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Exploring the effects of physical fatigue on cognitive performance of youth soccer players

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ABSTRACT

This study aimed to verify whether the peripheral perception and decision making of young soccer players are influenced by physical fatigue. The sample was composed of 48 soccer players from two youth academies of Brazilian clubs (17.03 ± 2.33 years old). In laboratory conditions, the Vienna Test System and the TacticUP® video test was used to assess peripheral perception and decision making (response time and decision-making quality), respectively. Physical fatigue was induced through T-SAFT^{90} that simulated the metabolic and physical demands of a soccer game (e.g., acceleration, deacceleration, change direction, jump, and technical action). Peripheral perception and decision-making abilities were compared between the control and physical fatigue "conditions". Results displayed that physical fatigue did not influence peripheral perception and decision-making quality, although it improved decision-making response time for the tactical principles of penetration, width and length with the ball, delay, defensive coverage, and recovery balance. In summary, physical fatigue did not affect players' ability to detect information from the peripheral visual field and did not influence the quality of decision-making of soccer players. In addition, physical fatigue induced players to make quicker decisions regarding tactical actions near the ball and inside the centre of play. Thus, we conclude that only the response time of decision-making of youth soccer players is influenced by physical fatigue.

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Decision making; cognition; fatigue; assessment; training

Introduction

Recent studies emphasise decision making as an important skill that enables soccer players to achieve superior performance (Assis et al., 2020; Cardoso et al., 2021). In a sports context, decision making is defined as the individual's ability to analyze, select and/or perform an appropriate action when facing the multiple response options provided by the environment and those generated by themselves (Musculus et al., 2019; Williams & Ward, 2007). Decision-making relates to the players' perceptual-cognitive and perceptual-motor skills. The perceptual-cognitive skills can be considered as the ability an individual has to use existing knowledge to capture, identify and process information

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to select an appropriate action, while the perceptual and motor skills refer to what the individual is capable of perceiving, processing, and executing through movement (Marteniuk, 1976; Starkes et al., 2004).

In this context, the dynamic and unpredictable nature of soccer results in countless problem-solving scenarios, which demand from players a large number of decisions under constraints of space and time (Hüttermann et al., 2019; Skala & Zemková, 2022). Studies on decision making in soccer have indicated that players with superior performance are more efficient in detecting information and selecting the best alternatives when facing the various stimuli present in the environment (Assis et al., 2020; Machado & Teoldo, 2020). Therefore, the efficiency of the decision-making process is based on well-developed perceptual-cognitive skills such as attention, working memory, and peripheral perception (Roca et al., 2018). A substantial body of work has demonstrated that these skills are essential for players executing specific actions during the game (Roca et al., 2020).

Among the perceptual-cognitive skills, peripheral perception has been emphasised as an intervening aspect for the decision-making process in sports (Gonçalves et al., 2020; Klatt & Smeeton, 2019). According to Friedenberg and Silverman (2006), peripheral perception is the process through which players gather and interpret environmental information from the periphery of the visual field. The peripheral perception is measured in degrees (starts at 0°) and is related to the ability to perceive stimulus on the left and right visual fields with the central vision directed to a fixed point. Research on this topic indicate that players who make better decisions display greater ability to detect information in amplitude from the game, as well as to superiorly incorporate them into the decision-making process (Andrade et al., 2021; Gonçalves et al., 2020). However, it is noteworthy that the need to sustain performance during training session, matches and over the competitive season has generated some debate in the literature about how the physical, technical, tactical and cognitive demands are likely to affect the quality of the game and the incidence of injuries (Akyildiz et al., 2022; Bengtsson et al., 2018).

