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Research article

THE IMPACT OF SMALL-SIDED GAMES ON COGNITIVE FATIGUE AND DECISION-MAKING ABILITY OF ELITE YOUTH SOCCER PLAYERS

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Abstract. *Fatigue is highly correlated to performance decline. Extensive periods of cognitive and physical demands induce cognitive and physiological fatigue respectively. The purpose of the present study was to investigate the impact of the number of small-sided games (SSG) on physical loading, cognitive fatigue, and decision-making ability on the ball action of youth elite soccer players. Ten U20 players were enrolled in the study and performed six 4vs4 plus 2 GK SSGs. Physiological loading was measured from blood lactate and heart rate, for cognitive fatigue players provided subjective ratings (VAS), while the decision-making ability was evaluated through video recordings in 3 phases. The results showed that the SSGs induced high mean values for physiological loadings, and reported statistically significant fatigue after the 3rd game, based on the questions "Cognitive Fatigue" and "Cognitive Effort". Regarding the decision-making ability, players demonstrated 59.8% positive decisions in Phase A of the actions, 86.5% in Phase B, and 55.1% in Phase C with no statistical significance between games. The comparison between games 1-3 and 4-6 indicated significantly greater motor outcome effectiveness for the first group of games (63.5%). The results indicated that the number of intense SSGs in training should be selected wisely, in order to contribute to improving the quality and the effectiveness of the decision-making ability of the soccer players under the pressure of time, space, and opponents in the match.*

Key words: *Football, Fatigue, Information-processing, Decision-making*

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INTRODUCTION

Fatigue constitutes a major detriment for sports performance. It can be expressed as physical, cognitive, emotional, and behavioral (Boksem et al., 2008). Extensive periods of cognitive demands induce cognitive fatigue, which is accompanied by a subjective feeling of exhaustion, a sense of worsened ability, and a decreased willingness to engage in activities with demanding cognitive load (Zenon et al., 2019). Such higher-order cognitive demands, which are engaged in decision – making, should be considered the recognition of the relevant stimuli during visual discrimination search (Boksem et al, 2006), sustained attention to these cues (Boksem et al., 2005), performance adjustment (Kato et al., 2009; Lorist et al., 2005), and rapid and accurate response (Boksem et al., 2006). As a consequence, literature has investigated the neural signature of cognitive fatigue in modifications in the function of brain areas which mediate these cognitive demands (Ridderinkhof et al., 2004). Specifically, the alterations on the anterior cingulate cortex (ACC) function, which is responsible for performance monitoring, detecting erroneous responses and initiating compensating procedures (Botvinick et al., 2001), seem to be the underlying mechanism of cognitive fatigue. Nevertheless, neural function of the ACC time-on-task, so the reinstatement of its functioning is compromised after 60 minutes of a continued task. On the contrary, brain structures which are engaged in response preparation and control implementation as the primary motor cortex are more and immediately susceptible to cognitive fatigue (Lorist et al., 2005).

Specifically, soccer is comprised of significant cognitive requirements as sustained attention for the soccer-specific decision-making ability, which relies on the extended visual search behavior from a constantly dynamic environment and the information processing system of the brain (Vaeyens et al., 2007, Walsh, 2014). Consequently, the accumulation of cognitive fatigue is responsible for the deterioration of the decision-making ability of soccer players (Afonso et al., 2012).

Apart from cognitive functioning, cognitive fatigue depletes several physical and technical soccer-specific activities. Several researchers attempted to approach this issue, although with some important drawbacks; either implementing assessing protocols with no soccer-specific character (e.g., heart rate measurements during the Yo-Yo IR1 test or LSST, LSPT, Slalom Dribble Test measuring technical performance) (Smith et al., 2016a), or inducing cognitive fatigue in laboratory conditions (e.g., with Stroop task) before performing the major physical or technical task (Badin et al., 2015; Coutinho et al., 2018; Smith et al., 2016a; Smith et al., 2016b; Smith et al., 2018). This was at expense of ecological validity, as these researchers did not reproduce the soccer match conditions and the respective cognitive demands as the alterations in attention allocation, the tactical decision-making requirements, and the match dynamics. On the contrary, a common training method which attenuates these limitations are small sided games, as they instigate various physical, technical (Hill-Haas et al., 2011; Kelly & Drust, 2009), perceptual (Casamichana & Castellano al., 2010), and tactical conditions (Dellal et al., 2011a).

