at different speed thresholds categories) within sided games (SSG and LSG) during different training sessions was measured using GPS (GPS sports SPI Elite, Canberra, Australia). Different types of SSG and LSG with different rules and formats were applied in order to examine the reproducibility or the time-motion characteristics in different sessions in successive weeks (Table 1). All players were asked to keep consistent nutritional intakes and sleep schedules during the study period. A standardized 20-30 min warm-up was performed before each test-session including an exercises on the hamstring, gluteus, quadriceps, gastrocnemius muscles, different exercises of short sprints distance and/or directional changes, and different exercises with ball. Consistent verbal encouragement was provided by the coaches and sufficient ball availability was ensured in order to maintain a consistently high work-rate. All players performed about 5-7 training sessions weekly and one match a week. All training included recovery strategies sessions before, during and after training such as massages, bicycling, recovery-drinks consumption and diet supplementation, and alternating cold and hot water immersion of the legs. Recovery strategies were consistent during the study period. All players were fully familiarized with the experimental procedures and the requirements of the SSG and LSG prior to the present study, and were extremely familiar with the use of GPS units worn throughout the season.

Methodology

Small- and large-sided games (SSG and LSG): All players have participated in different SSG (i.e. 5 vs. 5, 6 vs. 6, 7 vs. 7) and LSG (i.e. 8 vs. 8, 9 vs. 9, and 10 vs. 10 with or without goalkeeper, GK) with specific pitch ratio, rules and formats (Table 1) [1], with a 5 vs. 5 means 5 players against 5 other players. A large number of soccer balls were placed around the perimeter of the playing area to aid in a rapid continuation of play whenever a ball is lost and goes off the playing area. The order of play in which the game formats were played was randomly varied across the investigation period and was dependent of the technical staff choices. Therefore, this investigation was not counterbalanced but only randomized.

Games	Format	Duration (recovery)	Pitch size (m)	Pitch ratio per player (m^2)	Rules
5 vs. 5+goalkeepers	Opposition	5×4' (2')	40×36	144	free/3 passes max
5 vs. 5	Opposition with small goals	2×5' (2')	40×30	120	2 touches obligatory/1 touch
	Conservation	3×4' (2')	30×40	120	3 touches/Stop-Ball
6 vs. 6+goalkeepers	Opposition	5×3' (2')	40×40	133	Free
		4×5' (2')	50×40	166	
7 vs. 7+goalkeepers	Opposition	3×5' (2')	50×40	142	Free
		2×5' (2')	40×50	143	Free/5 Passes maximum
8 vs. 8+goalkeepers	Opposition	2×8' (3')	60×40	150	Free/3 touches
8 vs. 8	Conservation	2×8' (3')	42×42	110	2 touches obligatory/1 touch/Gate game
9 vs. 9+goalkeepers	Opposition	2×8' (3')	70×55	212	Free
		2×8' (3')	50×60	166	Free
10 vs. 10+goalkeepers	Opposition	2×10' (3')	60×50	150	Free/3 touches

Table 1: Characteristics of large and small sided-games used in the present study.

The technical staff ensured team selections with the best possible balance of both teams with special attention of technical skills, positional roles, fitness quality and players relationship. All sided

games were used 2 times, separated by at least one week in order to compare the reproducibility of physical performance during the SSG and LSG at two different occasions.

Physical activity: The physical activities within each SSG and LSG were measured using a portable global positioned system (GPS) device operating at a sampling frequency of 15 Hz (GPS sports SPI Elite, Canberra, Australia) previously used in soccer training analysis [17]. The system uses signals from at least three earth-orbiting satellites to determine the position and calculate movement speeds and distances. Units were placed in a harness on the player's upper back. After recording, the data were downloaded to a PC and analyzed using the software package (GPS sports teams AMS, SPI IQ).

Heart rate responses: The data analyzed were the maximum speed reached (V_{max}), the total distance covered (TDC), and the distance covered in each one of the following speed categories: walking 0-6 km.h^{-1}, very light>6-10 km.h^{-1}, light>10-16 km.h^{-1}, moderate>16-23 km.h^{-1}, and high>23 km.h^{-1} intensities.

