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# Effects of Acute Fatigue on Cognitive Performance in Team Sport Players: Does It Change the Way They Perform? A Scoping Review

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**Abstract:** Fatigue caused by exercise or mentally demanding tasks can lead to an alteration in the cognitive functioning of athletes. Therefore, it is important to investigate whether and to what extent fatigue influences athletes cognitive performance in sports with high cognitive demands. This scoping review aims to map research articles dealing with the effects of acute fatigue on players cognitive performance in team sports. The main inclusion criterium was that studies had to examine the impact of any form of acute fatigue on (i) cognitive functions only, (ii) reactive agility, (iii) sport-specific skills with reactive components included. In total, 12 articles met our inclusion criteria. Results indicated that 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. Mental fatigue and consequent decision-making deterioration can be triggered by at least 30 min of a Stroop color-word task as well as smartphone application exposure. Analysis of the studies revealed a lack of research investigating the acute effect of fatigue on reactive agility, along with cognitive functions such as memory or learning. Due to possible acute negative effects of fatiguing exercise or mentally demanding tasks on human cognition, future research should consider the examination of different types and intensities of exercise on players' cognitive performance.

**Keywords:** acute fatigue; cognitive performance; team sports



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## 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 [14–16]. In team sports, fatigue seems to be negatively implicated with a technical and tactical aspect of performance [14–18]. 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.

We were interested in the acute effects of fatigue on players' cognitive performance. The aims of this scoping review are to map: (1) research articles dealing with the effects of acute fatigue on players' cognitive performance; (2) assessment methods of cognitive performance in team sports; and (3) identify gaps in the existing literature and propose future research on this topic.

## 2. Methods

Three electronic databases (PubMed, Web of Science, Scopus) were chosen to search relevant studies. Google Scholar and backward search (i.e., assessing the reference lists of the included articles) were used for additional searches. The terms "cognitive functions", "cognitive performance", or "agility" were combined with "fatigue" and "sport" to find a title, abstract, or keywords related to our topic. The main inclusion criterium was that studies had to examine the impact of any form of acute fatigue on (i) cognitive functions only, (ii) reactive agility, (iii) sport-specific skills with reactive components included. Other criteria were a publication date of 2010–2021 and article full-text availability. Studies that failed to meet our criteria were excluded from this review.

The PRISMA flow diagram (Figure 1) adapted from Page et al. [35] illustrates the search and selection stages. Initially, we identified 243 articles from the main databases and another 27 articles which provided additional Google Scholar search and backward search of relevant studies reference lists. After the exclusion of duplicates, we eliminated studies that focused on cognitive changes related to sleep deprivation or nutrition interventions, sport-specific skills, agility without cognitive components, or did not examine team sport players. Twelve relevant articles are included in Table 1. Pre-post differences were calculated from the mean values and expressed as percentages. If the study did not provide the required data, we used the abbreviation "n.d." (no data) or the significance level. The last column shows available additional indicators such as: (a) standard deviation (SD), (b) 90% confidence interval (90% CI), (c) 95% confidence interval (95% CI), (d) effect size—Cohens d (ES [d]), and (e) effect size—Partial eta squared (ES [$\eta_p^2$]). These indicators serve to enhance the understanding of collected data.

In summary, although the number of studies included in our review is restricted, we consider that current research on this topic is focused rather on the general or trained population than athletes in their specific sports.