There are many forms of small sided games depending on the intensity and the tactical training purpose. Scrutinizing the most intensive of them, 4v4 SSGs induce a HR_{max} range between 85 – 90 % and the shortest possible decrease in lower limb power (Dellal et al, 2011a) in comparison with other highly intensive SSG types (2v2: 88 - 91% HR_{max}, 3v3: 87 - 90%HR_{max}) (Hill-Haas et al., 2010). In addition, 4v4 SSGs constitute a common conditioning training method during the peak of the microcycle (Köklü et al., 2013).

Regarding the restrictions of the SSGs, as the number of ball contacts, free play maintains the high intensity of the games and contributes to fewer technical and tactical mistakes (Dellal et al., 2011b). Regarding the duration of the bouts, 4 minutes seem to be a considerable time for the appearance of physiological adaptations, based on %HR (∽89.5%) and high intensity activities of the players (Fanchini et al., 2011). Moreover, literature reports that a larger number of bouts is connected to higher physical load. Specifically, comparing 4-a-side and 6-a-side SSGs, there is no significant difference in matters of %HR values as they range between 85 and 92% in each case (Dellal et al., 2011a; Köklü et al., 2011).

The purpose of this study was to examine the effect of 4-a-side SSGs (plus two GKs) on player's cognitive fatigue and decision-making ability. In accordance with the literature, our research hypothesis was that, progressing above the four SSGs, physical load and cognitive fatigue will increase, which will lead to extensive impairment of the players' decision-making ability.

METHODS

Participants

Ten male professional soccer players participated in this study (Table 1). All players were part of the same U20 Greek Super League team, performed 5 training sessions (90 to 120 minutes) per week with an official eleven-a-side match played during the weekend on a regular soccer field (105 x 65 m). Two goalkeepers were part of the study but were excluded from the analysis, given their specific positioning. The study was conducted during the November of 2018-19 season, during the peak training session of the microcycle. All players were informed about the research procedures, requirements, benefits, and risks, and their written consent, as well as that of their coaches, was obtained before the study began. The investigation was approved by the Ethics Committee of the National and Kapodistrian University of Athens and it conformed to the recommendations of the Declaration of Helsinki.

Design

A field study was used to identify the effect of a number of 4-a-side SSGs (plus two GKs) on the players' physiological loading, cognitive fatigue, and decision-making ability. During the experimental session, the players performed the main protocol of six SSGs 4vs4 plus 2 GK of 4-min match play and with 3-min of passive recovery period between games, as presented in Figure 1. Physiological intensity measurements included heart rate and blood lactate measurement, Visual Analogue Scales (VAS) was used to evaluate cognitive fatigue, and a video-analysis observational instrument was used to evaluate the decision-making ability.

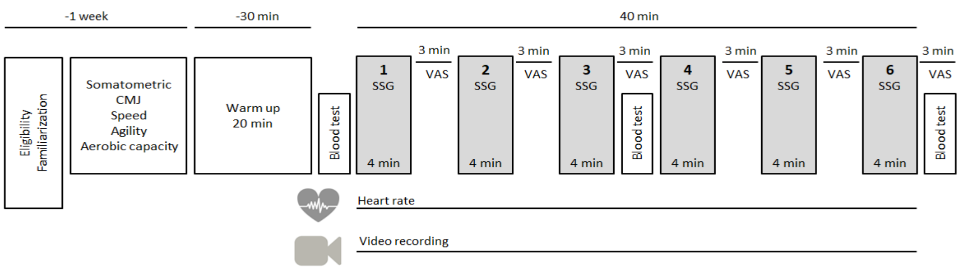

Fig. 1 A schematic layout of the experimental design.

Procedure

Preliminary measurements

One week before the experimental measurements, the players became familiar with the procedure and the instruments and were assessed for their physiological condition (Table 1). Specifically, players passed through the following tests: a somatometric examination (body height, weight, body fat %), lower limb explosiveness test with CMJ measurement (Bosco Jump Test) (Alves et al., 2010), 10m and 30m speed test (Photocells, Microgate, Italy) (Bastida Castillo et al., 2017), Little's agility (Little & Williams, 2005) test with (LTb) and without a ball (LTnb), and an aerobic capacity field test with Yo–Yo IR1 Test Performance (Bangsbo, 2016). These measurements conducted on one hand to exclude the possibility of a major involvement of any muscular or physiological fatigue on the reported cognitive fatigue, and on the other hand to confirm the participants' elite level. It is necessary to comment on the aerobic capacity indices [MPred.VO2max = 59.3±2.71 ml/kg/min, which contributed to the player's recovery from the long series of intensive SSGs performed at the 2nd phase of the treatment. Preliminary tests did not reveal any statistical differences between players, confirming a homogeneous participant status (CV<10%).

