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The Effects of Fatigue in Small-Sided Games Workouts

KEYWORDS: Small-sided games, soccer, fatigue, technical skills, anaerobic threshold.

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ABSTRACT *Soccer is a demanding physical game which requires resistance on fatigue so as to improve the performance. The mechanisms which relate the fatigue and the performance (i.e. cognitive, physiological, physical, and technical factors) are described to the current study. Although, nowadays the small-sided games (SSG) are considered as the main method of increasing the physical condition there is a literature gap on the mechanisms that contribute to this relationship. Consequently, the aim of the current study was to examine how the 3Vs3 SSG affect the fatigue and how training either above or under the anaerobic threshold (AT) influence it differently. Six semi-professional male soccer players (age 17.4±0.5 years, height 1.70±0.14 m, body mass 65.0±4.8 kg), participated in the study. It was measured the anaerobic threshold, the maximal oxygen uptake (VO2max), and the maximal heart rate (HRmax) of each player on the treadmill. The researchers also examined the heart rate, the blood lactic acid, the visual reaction, the juggling and the maximal ball speed during shooting of each player. The statistical analysis that was used was descriptive statistics and pairwise comparisons. The results revealed the relationships between fatigue and technical skills (i.e. anaerobic threshold and maximal ball speed during shooting). Specifically, it was found that players who practiced above AT presented a stronger reduction of the maximal ball speed during shooting.*

INTRODUCTION

The main target in soccer is the continuous improvement of the player's and team's performance, which is a consequence of the psychological, social, tactical, technical and physiological interactions (Bangsbo, 1994; Little & Williams, 2006). Soccer is mainly a physical game which requires techniques with (controls, passes, dribbles, shoots) and without the ball (jogging, sprints, tackles, jumps, challenges) and characterized as both an aerobic and anaerobic sport (Açıkada, Hazır, Aşçı, Turnagöl, & Özkara, 1998; Stølen, Chamari, Castagna, & Wisløff, 2005). The significance of endurance in soccer is supported from literature which concludes that players cover around 10 to 12 kilometers during a match (Dellal, Chamari, Wong, Ahmaidi, Keller, Barros, Bisciotti, & Carling, 2010; Di Salvo, Baron, Tschan, Calderon Montero, Bachl, & Pigozzi, 2007). Three decades ago, Edwards (1983) defined fatigue as the failure to maintain the required or expected power output. Specifically, the fatigue is described as a decrease of maximal force and power which is connected to a sustained exercise and is reflected in a lower performance (Rahnama, Reilly, Lees, Graham- Smith, 2003). Many findings demonstrated a reduction in physical performance during the match as the players perform less sprints and running of high intensity on the second half of the match (Krustrup, Mohr, Steensberg, Bencke, Kjaer, & Bangsbo, 2006; Mohr, Krustrup, Bangsbo, 2003; Rampinini, Impellizzeri, Castagna, Abt, Chamari, Sassi, & Marcora, 2007). Specifically, soccer is a demanding sport in which more than 90% of the energy that a match requires is produced through the aerobic metabolism in means values close to the anaerobic (Bangsbo 1994; Helgerud, Engen, Wisløff, & Hoff, 2001; Stolen et al., 2005). The fatigue that the players present is also associated to the reduction of cognitive factors such as decision making, game intelligence and the team tactics which probably influence the technical characteristics (Bangsbo, 1994; Cian, Koulmann, Barraud, Raphael, Jimenez, & Melin, 2000; Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002; Ostojic & Mazic, 2002; Williams & Reilly, 2000). The fatigue in high intensity intermittent exercise (i.e. soccer), is a consequence of the progressive loss of muscle glycogen, blood glucose, body fluids, disturbed muscle ion homeostasis and an increase of hyperthermia (Mohr, Krustrup, & Bangsbo, 2005). Factors such as the maximal oxygen uptake (VO2max) and anaerobic threshold (the exercise intensity at which blood lactic starts to accumulate in the blood stream), are also associated to the reduction of physical performance (Helgerud et al., 2001). It is obvious that performance is affected directly and indirectly by many factors. One factor that is connected to higher performance is reaction time to visual stimulus. Specifically, soccer players are required to analyze the information of the environment (ball movement, players' pitch position) and take quick decisions on a basis of visual reaction ability (Ado, Kida, & Oda, 2001; Williams, Davids, Burwitz, & Williams, 1994). This ability is probably affected by the fatigue. There are also findings which support the relationship between fatigue and technical skills. Specifically, the researchers concluded that the speed and velocity of passing and shooting were decreased because of fatigue (Helgerud et al., 2001; Lyons, Al-Nakeeb, & Nevill, 2006; Russell et al., 2011; Stone & Oliver, 2009). However the findings about the influence of fatigue on dribbling are conflicted (Russell, Benton, & Kingsley, 2011; Stone & Oliver, 2009). Passing and shooting are very important factors which are associated to the score of a game and differentiate the high and low performance teams (Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009; Sajadi & Rahnama, 2007). Fatigue also affects the technical abilities through changes on biomechanical characteristics of the skill (Kellis, Katis, & Vrabas, 2006). Although the obvious relationship between fatigue and technical skills, there is a lack of literature about the physiological factors which influence each technical skill. Nowadays, trainers use mainly small-sided games (SSG) so as to achieve an improvement by