Heart rate responses (HR) were continuously recorded at 5-sec intervals throughout all SSG and LSG using heart rate monitors (Polar team Pro2, Polar-Electro OY, Kempele, Finland). Individual mean HR during different exercise periods (excluding inter-repetition recovery) within each SSG and LSG was determined to provide an indication of the overall intensity in using percentage of HR maximal zone find according to the Vameval field test (>90%, >85-90%, >80-85%, ≤80% HR_{max}) [18] and previous studies (e.g. [19]).

Statistical analysis: All values are expressed as means ± standard deviations (mean ± SD). The normality distribution of the data was first checked using the Kolmogorov-Smirnov test and the Mauchly test. Pearson's product-moment correlation coefficient was used to examine the test-retest relationship between inter-session physical parameters of the same subject. The magnitude of the correlations was determined using the modified scale by Hopkins WG [20]: trivial: r<0.1; low: 0.1-<0.3; moderate: 0.3-<0.5; high: 0.5-<0.7; very high: 0.7-<0.9; nearly perfect ≥ 0.9-<1; and perfect: 1.

Coefficient of variation (CV) of all physical performance during SSG and LSG were calculated in order to analyse the performances variation between the two sessions (Table 2). Aone-way analysis of variance (ANOVA) was used to test for differences in performance measures between the two weeks of soccer players (week 1 vs. week 2) in each SSG. All the statistical analyses were performed using SPSS16.0 for Windows, with statistical significance being set at p<0.05.

Results

Reproducibility of physical activities during SSG and LSG

The reproducibility of the physical activity of different type of SSG and LSG were analyzed (Tables 2-4). Overall, the correlation between inter-session physical parameters was not statistical significant and even if the rules and formats varied. Only the correlation in the distance covered in light-intensity running in two SSGs, 5 vs. 5+GK (r=0.64, P<0.01) and 7 vs. 7+GK (r=-0.57, P<0.05); and the distance covered in moderate-intensity running in other SSG and LSG: 7 vs. 7+GK (r=0.57, P<0.05) and 10 vs. 10+GK (r=0.76, P<0.01) were statistical significant. No statistical significant differences were observed for V_{max}, HR, TDC, and TDC at high and moderate intensities for all SSG and LSG played in 2 different sessions (Tables 3 and 4), whereas at low intensities differences existed.

The inter-individual CVs (coefficients of variation) of HR during all LSG and SSG were lower than 8.6% with no statistical significant differences of CV when SSGs were repeated at 2 different occasions.

	5 vs 5	5 vs 5+GK	6 vs 6+GK	7 vs 7+GK	8 vs 8+GK	9 vs 9+GK
CV (%)	5,5	2,6	4,2	3,9	4	3,1
CV = Coefficient of variation						

Table 2: Intraclasss correlation coefficient and coefficient of variation of physical performance during two different training sessions.

	0-6 km/h	>6-10 km/h	>10-16 km/h	>16-23 km/h	>23 km/h	Max speed (km/h)	Total distance covered (m)
5v5+GK	0.64**	0.39	-0.1	-0.26	-0.26	-0.35	0.08
5v5	0.09	-0.29	-0.03	-0.12	-0.03 0	-0.34	-0.32
5v5 Conservation	0.15	0.13	0.32	0.4	0.08	0.17	0.3
6v6+GK	-0.42	-0.08	0.24	0.24	0.46	0.37	-0.39
7v7+GK	-0.57*	0.03	0.57*	0.29	0.19	0.35	-0.16
8v8+GK	-0.09	-0.4	-0.43	-0.22	-0.12	-0.46	-0.41
8v8 Conservation	0.03	-0.2	-0.06	-0.07	0.05	0.33	-0.09
9v9+GK	0.16	-0.31	-0.12	0.19	0.27	0.34	-0.11
10v10+GK	0.42	-0.31	0.76**	0.46	0.51	0.04	0.54
**p<0.01, *p<0.05							

Table 3: Inter-session reliability.