Table 1 Descriptive statistics of the preliminary measurements.

	Age (*Year*)	Height (*cm*)	Weight (*kg*)	Fat (*%*)	CMJ (*cm*)	10 m (*sec*)	30 m (*sec*)	LTb (*sec*)	LTnb (*sec*)	VO_2 max (*ml/kg/min*)
Mean	18.4	174	174	8.59	38.89	174	4.10	7.06	6.14	59.3
SD (±)	0.57	7.47	5.93	0.74	2.56	0.07	0.15	0.22	0.32	2.71
CV (%)	3.1	4.0	8.6	8.4	6.6	4.1	3.6	3.1	5.2	4.6

Experimental session

Before the experimental session, a 20-min warm-up was carried out with and without ball use (Smith et al., 2018). The ten best players were selected by the head coach according to his perception of their physical, technical and tactical skills (Sampaio et al., 2014), and then divided into two balanced teams. The 4-a-side SSG (plus goalkeepers) was performed on artificial grass as its surface 30 × 20 m (length × width) pitch using formal 11-a-side goals (Dellal et. al., 2011b). Several balls were placed around the field to allow replacement as fast as possible, while players were prohibited only from passing the ball to the goalkeeper in order to avoid game delay and intensity decline. To encourage high work-rate maintenance, coaches or other players were allowed to give verbal encouragement to all the players, but not specific feedback related to the players' performance or their technical/tactical behavior (Torrents et al., 2016). The experimental session was performed in the morning and was preceded by a day of rest. The players were asked to consume their usual meal at least 3 hours before the scheduled testing time and instructed to maintain regular sleeping patterns (at least 8 h), as well as to avoid caffeine, nicotine, alcohol, and cognitively demanding tasks before the experimental session (Badin et al., 2016).

Table 2 Decision-making observational instrument.

Phase	Category	Level	Definition
A	Starting position & ball receiving	Positive	Player receives the ball and is ready to take the next action
		Negative	Player couldn't receive ball and possession was lost
B	Decision making on ball action: Driving, Passing, Dribbling, Shooting	Positive	Decision to drive - Positive
		Negative	Decision to drive - Negative
		Positive	Decision to pass - Positive
		Negative	Decision to pass - Negative
		Positive	Decision to dribble - Positive
		Negative	Decision to dribble - Negative
		Positive	Decision to shoot - Positive
		Negative	Decision to shoot - Negative
C	Ball action execution	Positive	The execution of the ball action was positive
		Negative	The execution of the ball action was negative

Experimental measurements

Physiological loading

The measurement of blood lactate was conducted before the protocol initiation, during the 1st minute of the rest period between the 3rd and the 4th game and after the 6th game, from the pointer of the players with the Lactate Plus device (Nova Biomedica, USA). Moreover, heart rate measurement was conducted with Polar T31 cardiac tracers (Polar Electro, Finland), including a tracer zone and an electric hand watch. The tracer zone was wrapped around the thorax of the participants integrating electrodes that monitored electric load during each heart contraction, and an emitter which sent electric signal to the respective receiver (hand watch) connected with the software of the appliance. Thus, each heart rate was saved for subsequent analysis.

Cognitive fatigue

At the preliminary measurements, players had the opportunity to familiarize themselves with the questions and the marking upon the scales. In addition, researchers pinpointed the potential invalid marking in order to be avoided by the players. During the experimental session, during the 2nd and the 3rd minute of the rest period after each game, VAS were compiled from the players to evaluate cognitive fatigue, cognitive effort and motivation (Badin et al., 2016). The validity of this instrument was contrasted with EEG measurements for rating cognitive fatigue, sustaining its high practicality (Smith et al., 2019). Precisely, players responded to the following questions translated into Greek : 1) "How cognitively fatigued are you feeling right now?" 2) "How are you rating the cognitive effort you made in this SSG?", 3) "How do you classify your motivation for the next SSG?". Under each question was a 1 to 10 graded scale represented by a straight horizontal line of 100 cm, which was also indicated at the left edge as "None at all" and at the right edge as "Maximum". The players conveyed the extent of their fatigue, effort and motivation, marking a straight vertical line upon the scale between "None at all" and "Maximum". For the analysis of the questionnaire, researchers converted cm into arbitrary units (AU) and measured the distance of the player's mark from the left side of the scale.

