Acute Fatigue and Cognitive Performance in Team Sports

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Fatigue caused by exercise or mentally demanding tasks can lead to an alteration in the cognitive functioning of athletes. I is important to investigate whether and to what extent fatigue influences athletes cognitive performance in sports with high cognitive demands. Prolonged exercise causes a decline in the decision-making, attention, and perception abilities of players. Accuracy of sport-specific tasks with cognitive components included rather deteriorated after both exercise and mental fatigue inducement. However, alteration of players cognitive performance depends on the intensity and duration of fatigue-inducing tasks.

Keywords: acute fatigue ; cognitive performance ; team sports

1. Introduction

Adaptation to a highly variable environment (e.g., ball, opponent, teammates) is crucial in a variety of sports [1][2]. Cognitive functions such as attention, decision making, and working memory are essential for sports performance, especially in an unstable environment [3]. From the perspective of movement, the term reactive agility is widely discussed as an important aspect of individual performance in team sports [2][4]. In specific game conditions, players rapidly and effectively change their direction or velocity of movement in response to external stimuli. Therefore, agility in invasive sports consists of physical, technical, and cognitive factors [1].

Cognition, in general, plays an important role in athletes performance [5]. This is especially the case for sports teams who perform in an open environment full of tasks that are highly independent and cognitively demanding [6]. There is an interplay between physical and psychological aspects of sport-specific skills and movement [7]. Open skills are dependent on immediate changes in the environment. Therefore, cognitive components of rapid movement in team sports depend on abilities such as visual scanning, anticipation, pattern recognition, and knowledge of situations [1]. For example, in sports such as basketball or rugby, decision-making response time had a large relationship with reactive agility [4][8]. A recent meta-analysis also suggests that cognitive assessment correlates with motor test scores [7]. Consequently, current evidence points to the importance of cognitive functions in relation to sport-specific skills and movement [7][9].

Athletes have greater sensory-cognitive skills; however, these skills are related to their specific fields [10]. Cognitive abilities such as inhibition, short-term, and partially working memory seems to be superb in elite soccer players compared to sub-elites and amateurs [11]. In addition, processing speed, quick decision making, and executive functioning appear to be important performance factors in the open-skill environment of team sports [9][12][13].

Cognitive as well as physical performance can be impaired by fatigue. Central and peripheral forms of fatigue influences athletes' sport-specific skills [14][15][16]. In team sports, fatigue seems to be negatively implicated with a technical and tactical aspect of performance [14][15][16][17][18]. It is suggested that exercise-induced fatigue harms the executive functions [19][20] and proprioceptive feedback of humans in general [21]. On the other hand, arousal caused by acute bouts of exercise increases the brain concentration of the neurotransmitters and stimulates a release of the hormone cortisol [22]. Exercise can also have a positive acute impact on cognitive performance; however, this relationship is not linear with loading volume [19][22]. For example, submaximal aerobic exercise for up to 60 min facilitates information processing. With a prolonged time of exercise, fatigue impairs processing and memory functions [22]. Physical fatigue results in prioritizing activity in brain centers responsible for movement rather than frontal parts of the brain that are responsible for higher-order cognitive functions [23]. Diminished muscle glycogen stores, hyperthermia, and increased loss of fluid after intensive or long-duration exercise contributes to decrement of cognitive performance in sport [23][24]. Additionally, neurocognitive aspects of fatigue show evident interaction between physical and cognitive effort [25].

Prolonged cognitively demanding activity results in subjective feelings of “tiredness” and “lack of energy” [26]. It has been found that mental fatigue impairs physical and cognitive performance, even related to sport-specific environments [27]. Recent reviews unfold possible endurance, motor skills, and decision-making performance impairments [28][29]. The effects of mental fatigue on human performance probably lie in the complex neural mechanisms [25][27][30]. Physiological aspects related to athletes’ neuromuscular system obviously play an important role in this process [31]. Evidence supports the existence of mental facilitation and inhibition systems that modulate the activity of task-related brain regions to regulate cognitive performance. Impaired energy metabolism and oxidative damage may contribute to acute cognitive decline [30].