In general, studies have drawn attention to physical fatigue as an intervening variable of the game, since players usually experience it in the final periods of matches or after a high-intensity action with short recovery time (Bradley & Noakes, 2013; Linke et al., 2018). Fatigue occurs when the degree of effort exceeds the player's ability to support the task (Edwards, 1983; Gandevia, 2001). It is characterised by alterations in the organism manifested by neuromuscular changes and metabolic and psychometric responses (Mohr et al., 2005; Silva et al., 2018), which are induced by multi-factorial phenomena. In soccer, it is suggested that exercise-induced fatigue harms the abilities to perceive and anticipate the actions, and the process of decision-making (Skala & Zemková, 2022).

For instance, the study carried out by Alder et al. (2021) assessed the response accuracy and visual search behaviour of adult soccer players submitted to the Drust running protocol using a test film of 11 versus 11 side-on third-person perspectives. Their findings showed a reduction in the anticipatory accuracy and changes in the visual search behaviour (increased number of fixation) in the physical load condition. Therefore, they suggested that the physical load negatively interferes with the players ability to identify the information areas, which is associated with reduced accuracy.

Following the evolution of this research topic in soccer, Klatt and Smeeton (2021) investigated the impact of physical load on soccer players' perceptual and attentional capabilities as well as on their decision-making in soccer games situations. Participants carried out the soccer-specific decision-making task in a cycle ergometer at three different exercise loads in random order (rest; moderate – 70% of heart rate reserve and high – 90% of heart rate reserve). The results showed that the intensity of the exercise affected the ability of soccer players to perceive information by the peripheral field in detail, but no differences in decision-making were observed. In sum, the researchers suggested that the visual attention and perception capabilities of soccer players were negatively affected by physical exercise load, although it did not impact their decision-making performance (accuracy).

Despite the contributions of the studies mentioned above for the progress of knowledge on players' decision making under physical exertion, the decision making was assessed only from the perspective of the player in possession. Additionally, high-intensity or long-duration exercises have been associated with a decrement in cognitive performance in sport due to diminished muscle glycogen stores, hyperthermia, and increased loss of fluids (Skala & Zemková, 2022). Thus, further research is required to clarify the impact of physical fatigue on peripheral perception and decision making.

Thus, the purpose of the present study is to verify whether the peripheral perception and decision making of young soccer players are influenced by physical fatigue. We hypothesise that soccer players experience reduced peripheral perception and impairments in decision making following a physical fatigue-inducing protocol (Alder et al., 2021; Klatt & Smeeton, 2021). By addressing this problem, we expect to provide information that allow coaching staff to devise strategies and design activities to guide players' actions under physical fatigue.

Methods

Sample

The sample was composed of 48 male soccer players (mean age: 17.03 ± 2.33 years) from two Brazilian clubs (McKay et al., 2022). As inclusion criteria, players should regularly participate in systematic training (at least three weekly sessions of 90 min each) and compete in soccer tournaments at regional and state levels.

The software G*Power 3.1.9.4® was used to estimate a minimum sample size of 31 participants. This calculation of power analysis was based on power (1 - β) of 0.85, alfa (α) of 0.05, and effect size (ES) of 0.5 (moderate), as indicated in the scientific literature (Kadam & Bhalerao, 2010). The effect size used was defined based on data from a published study which used a similar design to examine effect of dehydration on passing decision making in soccer players (Fortes et al., 2018).

Ethical procedures

Participants were previously informed about the purposes of the research. The study was approved by the Ethics Committee in research with human beings (n° 3.208.190) and conforms to the norms of the National Health Council (CNS 466/2012) and the Declaration of

Helsinki (2013). To take part in the research, participants aged 18 years and older signed an Informed Consent Form. The participants who were less than 18 years old signed an Assent Form, while the participants' legal guardians signed an Informed Consent Form Figure 1.