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combining training of physical, technical, tactical and physiological factors (Allison & Thorpe, 1997; Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011; Little, 2009; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). For example, many top world players introduced to soccer through informal SSG such as beach, park and street soccer (Football Federation Australia, 2010). SSG include high intensity actions similar to soccer matches such as sprints, directional changes, tackles, passes, and shoots (Hill-Haas, Dawson, Coutts, & Rowsell, 2009; Kelly & Drust 2009; Sassi, Reilly, & Impellizzeri, 2003). Research findings conclude that SSG can elicit responses of HRmax around 90 to 95% and improve the aerobic and anaerobic condition (Helgerud et al., 2001; Hoff et al., 2002). According to the targets of the training the psychological, physiological, physical, tactical and technical demands are adjusted through changes on the rules, the ball size, the number of players and the size of the pitch (Bekris et al., 2012a; Bekris et al., 2012b; Kelly & Drust 2009; Owen, Twist, & Ford, 2004; Owen, Wong, McKenna, & Dellal, 2011; Platt, Maxwell, Horn, Williams, & Reilly, 2001; Reilly & White, 2003). Concerning the relationship between fatigue and technical skills in SSG, Kelly and Drust (2009) found a significant reduction of the technical skills (passing, shooting, dribbling etc). Other researchers concluded a decrease in passes, successful passes, and in technical proficiency (Fanchini, Azzalin, Castagna, Schena, McCall, & Impellizzeri, 2011). The literature review showed the existence of a relationship between technical skills and fatigue after competitive soccer matches. However, there is a lack in literature about how the fatigue during training sessions which include SSG affect the technical skills and which mechanisms contribute to this relationship (Owen et al., 2011; Rampinini, Impellizzeri, Castagna, Abt, Chamari, Sassi, & Marcora, 2007). The aim of the current research was to examine how the 3Vs3 small-sided games affect the fatigue and how training either above or under the anaerobic threshold influence it differently.

MATERIAL AND METHODS

Participants

Six semi-professional male soccer players (age 17.4±0.5 years, height 1.70±0.14 m, body mass 65.0±4.8 kg), participated in the study. All the players were members of the same team, and practiced 4 times per week. Both the players and the parents were informed about the research procedures, the benefits, the requirements, and the risks before giving informed consent. The University Research Ethics Committee granted approval for the current study.