Decision-making ability

All SSGs were recorded using a video camera (Sony UHD Video Recording FDR-AX53, Tokyo, Japan) placed on stands approximately 10 meters from the sideline and at a height of 8 meters, which allowed a view of the whole pitch without changing its position. The assessment of the decision-making ability of the players was fulfilled with the application of a video-analysis observational instrument (Table 2), considering only the player's action with the ball. Each action was divided into three phases matching the stages of the information processing model (perception, information processing, and execution of the decision) (Smith et al., 2018). In order to evaluate the stimuli perception, during the first phase (A), the starting position and ball receiving was recorded. During the second phase (B), both the selection of action (driving, passing, dribbling, shooting) and the evaluation of the decision were assessed based on the criteria provided by Gabbett et al. (2008). The final phase (C) evaluated the outcome of the execution. Two independent experienced soccer coaches (with degrees in Sports Sciences, certified with UEFA Pro license) analyzed the video footage using Lince software (Gabin, Camerino, Anguera & Castañer, 2012).

Statistical Analysis

The analysis was performed using the SPSS v26.0 statistics software (IBM, USA). The descriptive statistics were reported as mean and standard deviations for the three questions of the VAS, while normality of the distribution was assessed via the Shapiro-Wilk test ($p>.10$). The Friedman Two-Way repeated measure ANOVA was conducted to check the differences between the six SSGs based on the VAS questions. Where significant differences were found, pair-wise comparisons were performed using the post hoc Dunn-Bonferroni test to locate which pairs of games were significantly different. The Pearson (r) correlation was performed to check the relationship between the three VAS questions. A chi-square test was carried out to compare the frequency distributions between the variables (positive/negative), related to decision-making ability (Phase A, Phase B and Phase C), while a Spearman (Rho) correlation was performed to find the potential association between the dependent variables. To ensure the intra- and inter-reliability of the observational instrument, 20% of the data were reanalyzed after 2 weeks (to exclude any learning effects) by the same observer and by a different observer. The observers were trained following the protocols described by Losada & Manolov (2014). Kappa's coefficient was calculated and revealed values higher than 0.8 for all categories, thus the concordance was classified as "perfect" (Robinson & O' Donoghue, 2007).

RESULTS

Physiological loading

The physiological intensity of each game is represented by the indices of heart rate and blood lactate as mentioned before. Specifically, it is well established by the extracted data that nearly in every game, players outperformed the barrier of 89.5% of HRmax (>180.44 bpm for the examining sample). Moreover, a significant accumulation of blood lactate was reported during and after games (>4 mmol). More accurately, greater blood lactate accumulation was reported immediately after the third game (8.03 ± 1.2 mmol), while in Game 6 it approximated 6.2 ± 1.8 mmol (Figure 2).

Cognitive fatigue

Table 3 shows the descriptive statistics which represent the Mean and Std. Deviation of each of the three questions of the VAS per SSG. Friedman's Two-Way Analysis of Variance for the comparison of responses in each VAS question between the six SSGs showed a statistically significant difference for the questions “Cognitive Fatigue” ($\chi2(5)=31.805$, p=0.000) and “Cognitive Effort” ($\chi2(5)=26.868$, p=0.000). On the contrary, non-significant differences were recorded for “Motivation” ($\chi2(5)=5.590$, p=0.348).

Table 3 Descriptive statistics of the responses in VAS per SSG.

	Game 1 M ± SD	Game 2 M ± SD	Game 3 M ± SD	Game 4 M ± SD	Game 5 M ± SD	Game 6 M ± SD	*p*
Cognitive Fatigue	63.3± 9.20	71.5± 8.69	77.3± 6.46	82.1± 9.11	85.7±10.20	85.9± 9.91	<.001
Cognitive Effort	62.7±14.82	68.7±16.19	78.3±11.97	80.8± 9.87	82.0±14.50	82.4±14.29	<.001
Motivation	75.7± 8.74	71.8±14.94	79.1±15.30	80.6±16.61	77.8±18.66	75.4±22.48	>.10

The post-hoc analysis indicated a statistically significant difference in “Cognitive Fatigue” questions between Game1 vs Game4 (p=0.002), Game1 vs Game5 (p=0.000), Game1 vs Game6 (p=0.000), between Game2 vs Game4 (p=0.023), Game2 vs Game5 (p=0.001) and Game2 vs Game6 (p=0.001), and between Game3 vs Game5 (p=0.013) and Game3 vs Game6 (p=0.013). Moreover, significant differences were reported for the “Cognitive Effort” question between Game1 vs Game3 (p=0.045), Game1 vs Game4 (p=0.008), Game1 vs Game5 (p=0.003), and Game1 vs Game6 (p=0.001).