Instruments and procedures

Experimental design

The participants visited the laboratory on two different days. On the first day, named "Control" condition, all participants performed a test battery, which was carried out in the following order: (i) peripheral perception test; (ii) TacticUP® video test and (iii) peripheral perception test. The second day, named "Physical Fatigue" condition, occurred 21 days after the first visit to avoid the effects from learning and working memory related to the test (Wyse, 2021). All participants performed a test battery, which was carried out in the following order: (i) peripheral perception test; (ii) T-SAFT^{90} test – first part; (iii) peripheral perception test; (iv) T-SAFT^{90} test – second part; (v) TacticUP® video test and (vi) peripheral perception test. The intervals between the tests lasted around two minutes, as this was the approximate time participants took to move from one location to another. The RPE was collected 30 min after the end of the control and physical fatigue conditions. The dependent variables of the study were the visual field, tracking deviation, reaction time, response time and decision-making quality. On the other hand, the independent variable was the T-SAFT^{90} test.

Data collection procedures

Participants visited the laboratory on two different days. On the first day, named "Control" condition, all participants performed a test battery, which was carried out in the following order: (i) peripheral perception test; (ii) TacticUP® video test and (iii) peripheral perception test. On the second day, named "Physical Fatigue" condition, following a 48-hour minimum interval between assessments, all participants performed a test battery, which was carried out in the following order: (i) peripheral perception test; (ii) T-SAFT^{90}

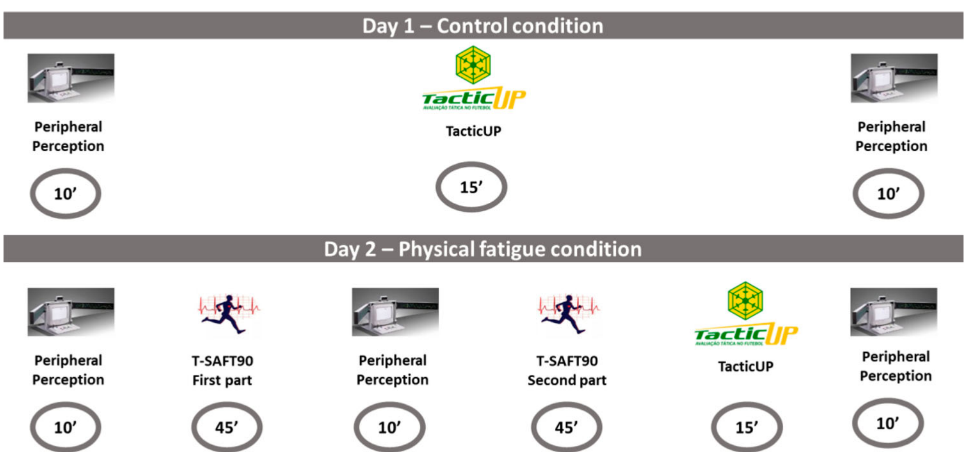

Figure 1. The representation of the experimental design.

test – first part; (iii) peripheral perception test; (iv) T-SAFT^{90} test – second part; (v) TacticUP® video test and (vi) peripheral perception test. The intervals between the tests lasted around two minutes, as this was the approximate time participants took to move from one location to another. The RPE was collected 30 min after the end of the control and physical fatigue conditions.

Participants were instructed to do not engage in any kind of physical exercise and to avoid the consumption of any caffeinated or alcoholic beverage within the 48-hour period prior to the interventions, in addition to have a 6- to 8-hour sleep in the previous night. As a means to ensure that participants intake the same food, a standard meal was provided 60 min before the start of the tests, in order to meet the estimated 18% energy demand for each participant (≅380kcal, 68 g CHO, 11 g proteins and 7 g fat). Water intake during the experiment was *ad libitum*. The average ambient temperature and air humidity in the day participants were subjected to the physical fatigue protocol were 22 ± 1°C and 61 ± 1%, respectively.

Peripheral perception

The peripheral perception test (PP) – version S1 included in the Vienna Test System was used to assess participants' peripheral perception (Schuhfried et al., 2011). The peripheral perception task was presented on two peripheral panels attached to the left and the right sides of the computer screen. Green light diodes were shown on these panels and when a full vertical light line appeared, the participants had to react by pressing a pedal with his dominant foot as quickly as possible. Simultaneously, a central tracking task had to be performed, in which a moving ball was tracked through a crosshair on the screen (participant should focus his attention on the centre of the visual field). During the test, the critical peripheral stimulus appeared several times and in different positions.