Design

The researchers measured the anaerobic threshold (AT), the maximal oxygen uptake (VO2max), and the maximal heart rate (HRmax) of each player on the treadmill one week before the research. Then the players participated in a program of eight bouts of games 3Vs3 duration's 3 minutes and passive recovery of 4 minutes between the bouts. The pitch size was 20 x 25 m. There was not any limitation about the touches of the ball during the match. The researchers chose this test as three-a-side games were superior to other SSG because of higher exercise intensity and more opportunities for technical performance (Fanchini et al., 2011; Mallo & Navarro, 2008; Owen et al., 2011; Platt et al., 2001; Rampinini et al., 2007). The researchers also motivated the players during the bouts. Before the program and during the passive recovery the researchers examined for each player: the heart rate, the reaction time to visual stimulus, the juggling ability and maximal ball speed during shooting. Furthermore, it the blood lactate was examined during the passive recovery. The measurements performed with different order after each bout.

Measurements/Questionnaires

One week before the research

The researchers measured the anaerobic threshold (AT), the maximal oxygen uptake (VO2max), the maximal heart rate (HRmax), and the heart rate (HR) of each player on the treadmill. The participants performed an incremental test until volitional exhaustion on a treadmill (Runrace1200, Technogym, Italy). The initial speed was set at 8 km/h with increments of 0.5 km/h per minute. Respiratory gas exchange was analyzed breath-by-breath using a computerized system (Quark b2, Cosmed, Italy), with the subjects breathing through a mask.

During the research

Before the experiment and between the eight repeats the researchers examined the following characteristics for each player. The heart rate was recorded at 4-s intervals via short-range radio telemetry (Hosand TM Group System). Blood lactate level measurement was performed after each game ended by means of a portable blood analyzer (Lactate Plus-Nova Biomedica). Juggling is the ability to play the ball in a row with the hock, the head and the chest without hitting the ground. The players with two efforts earned one point for each time they played the ball with the described order. The researchers recorded the points of the best effort (Rosch et al., 2000). The maximal ball speed during shooting was measured with radar (Sports Radar 3300, Sports Electronics Inc., USA). The measurement accuracy is around ± 0,0278 m/s, providing that the ball is moving through an area of 10° of the radar level. The participants shoot two times a non-moving ball on the line of the penalty area with the maximum speed. A standard ball of 450 grams, inflated to a pressure of 0.9 atmospheres was used. The researchers recorded the speed (km/h) of the best repeat. The reaction time was assessed using portable device called the OptoJump System (Microgate, Bolzano, Itali) which is an optical measurement system consisting of a transmitting and a receiving bar (one meter long each bar). Each of these bars contains photocells, which are positioned 2mm from the ground. The photocells from the transmitting and the receiving bar communicate continuously. The system detects any interruptions in communication between the bars and calculates their duration. Consequently it is possible to measure the flight time when the player raises his foot as a reaction to the optical stimulus. The players had three efforts for each foot and the researchers recorded the mean rates. The reliability of this system was recently supported for abilities measurements (Glatthorn, Gouge, Nussbaumer, Stauffacher, Impellizzeri, & Maffiuletti, 2011).

Statistical analysis

All statistical analyses were performed using the SPSS package (v. 17). Descriptive statistics for the variables were computed using the SPSS descriptive procedures. The researchers performed ANOVA analyses for repeated measures to examine the different bouts and pairwise comparisons for the differences among the groups.

RESULTS

The following table (table 1) conclude the descriptive statistics of the variables for the total sample (N= 6). There were some trends for blood lactate, juggling, and the maximal ball speed during shooting but not for the reaction time to visual stimulus. The descriptive statistics revealed an increasing trend of blood lactate and juggling ability during the small-sided games' bouts (1st - 4th columns). On the other hand, the results showed a reduction trend of the maximal ball speed during shooting through the bouts (5th - 6th columns).