According to recent knowledge, both exercise-induced and mental fatigue influence the cognitive component of a players performance. Alteration in the level of cognitive functions due to exercise depends on the type of exercise load (duration, intensity, specificity) and participants fitness level. In the general population, acute positive effects of exercise were found in specific cognitive abilities such as short-term visual memory and choice reaction [32]. Weightlifting and resistance training [33], as well as coordinative training [34], have shown notable positive psychological outcomes. On the other hand, prolonged acute exercise lead to their impairment [19][20][22]. Acute effects of physical or mental load on athletes’ cognition remain unclear. A variability in sport-specific loads (e.g., specific external and internal load, running speed, number and distance of sprints, sport-specific skills, game situations) may influence players’ cognitive functioning in different ways. Despite their importance in most team sports, the evaluation of these abilities is often underestimated at the expense of physical abilities. Therefore, it is necessary to investigate whether and to what extent exercise-induced and mental fatigue influence players’ cognitive performance in sports with high cognitive demands.

2. Effects of Acute Fatigue on Cognitive Performance in Team Sport Players

2.1. Exercise-Induced Fatigue and Cognitive Performance

For the evaluation of cognitive performance pre- and post-exercise, herein used mostly specific assessment approaches [35][36][37][38][39]. Reactive motor skill tasks (RMST) engage the motor and sensory components of specific performance [35][36]. Passing ability after intermittent running exercise (i.e., modified Yo-Yo IE 1 task–30 min) deteriorates in Australian rules football players (RMST handball task accuracy = −11 ± 12%; RMST performance index = −16 ± 14% p/t *, d = 0.79) [35]. Different results occurred after intermittent specific exercise in soccer players (i.e., Loughborough Intermittent Shuttle Task–45 min). Specific fatigue inducement resulted in lower RMST passing time (−2.7 ± 1.2% *); however, a higher performance index occurred (5.1 ± 3.6% p/t *). Passing accuracy remained stable (3.6 ± 3.3%) [36]. It is suggested that the specificity of fatigue-inducing tasks had a positive impact on cognitive performance in sport-specific skill assessment.

The passing ability of field hockey players was assessed by a passing skill test, which also included a decision-making component [37]. In comparison to values measured after the 1st set of repeated sprint ability tasks (RSA), the passing accuracy of field hockey players did not alter significantly after the 2nd, 3rd, 4th, and 5th set (−6.3 ± 16.9%, −4.2 ± 16.9%, 6.0 ± 12.6%, 7.5 ± 16.9%). Despite these findings, significant differences were found only between the 2nd and 5th (13.8 ± 14.6% *) as well as the 3rd and 5th set (11.7 ± 14.6% *). These results indicated that field hockey players were able to cope with the increasing loading volume of high-intensity exercise and maintain or even overpass their baseline values. Compared to intermittent endurance run in a previous study [35], cognitive performance decline was not present after repeated sprint effort [37]. As the importance of accurate passing in team sports is undeniable, findings suggest the consistency of this ability even in fatigued conditions. However, some studies that examined the passing ability of soccer players found alterations in the total time of test execution rather than in the accuracy of passing [36][39][40]. Hypothetically, different acute changes in the cognitive aspect of passing ability could be present in distinct team sports.

Reactive agility time in players of Australian rules football as well as in soccer players rose significantly after intermittent endurance tasks (5.7 ± 3.0% *; 1.1 ± 4.9% *) [35][36]. Total RMST time was higher after non-specific task in Australian rules football players (6.0 ± 3.0% *) [35]. Specific fatigue inducement did not cause a significant alteration of reactive agility in soccer players (0.6 ± 0.9%) [36]. Further research in different team sports would be beneficial to provide an interesting insight into a possible reactive agility performance alteration caused by fatigue inducement.

2.2. Mental Fatigue Inducement and Cognitive Performance

Mental fatigue was exclusively induced by the standardized Stroop color-word task (ST) in most of the studies [39][41][42][40][43][44]. The duration of ST was generally 30 min; however, in one study, the authors used protocol with 10 min only [39]. Except for Veness et al. [42], all of the other articles in this field were dedicated to soccer. For the evaluation of soccer-specific skills, some authors [35][36] used the Loughborough soccer passing test (LSPT) adapted from Ali et al. [45]. This test consists of passing to the colored target area shown on gymnasium benches and the participants' reaction to the examinators randomized color signals. Therefore, cognitive components play a significant role in this evaluation approach.