The central measure used in this test was the visual field. This measure is obtained through the sum of the right and left visual angles, which considers the participant's ability to react to stimuli on the edge of the visual field. The visual field is measured from the positions of the visual stimulus, target and distance between the participant's head and the equipment. Also, other variables were obtained, including the tracking deviation – distance of deviation from the object to be followed on the screen – and reaction time – time taken to respond to peripheral stimuli. The entire duration of the test was 10 min.

Decision making

Collection of decision-making data (response time and decision-making quality) was carried out using TacticUP®, an online platform (www.tacticup.com.br) that assesses offensive and defensive skills in situations near and distant from the ball based on the core tactical principles of soccer (Teoldo et al., 2022). These principles display central aspects of the educational process of tactical skills. Furthermore, core tactical principles indicated objective measures of players' movements related to the management of the playing space.

The TacticUP® video test for soccer is composed by offensive and defensive video sequences (scenes) of 11 versus 11 soccer situations. Participants performed 36 trials in random order, being three scenes for each tactical principle. The videos were displayed from a panoramic perspective, which is an elevated view of an object from above. It allowed the participants to visualise the whole field. The test allows the assessment of the player's decision-making skills during both phases of play (offensive and defensive), in actions with and without the ball that take place inside and outside the centre of play. The centre of play is a dynamic spatial reference, characterised by a circumference of 9.15 m radius from the location of the ball where movements and decisions made during the game are more intense/faster (Teoldo et al., 2022).

For each scene, participants had to choose the most appropriate solution from four possible scenarios. Participants were asked to answer to the question: "what should the observed players do?". The score for each scene was calculated based on the correspondence between the participants' responses and the responses given by a panel of experts ($n = 9$). Response time was calculated as the time between the participants seeing the question and choosing the answer. The final scores awarded by the TacticUP® video test for soccer are presented in 14 items (one for each core tactical principle), in addition to the scores for the offensive phase and defensive phase (for details, see Machado & Teoldo, 2020).

All procedures were described and presented to participants prior to the start of the tests. The main researcher was available to resolve any doubts during the entire experiment. The TacticUP® video test was taken individually by each participant in a 15-inch screen laptop (LENOVO, model 330 Intel Core™ i5 processor). The entire test application had approximate duration of 15 min.

Physical exertion measures

In this study, the modified CR10 scale proposed by Foster et al. (1995) was used to estimate the rating of perceived exertion (RPE) of the session according to its reference points (minimum 0 and maximum 10). The RPE scale is used to assess the individual's perceived exertion during an exercise and the exercise intensity. Thirty minutes after the end of the protocols in both days (control condition and physical fatigue condition), the participants informed the researcher in charge the RPE value that corresponded to their perceived effort during the sessions on the 10-point Borg scale (0 = rest to 10 = maximum effort) (Impellizzeri et al., 2004).

Physical fatigue induction protocol

The T-SAFT^{90} test was used as a physical fatigue-inducing protocol. This test is validated and consists in an activity that simulates the physical actions of a 90-minute competitive soccer match, with the purpose of replicating the metabolic demands of the game and generating similar responses regarding the internal and external match loads. This task was used based on its potential to induce muscle damage actions such as accelerations, decelerations, and changes of direction and consequently muscular fatigue.

The T-SAFT^{90} incorporates activities with the ball, including running, dribbling, shooting, passing and jumping, in an intermittent fashion and at varying speeds, such as in an actual soccer match (for details, see Silva & Lovell, 2020). In previous studies, this soccer simulated protocol caused an increase in biochemical blood-marker such as creatine kinase, cortisol, leukocytes, neutrophils, myoglobin, neutrophils, lymphocytes and elevated muscle soreness and perceived exertion (Silva et al., 2021; Silva & Lovell, 2020).