Performance within SSG according to the rule and format modifications

Table 4 presents the physical activity (peak speed and total distance covered at different thresholds categories) during various SSG and LSG. The manipulation of rules and format dramatically influenced the physical activity. The greater the pitch-ratio-per-player (m^2), the higher the peak speed and the distance covered by players in all SSG and LSG.

Moreover, the presence of goalkeepers induced different activities. The total distance covered and the high intensity activities during LSG of 8 vs. 8 with goalkeepers were lower than 8 vs. 8 without goalkeeper, whereas it was the opposite concerning the 5 vs. 5 SSG.

		0-6 km/h	>6-10 km/h	>10-16 km/h	>16-23 km/h	>23 km/h	Max speed (km/h)	Total distance covered (m)
5v5+GK	1st session	669.0 (94)	510.1 (71)	503.4 (127)	142.2 (75)	4.0 (9)	21.7 (2.5)	1828.2 (164)
	2nd session	564.2 (102)	427.2 (96)	459.5 (143)	163.2 (83)	6.0 (10)	22.8 (2.3)	1620.4 (346)
5v5	1st session	378.4 (118)	212.0 (39)	149.6 (65)	33.4 (30)	0.0 (0)	18.9 (2.3)	772.5 (180)
	2nd session	572.5 (48)	355.0 (82)	315.2 (139)	84.8 (53)	3.0 (6)	22.0 (3.5)	1329.6 (233)
5v5 Conservation	1st session	430.6 (47)	299.4 (45)	358.2 (71)	78.2 (25)	3.0 (6)	21.0 (2.1)	1166.3 (131)
	2nd session	439.2 (162)	295.5 (96)	267.2 (83)	94.1 (44)	7.0 (14)	22.8 93.2)	1102.7 (360)
6v6+GK	1st session	1103.3 (205)	582.4 (131)	656.0 (181)	226.0 (81)	19.0 (16)	25.0 (2.4)	2568.6 (437)
	2nd session	813 .3(142)	547.7 (137)	580.9 (108)	175.4 (66)	7.0 (10)	23.2 (2.5)	2122.1 (270)
7v7+GK	1st session	948 .4(100)	582.2 (110)	558.1 (103)	156.1 (40)	8.0 (12)	22.8 (2.0)	2246.8 (203)
	2nd session	1120.4 (356)	666.1 (164)	673.7 (178)	226.3 (64)	14.0 (12)	24.1 (1.7)	2699.6 (587)
8v8+GK	1st session	753.1 (86)	545.8 (116)	532.6 (171)	177.2 (71)	27.0 (24)	24.8 (2.0)	2034.2 (403)
	2nd session	620.0 (188)	367.2 (220)	318.5 (206)	84.2 (83)	6.0 (15)	21.0 (2.6)	1395.0 (692)
8v8 Conservation	1st session	943.9 (413)	612.2 (246)	638.3 (231)	200.5 (86)	16.0 (39)	23.4 (2.6)	2404.2 (867)
	2nd session	909.6 (319)	584.1 (160)	632.3 (210)	241.7 (96)	32.0 (41)	24.7 (3.7)	2398.2 (652)
9v9+GK	1st session	794.5 (126)	486.0 (93)	499.0 (138)	155.4 (74)	15.0 (25)	23.9 (2.7)	1949.8 (233)
	2nd session	790.8 (108)	590.4 (115)	599.1 (138)	188.4 (72)	27.0 (24)	24.4 (3.4)	2193.2 (243)
10v10+GK	1st session	863.2 (54)	495.4 (44)	562.1 (147)	352.2 (262)	46.0 (25)	26.4 (2.2)	2271.1 (401)
	2nd session	689.3 (54)	579.8 (96)	674.4 (166)	241.7 (94)	28.0 (21)	25.0 (2.9)	2212.1 (212)

Table 4: Mean (SD) of the physical parameters during various sided-games.

The impact of the presence of goalkeepers increased the time-motion characteristics when the number of players was reduced (6 vs. 6>7 vs. 7>8 vs. 8), except no specific differences between LSG 8 vs. 8, 9 vs. 9 and 10 vs. 10+goalkeepers.