Research showed no alteration in the LSPT performance time of sub-elite players (0.1 ± 9.4%) [43]; however, a significant difference was observed in the under-18 youth players (17.5 ± 12.3% ***) [40]. Youth soccer players in categories under-14 and under-16 were not significantly affected by mental fatigue (7.5 ± 17.0% and 4.2 ± 17.8%) [40]. One study showed no difference in LSPT total time between the pre- and post-fatigue assessment; however, the number of errors in mental fatigue conditions rose by mean 60% * [43]. An increase of penalty time (errors) in LSPT was observed in all groups of youth players with the highest mean values in the under-18 category (91% ***). It is assumed that mentally fatigued players tended to make more errors in sport-specific performance assessment, which includes the cognitive component. Furthermore, Smith et al. [43] did not observe alterations of movement speed in LSPT, though intermittent running performance in a different study [40] deteriorated in all groups of youth players. It is considered that mental fatigue influences the motor component of movement, especially in endurance tasks. On the other hand, in shorter bouts, the cognitive abilities related to executive functions can alter.

In addition, the previously described "footbonaut" soccer-specific evaluation [39] discovered a significant difference between pre and post mental fatigue conditions in speed of action parameters (−5.4 ± 12.4% *), whilst ball control scores remained largely unaffected (0.7 ± 4.0%). Mental fatigue impaired both the accuracy (−4.8 ± 5.7% **; d = 0.89) and reaction time (−12.1 ± 21.2% *; d = 0.49) of soccer-specific visual tasks in sub-elite soccer players [41]. This task consisted of various film-based simulations of soccer-specific situations with a variable number of defensive or offensive players. Response accuracy was very likely decreased in situation 5 vs. 3 formation (d = 1.00) and likely lower in formation 3 vs.1 (d = 0.49). Reaction time likely differed in all of the five showed formations. Furthermore, mentally fatigued elite cricket players performed worse in a reactive assessment based on multiple visual reactions to light sensors [42]. Reaction-time and hand-eye coordination scores did not become significantly worse after 30 min of ST (−9.5 ± 11.9%). It is suggested that visual search and decision-making abilities deteriorated with mental fatigue inducement, as well as visual reaction ability which was affected slightly.

3. Conclusions

Obviously, fatigue can influence cognitive functions and subsequently change the way players perform not only in performance tests but also in simulated games. However, the alteration in level of cognitive functioning seems to be dependent on the duration and intensity of the fatigue-inducing task, whilst the role of specificity is unclear. Though performance in many team sports such as soccer, cricket, rugby, etc., is highly dependent on cognitive functions, the literature mainly focused on their assessment in the general population. In addition, recent studies are related to sleep deprivation and nutritional interventions rather than acute mental or exercise-induced fatigue.

Both types of fatigue can cause an alteration in players levels of attention and perception. Fatigue triggered by prolonged intermittent exercise (30 to 140 min) affects higher-order cognitive functions (decision-making, response selection, response execution) in amateur and sub-elite team sport players. On the other hand, cycling ergometry does not significantly impair sport-specific decision making. Sport-specific testing methods revealed a decline in passing accuracy, especially in adult soccer players, whilst the total execution time of specific tasks remained stable. Mental fatigue triggered by at least 30 min of the Stroop color-word task and smartphone application exposure led to a decline in cognitive performance in sport-specific tests (Loughborough Soccer Passing Test) and directly in soccer games (Decision Making Index). Therefore, coaches should raise attention to players' exposure to smartphones prior to competitions as it may influence their upcoming cognitive performance.

Besides previous findings, there is a lack of evidence about the effect of acute fatigue on memory, learning, and reactive agility. Additionally, the target population is mainly soccer players as only three studies were related to other sports (i.e., Australian rule football, field hockey players, cricket).

Modern technologies offer various cognitive evaluation approaches therefore further research on this topic is possible and necessary. More research is needed to investigate whether and to what extent acute fatigue influences players' cognition, especially related to matches or training. It would also be beneficial to focus on different types of training loads and their effects on cognitive performance. Useful considerations for training design or warm-up setup prior to demanding cognitive tasks (e.g., competitive match) could be discovered in further investigations.