Descriptive Statistics

	Blood Lactate (mmol/l)		Juggling (number)		Max. ball speed (km/h)		
Bouts	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
Before SSG	,000	,000	6,667	2,338	111,833	5,741	6
1st SSG	4,000	3,605	8,500	8,939	107,533	7,465	6
2nd SSG	5,533	5,096	9,167	5,707	110,217	5,151	6
3rd SSG	6,950	5,504	10,833	8,931	110,200	6,299	6
4th SSG	6,833	2,372	9,667	4,082	108,617	5,984	6
5th SSG	7,300	5,805	11,000	9,466	108,617	6,935	6
6th SSG	5,167	2,054	8,500	6,804	106,733	3,875	6
7th SSG	7,050	3,573	8,333	5,241	107,550	6,039	6
8th SSG	6,650	4,282	15,000	14,805	105,167	6,092	6

Table 1: Descriptive statistics of blood lactate, juggling and maximal ball speed during shooting.

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The following table (table 2) presents the descriptive statistics of blood lactate for the groups that practiced above and under the anaerobic threshold (AT). It is obvious that the group which practiced above the anaerobic threshold revealed higher levels of blood lactate (1st and 2nd columns) than the group that practiced under the anaerobic threshold (3rd and 4th columns).

Descriptive Statistics (blood lactate)					
	Above AT		Under AT		
Bouts	*Mean*	*Std. Deviation*	*Mean*	*Std. Deviation*	*N*
Before SSG	,000	,000	,000	,000	3
1st SSG	2,900	5,023	5,100	1,908	3
2nd SSG	9,900	1,908	1,167	2,021	3
3rd SSG	7,767	7,956	6,133	3,232	3
4th SSG	6,533	2,485	7,133	2,761	3
5th SSG	9,800	7,712	4,800	2,456	3
6th SSG	6,600	1,386	3,733	1,569	3
7th SSG	9,600	2,778	4,500	2,166	3
8th SSG	9,633	4,188	3,667	1,266	3

Table 2: Descriptive statistics of blood lactate according to anaerobic threshold.

The researchers examined the significance of the differences between the practice groups through ANOVA analyses for repeated measures. The result showed that when using an ANOVA with repeated measures the differences were statistically significant ($F(1, 4) = 20.827$, $p < 0.01$). As the ANOVA analyses were significant the researchers examined between which bouts the differences were occurred. However, the differences among most of the bouts were not significant. According to the differences of the maximal ball speed during shooting it was found a significant reduction ($p < 0.1$) when comparing all the SSG bouts with the initial maximal ball speed (table 3).

Pairwise Comparisons (all the players)				
(I) Games	(J) Games	Mean Difference (I-J)	Std. Error	Sig.[a]
Before SSG	1st SSG	4,300	1,143	,013
	2nd SSG	1,617	1,865	,426
	3rd SSG	1,633	1,765	,397
	4th SSG	3,217	1,226	,047
	5th SSG	3,217	1,359	,064
	6th SSG	5,100	1,585	,024
	7th SSG	4,283	1,774	,061
	8th SSG	6,667	1,999	,021

Table 3: Pairwise comparisons of the maximal ball speed during shooting.

Then the researchers divided the players in two groups according to their levels of anaerobic threshold (above and under anaerobic threshold). The pairwise comparisons through these two different categories showed that only for the players that exercised above the anaerobic threshold the differences on the maximal ball speed during shooting were significant (table 4).

Pairwise Comparisons (group above the anaerobic threshold)				
(I) Games	(J) Games	Mean Difference (I-J)	Std. Error	Sig.[a]
Before SSG	1st SSG	3,233	1,848	,222
	2nd SSG	2,133	3,901	,639
	3rd SSG	,567	3,518	,887
	4th SSG	5,333	1,067	,038
	5th SSG	4,800	,924	,035
	6th SSG	6,433	2,466	,121
	7th SSG	5,333	1,923	,109
	8th SSG	8,533	,533	,004

Table 4: Pairwise comparisons of the maximal ball speed during shooting (group above the anaerobic threshold).

As far as the rest of the variables the pairwise comparisons indicated that there were not significant differences among the groups. Specifically, although some trends the juggling ability and the reaction time did not change significantly through the SSG bouts.