HR responses were lower during 8 vs. 8 and 5 vs. 5 when the goalkeepers were presence (Figure 1). When the HR responses observed during all the SSG and LSG were compared, it appeared that the absence of goalkeepers induced greater cardiovascular impact (8 vs. 8 conservation>5 vs. 5 conservation>from 5 vs. 5 to 10 vs. 10+goalkeepers).

Discussion

The present study was the first to examine the reproducibility of physical activity of different format of SSG and LSG in different successive training sessions in elite soccer players, which was not yet elucidated in the previous studies (only physiological and technical data have been investigated by other researchers but not in elite players). The main findings of the present study were that the reproducibility of physical demands, especially high intensity solicitation (V_{max} and TDC at high and moderate intensities) was good between SSG and LSG played in different training sessions within a

competitive season (successive weeks) and in elite soccer players, even if the rules and format have been manipulated.

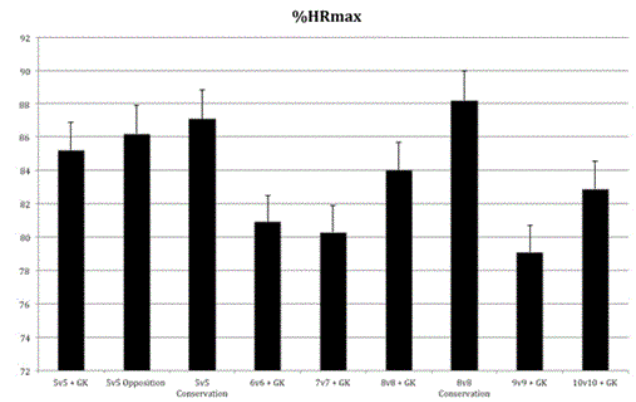

Figure 1: Percentage of maximal heart rate reached during each type of SSG.

To the best of our knowledge, all previous studies have analyzed the reproducibility of physiological impacts within SSG i.e. But no one has attempted to do it in a physical point of view and in elite soccer players. The present study clarify that the reproducibility of time-motion characteristic are good enough regardless the game rules and format in SSG and LSG. It contrasted with Hill-Haas et al. [21] who showed that smaller games format (2 vs. 2) presents better reproducibility than larger format (4 vs. 4) but with especially poor scores reproducibility concerning total distance covered >18 $km.h^{-1}$ and blood lactate concentration. Similarly, Rampinini et al. [11] have showed that the reproducibility appeared to be better when the intensity of SSG is higher (3 vs. 3>6 vs. 6). Rampinini et al. [11] added that the intra-participant variability for heart rate, RPE and blood concentration were considered as limits which are not supported by our results showing HR reproducibility. The present study showed no statistical significant difference of reproducibility of SSG and LSG, and differences between results from the present studies and [11,21] could be explained by the difference of population tested. It is essential to mention that the present study used elite soccer players whereas the other studies presented amateur or young soccer players. Amateur and young players presented lower technical skills and physical capacities and it appears that these could affect the performance during SSG and LSG, probably explicating the difference of results from the present study (top-level players) and other studies (amateur or young players).

Complementarily, literature presented only descriptive analysis of technical, physical and physiological solicitation with all type of SSG (in all game format and rules), without checking if these solicitations were stable through time and successive weeks. This information is essential for the reliability and thus the appropriate use of SSG in modern soccer. The use of SSG is traditionally used in training and that a lot of factors influencing the physical and technical solicitation had been elucidated by recent studies. Nevertheless, coaches need more information about the reproducibility of the physical activity/solicitations during SSG as there was a lack of such information in the literature. In elite soccer, the capacity to repeat high intensity actions is considered as essential e.g. and the present study shows that if coaches use the same SSG in different sessions, they will reproduce similar total distance covered at high intensity and V_{max} reached. This last information is fundamental because the modern soccer training seriously considers the ability to perform and to repeat high intensive actions as important determinants of soccer performance and an important part of training regimens.