Moreover, Pearson’s correlation between the three VAS questions revealed significantly positive values [r(Cognitive Fatigue- Cognitive Effort)=.884, p=.004, r (Cognitive Fatigue-Motivation)=.724, p=.042 και r (Cognitive Effort - Motivation), 48=.788, p=.020].

Decision-making ability

Phase A - Starting position and ball receiving

From 396 examined ball receive actions, the players assumed a right staring position in 59.8% (237) of them, while in 40.2% (159) they made a starting position under pressure from the opponents or the hold bad position, which was preventing the forward game. Overall, players received the ball in 97.2% (385) of the cases to continue on the next action, with only a 2.8% (11) tries ending with ball loss ($\chi2(2)=87.059$, $p<0.001$, cc=.425).

Phase B - Decision-making on ball action

During the second phase of the competitive actions, as depicted on Table 4, from the 385 positive ball receive actions, the players decided to perform a passthe (44.9%), driving (36.6%), shooting (14.8%) and dribbling (3.6%). From these actions players performed a significantly higher number of positive decisions (86.5%) in comparison to negative ones (13.5%). Precisely, chi-square test reported significant differences in frequency distribution of positive and negative decisions within the four action types ($\chi2(3)=8.046$, $p<0.05$). Nevertheless, the overall comparison of positive and negative decisions independently of the action type within the six SSGs (Figure 2) showed non-significant differences ($\chi2(5)=9.262$, $p=0.099$, $\varphi=0.099$).

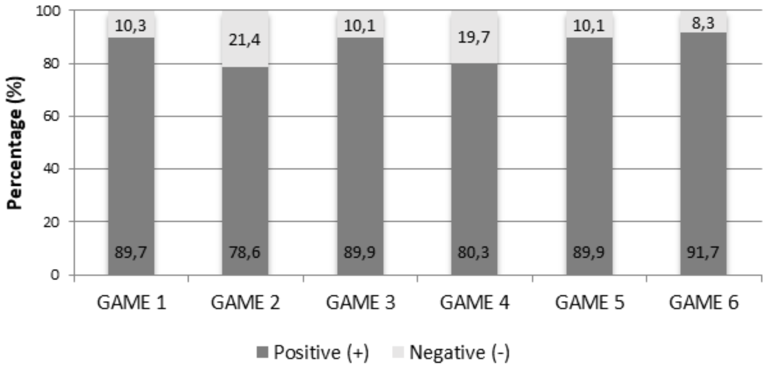

Fig. 2 Decision-making on ball action per SSG.

Phase C – Ball action execution

Although the majority of actions during the execution phase proved to have a positive note (55.1%), non-statistically significant differences were found at the frequency distribution among the four action types ($\chi^2_{(3)}=4.489$, $p=0.213$, $\varphi=0.213$). Table 4 reveals that driving and passing demonstrated positive execution (51.8% and 60.7% respectively), while dribbling and shooting more negative execution (57.1% and 50.9% respectively).

Table 4 Decision-making on ball action (B) and Execution (C) per ball action.

Ball Action	Total N (%)	Decision-making (B)		Ball action execution (C)	
		Negative	Positive	Negative	Positive
		N (%)	N (%)	N (%)	N (%)
Driving	141 (36.6)	27 (19.1)	114 (80.9)	68 (48.2)	73 (51.8)
Passing	173 (44.9)	15 (8.7)	158 (91.3)	68 (39.3)	105 (60.7)
Dribbling	14 (3.6)	1 (7.1)	13 (92.9)	8 (57.1)	6 (42.9)
Shooting	57 (14.8)	9 (15.8)	48 (84.2)	29 (50.9)	28 (49.1)
Total	385 (100.0)	52 (13.5)	333 (86.5)	173 (44.9)	212 (55.1)
		$x^2_{(3)}=8.046$, $p=0.045^*$, $\varphi=0.145$		$x^2_{(3)}=4.489$, $p=0.213$, $\varphi=0.213$	

Notes: $^*=p<0.05$. $^{**}=p<0.01$. $^{***}=p<0.001$

Concerning the effect of the decision made in the second phase of the action (B) on the execution of the third one (C), statistical analysis indicated that 96.2% of the 52 negative decisions of the second phase led to negative execution (Table 5). On the contrary, 63.1% of 333 positive decisions contributed to positive execution of the players. This finding was also validated by the Spearman correlation, which presented an increased and significant correlation between the decisions of the two phases (ρ =.407, p<.001).