Statistical analysis

Descriptive analysis (means and standard deviation) of the sample was performed. The normality of data distribution for all variables was verified using the Shapiro-Wilk's test. The paired t-test and Wilcoxon's test were used to compare variables (decision-making response time, decision-making quality and RPE) between the control and physical fatigue conditions. Paired t-test and Wilcoxon's test were used to analyse the peripheral perception variables in the control condition, and ANOVA of repeated measurements was used to evaluate the peripheral perception variables in the physical fatigue condition. Effect sizes were obtained using Cohen's *d*, and magnitudes were classified as: null (< 0.20), small (0.21–0.60), medium (0.61–1.20) and large (> 1.20) (Cohen, 1992).

For all statistical procedures, the significance level was set at $p < 0.05$. Statistical analyses were performed using IBM SPSS (Statistical Package for Social Sciences) for Windows®, version 24.0.

Results

Physical exertion measures

Participants displayed higher perceived exertion in the physical fatigue condition (7.8 ± 1.1 AU) compared to the control condition (1.1 ± 0.9 AU) ($z = -6.08$; $p < 0.001$; large effect). This indicated that players experienced the fatigue as being "very hard".

Peripheral perception

In the "control" condition, a significant difference was found in the tracking deviation measure after the decision-making test (TacticUP®) ($z = -2.55$; $p = 0.011$; $d = 0.37$) (Table 1). On the other hand, no significant differences were found in the comparison of peripheral perception variables in the "physical fatigue" condition (Table 1).

Decision making

No significant differences were found regarding players' decision-making quality, in the comparison between the "control" and "physical fatigue" conditions (Table 2).

Under physical fatigue, players improved their response time, i.e., they were quicker in making decisions related to the tactical principles of penetration ($z = -2.50$; $p = 0.012$; $d = 0.45$), width and length with the ball ($z = -1.97$; $p = 0.049$; $d = 0.27$), delay ($z = -2.13$; $p = 0.033$; $d = 1.56$), defensive coverage ($z = -2.32$; $p = 0.020$; $d = 0.45$) and recovery balance ($z = -2.75$; $p = 0.006$; $d = 0.45$) (Table 3).

Discussion

The purpose of this study was to verify whether the peripheral perception and decision making of young soccer players are influenced by physical fatigue. Findings indicated that peripheral perception is not dependent on physical exertion to which the player was submitted. On the other hand, results showed an improvement on players' decision-making response time, yet only for the tactical principles performed inside the

Table 1. Comparison between the results pre and post the peripheral perception test in the control condition, and comparison among the results pre, interval, and post the peripheral perception test in the physical fatigue condition

	Control								Physical Fatigue										
	Pre			Post					Pre			Interval			Post				
Peripheral Perception	*M*		*SD*	*M*		*SD*	*p*	*d*	*M*		*SD*	*M*		*SD*	*M*		*SD*	*p*	*d*
Visual Field (°)	180.27	±	7.71	182.13	±	8.88	0.108	–	182.17	±	7.96	182.53	±	9.54	181.8	±	9.98	0.961	–
Tracking Deviation (pixels)	6.56	±	2.05	5.92	±	1.32	0.011*	0.371	6.38	±	1.97	6.22	±	1.49	6.83	±	2.27	0.497	–
Reaction Time (s)	0.63	±	0.09	0.64	±	0.11	0.666	–	0.61	±	0.08	0.60	±	0.08	0.61	±	0.08	0.695	–

*Significant difference at $p < 0.05$.

Table 2. Comparison of decision-making response time between the control and physical fatigue conditions.