In fitness training, the objective is to control all the fitness parameters and therefore, some coaches prefer using dissociated method of training (including intermittent exercise) than integrated methods (as SSG). Previous studies have showed that SSGs could induce similar cardiovascular responses as compared to intermittent exercises but also a high solicitation of physical capacities and technical abilities in line with those found during official games. However, the issue linked with the use of SSG lies in the high inter-players' involvement homogeneity. In this context, it has been shown that this latter involvement during SSG could be two-fold less homogeneous than during intermittent exercise (11.8% vs. 5.9%). This belief was contradicted by the present study, which shown that the reproducibility of the sided games in different sessions reproduced the same high intensity physical activity. Moreover, the authors could add that this finding could help coaches to better plan the physical training schedule, by selecting the appropriate SSG format and rules according to the fitness aims.

At the opposite, the total distance covered at low intensity was not consistent when SSG and LSG are repeated during different sessions in successive weeks. The ability to perform high intensities is essential in soccer but the time between each type of these actions is also crucial. In this context, the literatures on repeated-sprint ability were in this direction, and it was reported that the repeated-sprint performance depends on the recovery between sprints and duration of sprints. In the same context, it should be hypothesized that although high intensities actions are similar in SSG and LSG played in different sessions, the workload of the sessions are not identical. Some players could present different durations of recovery period within the same sided-games played in different sessions and therefore induce not homogeneous workload. Therefore, it seems that the quantity of high intensity actions within SSGs stays consistent throughout the same type of sided-games even when these are repeated in different training sessions. Nevertheless, the low intensity actions, which have less importance with regard to the training solicitation, are less homogenous.

In line with the previous researches, the present study confirmed that the manipulation of the presence of goalkeepers, the number of players affected the physical demands and heart responses, but with similar reproducibility whatever the SSGs. The time-motion analysis of the present study SSGs show that the different formats used are in-line with most of the already published studies on SSGs. This allows deducing that the present study of SSGs are representative of what is usually observed with the soccer players that participated to the above mentioned studies. It could therefore be argued that the present study findings could be representative of soccer at a wider range of soccer levels. But this has to be further examined. Indeed, although the present study elucidated the problematic of the reproducibility of physical activity and confirmed HR responses reproducibility in SSG played in different sessions in elite seniors players, there is still a lack of knowledge in this area. For example, whether the physical activity during SSG is dependent of playing position as reported in official matches.

Practical applications

SSG is commonly used in soccer training to solicit the tactical, physical and technical components similar to match-play condition. Although a lot of studies have analyzed the influence of rules and format manipulation on players activities, no study have attempted to investigate if the SSG reproduce exactly the same physical activities when it is repeated in different sessions in consecutive weeks. The present study demonstrated that SSG induce reproducible high-intensity activities whatever the rules, the format and the playing positions. According to the training objectives, coaches and sport scientists could use SSG in being sure that the repetition of this training method in different sessions within the same period induced similar cardiovascular pattern and physical demands, especially high intensity solicitation (V_{max} and TDC at high and moderate intensities) in competitive period in elite soccer players, both for SSG and LSG. This study is the first showing clearly the practical interests of SSG concerning the reproducibility of physical performance allowing a better training design and workload control week after week.

Limitations of the study

The first limitation of this study is that coaches know that the physical activity within SSG is controlled whereas the workload is less controlled. The present study use the GPS technology which has been previously determined as reliable and validated for monitoring the players´ high-intensity activities in soccer. However, Buchheit et al. [22] have shown that GPS units could provide greater differences with the decceleration/acceleration measures (9-30%). In this context, the analyzed of SSG needs complementary investigation using for example semi-automatic video tracking, which are considered as better reliable for the high-intensity running. Perhaps, the use of metabolic power, the body load impact and accelerations as [23,24] suggested are an interesting alternative to appropriately analyze the high intensities actions and external workload during SSGs in elite soccer [25-30]. The main findings of the present study were that the repetition of traditional SSGs in different sessions induced similar cardiovascular incidence and physical demands, especially high intensity solicitation (V_{max} and TDC at high and moderate intensities) in the same period in elite soccer players setting.

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