Table 5 Relationship between effectiveness of decision-making (B) and ball action execution (C).

Variables		Ball action execution (C)			
Decision-making (B)	N	Negative N (%)	Positive N (%)	Chi square	Phi Coefficient (Phi)
Negative decision	52	50 (96.2)	2 (3.8)	$x^2_{(1)}$=63.741	.407
Positive decision	333	123 (36.9)	210 (63.1)	p=0.000***	
Total	385	173 (44.9)	212 (55.1)		

Note: *=p<0.05. **=p<0.01. ***=p<0.001

Assessing the effectiveness of the action execution between the six SSGs, the comparison between Games 1-3 and 4-6 unveiled a significantly higher relative frequency of effectiveness for the first cluster of games (63.5%) against the second one (47.8%) ($\chi^2_{(1)}$=9.482, p<0.01, phi=.155). This particular finding is depicted in Figure 3, which highlights the effect of the number of games on execution effectiveness on ball actions, apart from cognitive and physiological fatigue.

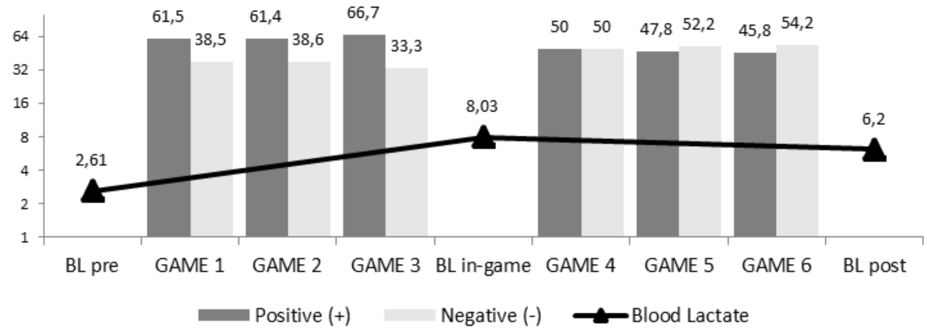

Fig. 3 Blood lactate concentration and effectiveness of ball action execution (C) per SSG.

DISCUSSION

The purpose of the current study was to investigate the potential impact of SSGs during a training session on cognitive fatigue and the decision-making ability of the players. A number of intensive SSGs above four was associated with higher values of subjective cognitive fatigue and the impaired outcome of the decision-making process of the players, which is consistent with our research hypothesis.

In line with a recent study (Trecroci et al., 2020), we assessed decision-making ability of the players defined from the technical-tactical performance in a common realistic soccer-specific training method as SSGs. In field method, this secured the ecological validity of our study, in contrast to researches using laboratory film-based simulations (Smith et al., 2016b; Vaeyens et al., 2007). Having ensured the adequate physical intensity of the games (which emerged from the heart rate and blood lactate measurements) (Dellal et al, 2011a; Fanchini et al., 2011), significant differences were found during VAS responses of cognitive fatigue and effort concepts exept from motivation of the players. In fact, the fourth game proved to be a critical benchmark for the perceived cognitive fatigue and effort, as greater mean values in the VAS were recorded for games 5 and 6. Given the fact that SSGs can potentially induce cognitive fatigue, our results for cognitive fatigue and effort are aligned with studies, which provoke and examine cognitive fatigue with paper/computer-based Stroop tasks, video-watching or tactical sessions (Badin et al., 2016; Coutinho et al., 2018; Smith et al., 2016a; Smith et al., 2016b; Smith et al., 2018). At the same time, the experimental manipulation between these studies and ours still remains controversial, as our endeavor focused on addressing the cognitive-fatigue induced from the SSGs with no intention of seeking pre-triggered cognitive-fatigue effects on SSG performance.