	Control			Physical Fatigue			CI 95%		
Tactical principles	*M*		*SD*	*M*		*SD*	*Lower – Upper*	*p*	*d*
Offensive principles									
Penetration	6.66	±	2.94	5.37	±	2.74	−2.42 to −0.29	0.012*	0.454
Offensive Coverage	5.29	±	2.33	4.69	±	2.31	−1.40–0.39	0.243	0.259
Depth Mobility	5.78	±	3.79	5.35	±	3.04	−1.20–0.80	0.689	0.125
Width and Length with the ball	6.29	±	3.57	5.44	±	2.67	−1.47–0.00	0.049*	0.270
Width and Length without the ball	5.58	±	2.12	5.10	±	2.23	−1.09–0.20	0.150	0.244
Offensive Unity	5.15	±	3.18	5.05	±	3.04	−0.89–0.65	0.631	0.032
Defensive principles									
Delay	5.50	±	2.31	5.16	±	3.48	−1.56 to −0.11	0.033*	1.561
Defensive Coverage	6.69	±	3.71	5.52	±	3.00	−2.15 to −0.19	0.020*	0.446
Defensive Balance	5.49	±	2.51	5.38	±	3.13	−1.27–0.51	0.302	0.039
Recovery Balance	6.84	±	3.76	5.35	±	2.86	−2.37 to −0.44	0.006*	0.446
Concentration	5.37	±	2.27	5.29	±	2.91	−0.93–0.55	0.538	0.031
Defensive Unity	5.77	±	2.27	5.60	±	3.19	−0.89–0.86	0.808	0.061
Totals									
Offensive principles	5.79	±	2.51	5.17	±	2.20	−1.24–0.09	0.101	0.263
Defensive principles	5.91	±	2.68	5.42	±	2.45	−1.33–0.27	0.170	0.191

*Significant difference at $p < 0.05$.

Table 3. Comparison of decision-making quality between the control and physical fatigue conditions.

	Control			Physical Fatigue			CI 95%		
Tactical principles	*M*		*SD*	*M*		*SD*	*Lower – Upper.*	*p*	*d*
Offensive principles									
Penetration	78.09	±	12.69	76.55	±	14.50	−5.83–5.50	0.519	0.113
Offensive Coverage	67.37	±	17.94	64.27	±	18.25	−10.17–2.17	0.452	0.171
Depth Mobility	62.25	±	20.78	58.65	±	18.03	−10.50–0.00	0.142	0.184
Width and Length with the ball	84.95	±	14.32	86.35	±	13.53	−3.34–5.83	0.580	0.100
Width and Length without the ball	78.06	±	17.93	78.10	±	18.22	−6.01–8.34	0.783	0.002
Offensive Unity	50.07	±	23.71	44.15	±	20.65	−13.33–0.00	0.176	0.266
Defensive principles									
Delay	75.04	±	21.05	71.41	±	17.38	−11.50–1.17	0.172	0.188
Defensive Coverage	52.16	±	20.83	52.18	±	18.27	−7.71–7.66	0.995	0.001
Defensive Balance	78.62	±	19.40	72.11	±	26.52	−15.33–2.67	0.129	0.280
Recovery Balance	55.88	±	17.66	57.19	±	18.91	−8.50–5.88	0.715	0.071
Concentration	73.79	±	20.88	67.31	±	25.22	−1.67–0.00	0.069	0.280
Defensive Unity	50.47	±	14.15	52.89	±	11.47	−3.00–5.00	0.570	0.188
Totals									
Offensive principles	70.13	±	6.71	67.99	±	7.66	−0.68–4.96	0.133	0.297
Defensive principles	64.59	±	10,00	61.42	±	11.28	−0.64–6.98	0.100	0.297

centre of play. Lastly, with respect to decision-making quality, no differences were found between the "control" and "physical fatigue" conditions. Therefore, in contrast to our initial hypothesis, the peripheral perception and decision making of soccer players are not negatively influenced by the effect of physical fatigue.