DISCUSSION

The current study examined how small-sided games' exercising affects the physiological and technical abilities of soccer players. The literature review identified the fatigue as the chief cause of performance decrease on soccer. However, it is hard to explain either the direct or the indirect mechanisms through which the fatigue influences the performance. The researchers examined the influences on factors such as the blood lactate, the juggling ability, the reaction time, and the maximal ball speed during shooting of the players.

Blood lactate

The results indicated a gradual increase of the blood lactate levels, finding that is supported from the literature review (Davis, 1985; Hoff & Helgerud, 2004). Although, the increasing trend of the blood lactate levels, these changes were not statistically significant for all the comparisons between the bouts. The rates of blood lactate appear to be higher for the group that practiced mostly above the anaerobic threshold than the group that practiced more under the anaerobic threshold. However the differences were not statistically significant for all the comparisons between the bouts. This difference highlights the role of the coach to intervene and individualize the session as the intensity is differentiated among the players.

Maximal ball speed during shooting

Concerning the technical ability of the maximal ball speed during shooting it was found a significant reduction of this skill after practicing on SSG. Specifically, the players that practiced above the anaerobic threshold presented the lowest levels of maximal ball speed. Although the previews findings did not focus on the maximal ball speed the literature review showed a decrease on the ability of shooting (Fanchini et al., 2011; Kelly & Drust, 2009). This finding is extremely significant as shooting is connected to goal scoring. Neuromuscular and muscle impairments because of fatigue also alter the mechanics of kicking performance (Kellis et al., 2006). In conclusion one suggestion for the findings is the influence of blood lactate production and elimination mechanism (Beneke & Von Duvillard, 1996; Helgerud, Ingjer, &Strømme, 1990; Jones & Doust, 1998; Reilly, 1997). This mechanism influences the physiological and technical responses of fatigue. It is extremely important for the trainers to develop individualized training sessions according to the exercise targets.

Juggling ability

The juggling ability of the players was not changed statistically significant. However, there was a gap on literature review about juggling changes through SSG bouts so we could not support this finding. It appears that the neuromuscular coordination in performing technical skills (without competitive conditions) is not affected by practicing on 3Vs3 SSG bouts, regardless of working time over the anaerobic threshold.

Reaction time

The reaction time to visual stimulus was not changed as a consequence of fatigue through SSG bouts. A study limitation that probably affected this finding was that the researchers examined a simple visual reaction and not a complex realistic reaction which probably would be influenced by the reactions and movements of the other players. Other studies that concluded reductions on passing accuracy probably would have been violated by game conditions (i.e. teammates, opponents). It seems that while the fatigue could affect the cognitive factors in complex reactions (decision time, forecasting, and action time), it does not affect simple reactions even if the intensity exceeds the anaerobic threshold for quite some time (group above the anaerobic threshold).

CONCLUSION

The findings show that when the players practice on 3Vs3 small sided games above the anaerobic threshold (M= 126.3 sec), the fatigue appears sooner and the reduction of the maximal ball speed during shooting is higher. The gradual increases of blood lactate through the bouts and the cu-

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mulative influence in the end of the SSG (8th bout) probably explain the reduction of the maximal ball speed during shooting. It is obvious that the gradual movement of the anaerobic threshold upwardly (higher heart rate) through the proper training will delay the fatigue and its consequences (i.e. reduction of the maximal ball speed during shooting). The trainers have to develop the practice sessions with workout intensities similar to the competitive. Specifically, the average workout intensity of a match is around the anaerobic threshold (80-90% of the HRmax), and 20 minutes on the limit of the anaerobic threshold (Bansgo, 1994; Helgerud et al., 2001). It seems that the workout intensity that was applied in the current study was close to the requirements of a competitive match. Although most of the studies focus on the average intensities of the SSG, the current study reveals the individualized influences on each player that probably affect the training process and the players' fatigue. Soccer coaches must take into consideration these findings so as to better manage the training process and the adjustment of the arising targets. Moreover, in order to a high level of performance, it is important for the player to maintain the quality of all skills at the highest level in fatigue conditions during the training sessions (i.e. 3Vs3 SSGs) and the official games.

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