In particular, the findings for motivation are in accordance with the study of Smith et al. (2016b), who reported similar values for these parameters after cognitive fatigue treatment – given the consensus that game progression caused cognitive fatigue. As the authors mentioned, their – and our – findings are in opposition with inverse relationship between cognitive fatigue and motivation, which was reported by Boksem and Tops (2008). Moreover, this result is contradictory to previous research carried out by Boksem and his colleagues (2006), which also indicates that as the subjective effort overcomes the possibility of reward at the end of the task, the motivation to sustain productivity until the end ceases to exist and the participant feeling fatigue desires to be disengaged from the task. A possible explanation for our findings could be the vigourous verbal encourgement provided by the players' coach throughout the overall treatment, which was also reported by Barte and his colleagues (2019). Another safety valve to establish our findings was the positive correlation in value augmentation between each pair of cognitive indices.

The other primary indication of our study was the effect of the SSGs on the decision-making ability of the players. The implicated extensive technical-tactical notational analysis of the recorded activities provided a cascade of sub-actions accompanied with evaluations of the respective decisions. At first, the ability of the players to scan the dynamically changing environment and attend to the most essential cues was assosiated with the motor response of their starting position and ball receive (Nedelec et al., 2012). Particularly, a significant difference was found between safe and risky or bad starting position and the quality of the ball receive. Precisely, better location in the field was associated with a promising ball receive. The stage of integration of relevant information as the opponents' and teammates' position with tactical behavior and the selection of consecutive motor execution was assesed during the second phase of the action (Smith et al., 2018). The results indicated a greater number of positive decisions, for most of the action types (e.g. passing). Progressing to the third phase of the action, a similar pattern emerged for the execution outcome.

Furthermore, the results highlighted the contribution of the second decision for execution of ball action (the third phase), as automatically planning and selecting a correct action is correlated with better execution (Diedrichsen & Kornysheva, 2015). Finally, retrospecting the impact of the number of games on the overall decision-making ability, gradual decrease was demonstrated for the phase to phase performance of activities, which looks reasonable if we reflect on the effect of physiological intensity and the highly cognitive demanding task of the games (Smith et al., 2016a). Moreover, the outbreak of the opponents' pressure could potentially limit the range of playing options

(Phillips et al., 2010). On the contrary, the number of games had no clear effect on the same action phase (A,B,C). Especially considering the first phase (A), our findings are in agreement with the study of Smith and his colleagues (2016b) who invsestigated visual search behavior of youth soccer players and found no evidence for the effect of cognitive fatigue in this competence, which is related strongly to perception (the first stage of information processing and decision-making).

Independently of the game's progression, supplementary findings concerning the correlation between decisions unveiled a positive correlation of positive decisions throughout the task. Finally, the number of games had an effect on the execution outcome, as significant differences were found between game clusters 1-3 and 4-6. This result remains in line with the present literature (Smith et al., 2018) and with the cognitive fatigue findings, highlighting similar effect of the number of games on technical and tactical performance, which reflects the decision-making ability of the players.

In general, these findings are in accordance with previous studies, which pointed out the negative effect of intensive games on the decision-making ability of the players. Previous research (mentioned before for cognitive fatigue increase) complies with this finding, on the condition that SSGs induce cognitive fatigue and therefore diminish the decision-making ability by reverting the sources of attention to irrelevant cues and impairing information processing (Linden et al., 2003). Despite this congruency, to be accurate, the purpose of these studies was to investigate the effect of pre-disposed cognitive fatigue on cognitive processes as decision-making and its observable outcome – technical/ tactical performace. As a consequence, we could not indicate a salient point of convegence between them and us. Overall, our method was the one that obtained the most robust results for the decision-making process, as the extent of our analysis demonstrated and evaluated the whole decision-making process, and not only its outcome (Badin et al., 2016; Smith et al., 2016b; Trecroci et al., 2020).

Despite the novelty of the research problem of investigating cognitive fatigue and the decision-making ability during realistic training conditions such as SSGs, the current study features some limitations. At first, in spite of its purposeful validity, VAS remains a subjective report of the athlete regarding his perception about his cognitive state. More objective techniques such as electroencephalography for recording brain waves relative to decreased function of the frontal lobe (where post-synaptic action potentials reveal the localization of decision-making ability) (Balasubramanian et al., 2011; Lorist 2005) or reaction-time behavioral tasks to validate the state of declined vigilance (Lamond et al., 2005) could be appropriate proxies, in order to eliminate the possibility of physiological fatigue interference. On the other hand, it is uncertain whether such techniques could be implicated in such a field of study.