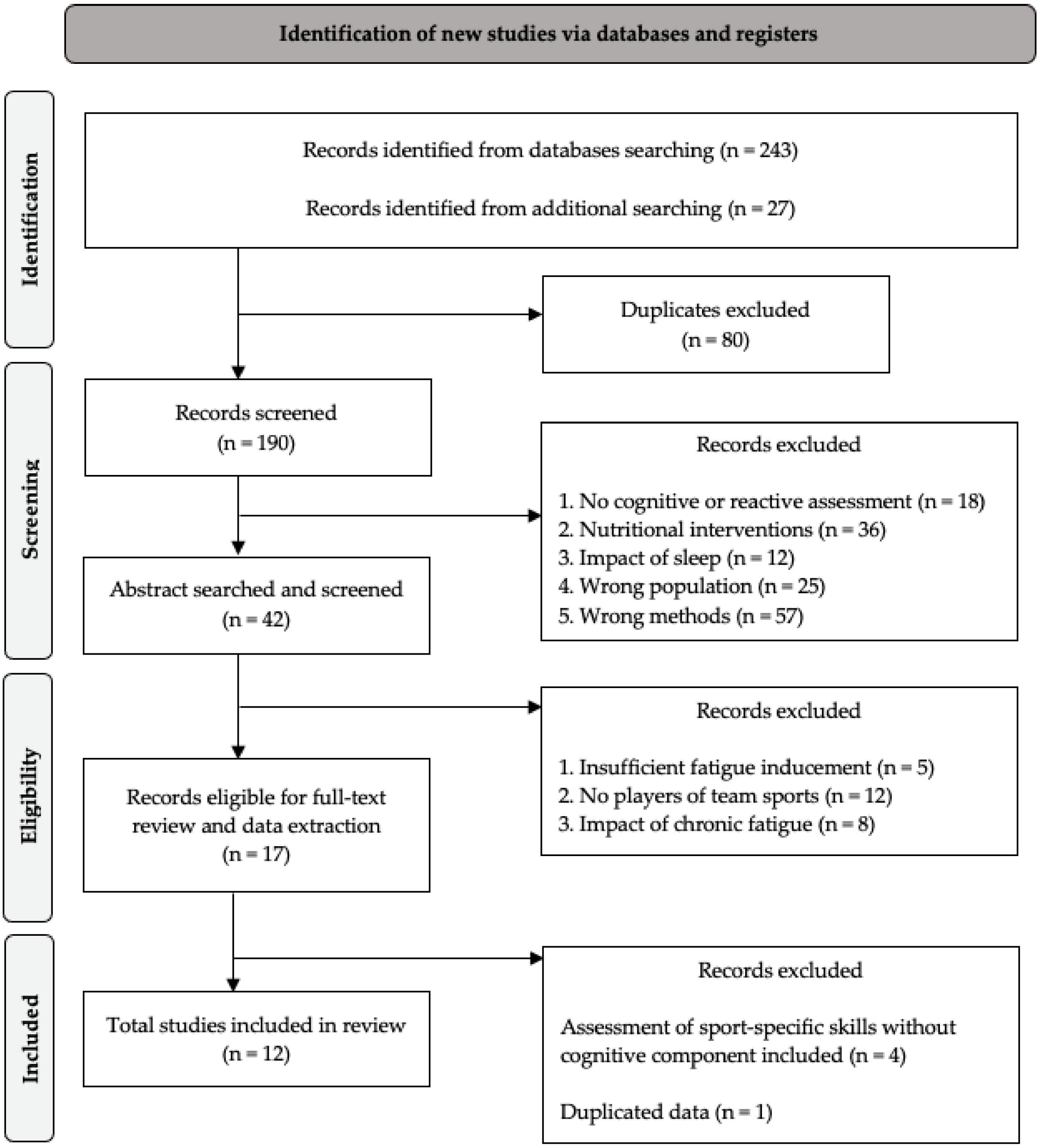


**Figure 1.** Search methodology.

**Table 1.** Summary of articles dealing with pre-post fatigue differences in cognitive performance of team sport players.