With respect to the peripheral perception skills, our findings did not indicate any changes in the analyzed variables in either conditions ("control" and "physical fatigue"), which suggests that players were still capable of focusing on a central task and concurrently maintaining the ability to deal with dynamic visual stimuli from lateral areas (Klostermann et al., 2020; Schumacher et al., 2019). The unchanged peripheral perception implies that players kept their engagement during the entire test, even under physical fatigue. Therefore, it is possible to infer that by sustaining peripheral perception players may have contributed to their own decision-making skills, since several studies have indicated a positive relationship between peripheral perception and decision-making skills in sport (Andrade et al., 2021; Gonçalves et al., 2020). However, in the present study, players were submitted to peripheral stimuli for only 10 min, a considerable short time compared to that to which players are exposed during a soccer match. Hence, it is possible that the results on peripheral perception may be different in the case players are submitted to a task with longer duration.

In connection with this topic, data from separate studies suggested that physical load changed the visual search behaviour. After physical effort, soccer players started fixating for a longer time on the players in possession (Casanova et al., 2013), besides increasing the number of fixations (Alder et al., 2021). Thus, whereas researchers did not consider this hypothesis, soccer players under physical fatigue seem to adopt a "visual pivot" behaviour. This phenomenon is understood as the action of shifting the central gaze towards a given spot (i.e., player in possession) through foveal vision, and employing the parafoveal vision to draw information in amplitude (i.e., teammates, opponents and space) (Piras & Vickers, 2011; Ryu et al., 2013). This behaviour facilitates searching and helps preserving the player's ability to detect information, enabling him to choose better courses of action for a given context during the game (Klostermann et al., 2020; Vater et al., 2020). The players under physical fatigue tend to opt for the strategy that requires less effort, although this may not present itself as the best tactically and technically option for the situation (Coutinho et al., 2018; Iodice et al., 2017).

Our findings also indicated an improvement in decision-making response time for some tactical principles, in particular the ones performed near the ball and inside the centre of play (i.e., penetration, width and length with the ball, delay, defensive coverage, and recovery balance), when players were under physical fatigue. Although our study did not include visual search measures, it is acknowledged that physically exhausted players is capable of regulating their visual focus and searching for relevant information on the player in possession and on the players located inside the centre of play in crucial moments (Casanova et al., 2013). Therefore, this change in visual search patterns seems to enable quicker decision, especially about actions with the ball or that take place near the ball. These findings from the response time contradict researchers that assumed that under physical fatigue, the individuals show a decreased motivation and alertness (Dantzer et al., 2014).

Accordingly, the present study represents a progress in literature, as we also assessed players' decision making in the offensive phase in off-the-ball situations, as well as in the defensive phase. In offensive actions in which the player in the video was not in possession, no changes were observed in decision-making response time (offensive coverage, width and length without the ball, depth mobility and defensive unity). In a similar fashion, no improvements in response time were observed for the defensive tactical principles of defensive unity, defensive balance, and concentration. Consequently, although the results exhibit shorter response times for some tactical principles when the player was physical fatigued, caution is advised when interpreting physical fatigue as a contributing factor for improving decision making, since in soccer, players are not in possession of the ball for approximately 97% of the time in a full match (Garganta, 1997) and decision making was analyzed through video scenes while participants were static. Considering that decision-making evaluated in dynamic ambient integrated with motor action impaired visual-motor response time (Frýbort et al., 2016), then it would be interesting regard it in future studies.

Another possible explanation for this finding is related to an increase in catecholamine (adrenaline, noradrenaline and dopamine) release, and ensuing changes in their concentration in the regions of the anterior cingulate and prefrontal cortexes, following physical effort (McMorris et al., 1999; Singh & Staines, 2015). The prefrontal cortex is involved in several complex cognitive processes, such as reasoning, action planning and learning (Miller & Cohen, 2001), whereas the anterior cingulate cortex is responsible for cognitive processing, and is characterised by its contributions to motor control (Devinsky et al., 1995). The catecholamines work by reducing energy costs and by making the decision process more efficient, as they provide stimuli that enable the increase of information processing speed through a greater flow of information, selection of verbal and motor responses, and quick access to working memory (Bush et al., 2000). Based on this evidence, it is possible to infer that the release of adrenaline, noradrenaline, and dopamine, triggered by physical fatigue, can improve players' ability to perceive environmental stimuli through shorter pathways to the memory-stored information and, consequently, speed up the decision-making process.