In terms of investigating the physiological intensity and its potential engagement in decision-making, more sophisticated methods could have been recruited as GPS measurements (Fernandes-da-Silva et al., 2016). Nevertheless, such an extensive analysis about the physical characteristics of fatigue were beyond the scope of this study. In fact, heart rate and blood lactate were used to depict that the games were performed actually at the right intensity. Concerning sample size, only the most skillful players of one elite team participated in the study, something that guides future research to examine more teams in to order to increase their amount of data.

Considering all the above-mentioned topics and the methodological issues of the current study, future work should concentrate on replicating our approach in full-length match conditions, in order to record differences compared to SSGs in matters of cognitive and decision-making exhaustion (Smith et al., 2018). Moreover, our proposal for extending the diversity of the extracted data is to implement our approach among professional soccer players or players of grassroots ages and other competences. Furthermore, a longitudinal study could investigate the differences within several training sessions regarding cognitive fatigue and decision-making, in order to derive purposeful conclusions about players learning adaptation within SSGs.

CONCLUSIONS

Overall, the findings of the current study demonstrates a significant effect of the number of intensive SSGs on the cognitive fatigue and decision-making ability of elite youth players. Precisely, it could be inferred that three to four SSGs could be an effective prescription guideline for coaches, in order to deliver an exerting training protocol within the accomplishment of the technical-tactical learning profit. To our knowledge, this is the first report addressing the issue of cognitive fatigue during a realistic training condition, which is a close approximate of the match. These results did not delve deeper to seek the neurophysiological signature of cognitive fatigue and the diminished decision-making ability. Nevertheless, according to the literature, potential factors include the decreased function of the anterior cingulate cortex and execution functions, which assist decision processes (anticipation/identification of relevant cues, their interpretation and forging the appropriate response). In the direction of covering this issue, our notational analysis for the evaluation of decision-making was carried out at greater depth in comparison to previous studies.

The current study sustains a high level of practical implications, as it is supposed to modify coaches' perceptions about the critical issue of designing their training programs based on the optimal amount of load for their players. The reported data of our research indicated that elite soccer players could gain learning profits for their decision-making ability, when a definite number of intensive SSGs is performed. The major condition for coaches to reach the aforementioned is to foster the evaluation of more validate subjective ratings such as VAS, in order to monitor their players' cognitive and not just physical fatigue throughout the training process.

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UTICAJ IGRE SA MALIM BROJEM IGRAČA NA KOGNITIVNI UMORU I SPOSOBNOST ODLUČIVANJA ELITNIH MLADIH FUDBALERA

Umor je u velikoj meri povezan sa smanjenjem performansi. Dugi periodi kognitivnih i fizičkih napora izazivaju kognitivni i fiziološki zamor. Svrha ove studije bila je da se istraži uticaj broja igre sa malim brojem igrača (SSG) na fizičko opterećenje, kognitivni umor i sposobnost donošenja odluka na akciju loptom mladih elitnih fudbalera. Deset U20 igrača je upisano u studiju i izveli su šest 4 na 4 plus 2 GK SSG. Fiziološko opterećenje je mereno na osnovu laktata u krvi i pulsa, za kognitivni umor igrači su davali subjektivne ocene (VAS), dok je sposobnost donošenja odluka procenjivana kroz video snimke u 3 faze. Rezultati su pokazali da je SSG indukovao visoku srednju vrednost pri fiziološkim opterećenjima i prijavio statistički značajan umor nakon 3. igre iz pitanja „Kognitivni umor"i „Kognitivni napor". Što se tiče sposobnosti donošenja odluka, igrači su pokazali 59,8% pozitivnih odluka u fazi A akcija, 86,5% u fazi B i 55,1% u fazi C, ali nisu značajne između utakmica. Poređenje između igara 1-3 i 4-6 pokazalo je značajno veću efikasnost motoričkog ishoda za prvu grupu igara (63,5%). Rezultati su pokazali da broj intenzivnih SSG-a na treninzima treba da se bira mudro, kako bi se doprinelo poboljšanju kvaliteta i efektivnosti sposobnosti donošenja odluka fudbalera pod pritiskom vremena, prostora i protivnika na utakmici.

Ključne reči: *fudbal, umor, obrada informacija, donošenje odluka*