| Author | Level and Specialization | Participants | Fatigue Inducing Task | Cognitive Abilities | Type of Assessment | Pre–Post Differences [Mean Δ%] | SD [%] [a]<br>90% CI [%] [b]<br>95% CI [%] [c] ES [d] [d]<br>ES [$\eta_p^2$] [e] |
|---|---|---|---|---|---|---|---|
| Stepto et al., 2011 [36] | Sub-elite Australian Rules Football Players | Male ($n$ = 13; 22 ± 3 y) | Modified Yo-Yo IE test 1<br>30 min | Executive functions<br>Decision-making | Reactive Agility Test<br>Reactive Motor Skill Test<br>Handball task<br>Performance index | 5.7 [t] *<br>6.0 [t] *<br>−11.0 [a] *<br>−16.0 [p/t] * | ±3.0 [b]<br>±3.0 [b]<br>±12 [b]<br>±14 [b], 0.79 [d] |
| Bullock et al., 2012 [37] | Amateur Soccer Players | Male ($n$ = 42; 18 ± 4 y) | Loughborough Intermittent Shuttle Task 45 min | Executive functions<br>Decision-making | Reactive Motor Skill Test<br>RMST (Reactive agility)<br>RMST (Passing time)<br>RMST (Passing accuracy)<br>RMTS (Performance index) | −0.6 [t]<br>1.1 [t] *<br>−2.7 [t] ***<br>3.6 [a]<br>5.1 [p/t] * | ±0.9 [b]<br>±1.1 [b]<br>±1.2 [b]<br>±3.3 [b]<br>±3.6 [b] |
| Goble and Christie 2017 [38] | Youth Cricket Players | Male ($n$ = 15; 17 ± 0.9 y) | Intermittent Batting Exercise<br>140 min | Executive functions<br>Decision-making<br>Attention<br>Learning and Memory | Maze task<br>Detection<br>Identification<br>One-card learning<br>One-back attention | 19.3 [t] *<br>26.8 [e]<br>0.8 [t]<br>0.7 [a]<br>1.5 [t]<br>0.8 [a]<br>−1.4 [t]<br>−1 [a]<br>0.7 [t]<br>−7.9 [a] | ±20.6 [a], ±0.93 [d]<br>±45.4 [a], ±0.58 [d]<br>±2.2 [a], 0.37 [d]<br>±8.1 [a], 0.11 [d]<br>±2.4 [a], 0.56 [d]<br>±3.1 [a], 0.06 [d]<br>±2.8 [a], 0.42 [d]<br>±1.1 [a], 0.43 [d]<br>±2.9 [a], 0.18 [d]<br>±14.2 [a], ±0.61 [d] |
| Hollville et al., 2018 [39] | Elite Field Hockey Players | Male ($n$ = 10; 18.9 ± 1.1 y) | 5 × RSA test (6 × 20 m) | Executive functions<br>Attention | Passing skill test (1st–2nd set)<br>Passing skill test (1st–3rd set)<br>Passing skill test (1st–4th set)<br>Passing skill test (1st–5th set)<br>Passing skill test (2nd–5th set)<br>Passing skill test (3rd–5th set) | −6.3 [a]<br>−4.2 [a]<br>6.0 [a]<br>7.5 [a]<br>13.8 [a] *<br>11.7 [a] * | ±14.6 [a]<br>±16.9 [a], 0.09 [e]<br>±12.6 [a]<br>±16.9 [a]<br>±14.6 [a]<br>±14.6 [a] |

**Table 1.** *Cont.*

| Author | Level and Specialization | Participants | Fatigue Inducing Task | Cognitive Abilities | Type of Assessment | Pre–Post Differences [Mean Δ%] | SD [%] [a]<br>90% CI [%] [b]<br>95% CI [%] [c] ES [d] [d]<br>ES [$\eta_p{}^2$] [e] |
|---|---|---|---|---|---|---|---|
| Klatt and Smeeton 2021 [40] | Sub-elite Soccer Players | Male (*n* = 24)<br>Female (*n* = 6)<br>(24 ± 2.3 y) | Cycling Ergometry (70% and 90% HRR) | Decision-making<br>Attention<br>Perception | Soccer-specific visual task<br>Decision-making<br>SSVT (r–70%)<br>SSVT (70–90%)<br>SSVT (r–90%)<br>Object detection<br>SSVT (r–70%)<br>SSVT (70–90%)<br>SSVT (r–90%)<br>Feature-recognition<br>SSVT (r–70%)<br>SSVT (70–90%)<br>SSVT (r–90%) | n.s [a]<br>n.s [a]<br>n.s [a]<br>2.1 [a]<br>−14.7 [a] *<br>−12.6 [a] *<br>2.2 [a]<br>8.6 [a]<br>−6.4 [a] | n.d.<br>n.d.<br>n.d.<br>±17.8 [a]<br>±13.2 [a], 0.79 [d]<br>±13.5 [a], 0.64 [d]<br>±12.2 [a]<br>±10.9 [a], 0.52 [d]<br>±10.8 [a] |
| Vogt et al., 2018 [41] | Youth Soccer Players | Male (*n* = 33; 13.5 ± 1.0 y) | Soccer-specific course<br>4 × 4 min<br>+<br>Active recovery (jogging)<br>4 × 3 min | Executive functions<br>Attention | Footbonaut<br>Speed of action<br>Ball control | −1.1 [t]<br>1.8 [s] | ±10.3 [a]<br>± 4.5 [a] |
| Smith et al., 2016 [42] | Sub-elite Soccer Players | Male (*n* = 14; 19.3 ± 1.5 y) | Stroop Task 30 min | Decision-making<br>Attention<br>Perception | Soccer-specific visual task | −4.8 [a] **<br>12.1 [t] | ±5.7 [a], 0.89 [d]<br>±21.2 [a], 0.49 [d] |
| Veness et al., 2017 [43] | Elite Cricket Players | Male (*n* = 21; ±8 y) | Stroop Task 30 min | Executive functions<br>Attention<br>Perception | Batak Lite Reaction time test | 9.5 [s] | ±11.9 [a], 0.41 [d] |