As for the results on decision-making quality, no changes were found following fatigue induction, which suggests that players, even when physically fatigued, retained conscience and the ability to select decision-making responses when facing problem-solving situations. The findings of the present study do not agree with previous empirical studies that reported a reduction in the accuracy response and difficulties in identifying the information in the environment (Alder et al., 2021; Klatt & Smeeton, 2021). However, these studies employed methodological procedures that differ from ours, since the decision-making tasks used by the authors were limited to the assessment of the actions performed by the player in possession. In addition, the physical protocols employed were characterised by a fixed intensity, and were performed under controlled conditions, thus implying limited representativeness regarding the physical demands of the game (Skala & Zemková, 2022). In contrast, in our study players were assessed through a decision-making test based on the core tactical principles of soccer, which represents a methodological advancement, when compared to previous research (Machado & Teoldo, 2020; Teoldo et al., 2022). Hence, literature advocates that tests that are more representative of the specific nature of soccer, such as the one used in this study, are more appropriate to assess players' performances, as they are based in the game's action rules and thus minimise the randomness of responses (Petiot et al., 2021; Silva et al., 2020).

The findings indicate that physical fatigue per se, such as the one induced by the T-SAFT[90] test, even including changes of direction, intensities, accelerations, decelerations and on-the-ball actions, was not determining to prompt decrements in the peripheral perception and decision making of soccer players. In contrast, empirical studies indicate that players induced to mental fatigue had deleterious effects on decision making, considering the decrease of quality and increase of response time (Smith et al., 2016), as well as on peripheral perception, as shown by the reduction of the visual field and loss in performance (Kunrath et al., 2020). Based on our findings and previous research on mental and physical fatigue, it is possible to suggest that fatigue makes players more susceptible to choose actions that require less effort instead of the best tactical strategy for the game (Coutinho et al., 2018; Iodice et al., 2017). During the game, this can take the players to making mistakes and to ignoring relevant environmental signals. For this reason, in future studies, we suggest the evaluation of decision-making in field and laboratory conditions to understand if, in a game situation with greater amplitude, this difference in decision-making response time could be influenced by movements far from the ball.

Although some studies reliably demonstrate a positive relationship between decision-making results obtained through laboratory tests with players' performances (Assis et al., 2020; Cardoso et al., 2019; Roca et al., 2011), such assessments tend to be carried out under controlled situations, in which players are not submitted to any interventions. Therefore, given the dynamics of the soccer game and the freedom enjoyed by the players to organise themselves in the playing field, one limitation of the present study is the absence of data on decision making within actual game settings. These results could provide complementary information that support the comprehension of players' performance under physical fatigue. Consequently, we recommend that future studies assess players' decision making using a field test, for example, Game Performance Assessment Instrument – GPAI (Oslin et al., 1998), Game Performance Evaluation Tool – GPET (García-López et al., 2012), and System of tactical assessment in Soccer – FUT-SAT (Teoldo et al., 2017), to verify whether their abilities to detect information and make decisions are likely to change in more ecological settings and under the influence of contextual variables.

Conclusions

In short, the findings of this study indicate that participants maintained their peripheral perception and decision-making quality, and that they improved their decision-making response time in actions performed inside the centre of play. Thus, we conclude that only decision making of youth soccer players are influenced by physical fatigue. Although this research provides relevant information regarding the study of physical fatigue on the performance of players using video scenes of offensive and defensive situations, with and without the ball, the development of more ecological assessments is essential to improve this line of research, in particular, encompassing aspects of movement and displacement across the playing field with the player's ability to perceive information and make decisions.

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