**Table 1.** *Cont.*

| Author | Level and Specialization | Participants | Fatigue Inducing Task | Cognitive Abilities | Type of Assessment | Pre–Post Differences [Mean Δ%] | SD [%] [a] 90% CI [%] [b] 95% CI [%] [c] ES [d] [d] ES [$\eta_p^2$] [e] |
|---|---|---|---|---|---|---|---|
| Filipas et al., 2021 [44] | Youth Soccer Players | Male (*n* = 36; 13–18 y) | Stroop Task 30 min | Executive functions<br>Attention | Loughborough Soccer Passing Test<br>U14<br>U16<br>U18 | 7.5 [t]<br>4,2 [t]<br>17.5 [t] *** | ±17.0 [a]<br>±17.8 [a]<br>±12.3 [a] |
| Smith et al., 2017 [45] | Sub-elite Soccer Players | Male (*n* = 14; 19.6 ± 3.5 y) | Stroop Task 30 min | Executive functions<br>Attention | Loughborough Soccer Passing Test | 0.2 [t]<br>60 [e] * | ±9.4 [a], 0.00 [e]<br>0.39 [e] |
| Vogt et al., 2018 [41] | Youth Soccer Players | Male (*n* = 33; 13.5 ± 1.0 y) | Stroop Task 10 min | Executive functions<br>Attention | Footbonaut<br>Speed of action<br>Ball control | −5.4 [t] *<br>0.7 [s] | ±12.4 [a]<br>±4.0 [a] |
| Gantois et al., 2020 [46] | Professional Soccer Players | Male (*n* = 20; 22.6 ± 3.3 y) | Stroop Task (CON, 15 and 30 min) + Simulated Soccer Game (2 × 45 min) | Executive functions<br>Decision-making<br>Attention<br>Perception | Decision-making index (in SSG)<br>CON-15ST<br>15ST–30ST<br>CON-30ST | n.s [a]<br>* [a]<br>* [a] | 0.21 [e]<br>0.31 [d]<br>0.30 [d] |
| Fortes et al., 2019 [47] | Professional Soccer Players | Male (*n* = 20; 24.7 ± 3.6 y) | Smartphone exposure (CON, 15, 30, 45 min) + Simulated Soccer Game (2 × 45 min) | Executive functions<br>Decision-making<br>Attention<br>Perception | Decision-making index (in SSG)<br>CON-15SMA<br>CON-30SMA<br>CON-45SMA | 1.9 [a]<br>−4.2 [a] *<br>−6.6 [a] * | ±9.6 [a]<br>±8.9 [a], 0.6 [d]<br>±9.7 [a], 0.6 [d] |

(Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$). t—time; s—score; e—number of errors; a—accuracy; p—points; ES—effect size; [a]—standard deviation (SD); [b]—90% confidence interval (90% CI); [c]—95% confidence interval (95% CI); [d]—effect size—Cohens d (ES [d]); [e]—effect size—Partial eta squared (ES [$\eta_p^2$]); CON—control group; SMA—smartphone exposure; 15,30,45ST—duration of Stroop task [min]; SSG—simulated soccer game.

## 3. Results and Discussion

### 3.1. Exercise-Induced Fatigue and Cognitive Performance

For the evaluation of cognitive performance pre- and post-exercise, the authors used mostly specific assessment approaches [36,37,39–41]. Reactive motor skill tasks (RMST) engage the motor and sensory components of specific performance [36,37]. 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) [36]. 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%) [37]. 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 [39]. In comparison to values measured after the 1$^{st}$ 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 [36], cognitive performance decline was not present after repeated sprint effort [39]. 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 [37,41,44]. 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% *) [36,37]. Total RMST time was higher after non-specific task in Australian rules football players (6.0 ± 3.0% *) [36]. Specific fatigue inducement did not cause a significant alteration of reactive agility in soccer players (0.6 ± 0.9%) [37]. 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.

Goble and Christie [38] evaluated cognitive functions learning, detection, attention, and executive functions after specific cricket batting simulation. Prolonged batting affected a task that required decision-making but not simple tasks. Maze task performance improved in processing speed with large effect (19.3 ± 20.6% *; d = 0.93). Changes in the accuracy of the maze task (26.8 ± 45.4%; d = 0.58) and the accuracy of the one-back attention task (−7.9 ± 14.2%; d = 0.61) were not significant. Despite this, the potential impairment of working memory and attention cannot be proven because of a non-significant difference observed. Visual attention and vigilance did not decrease and no effect was shown in the accuracy of the detection and identification task. After the prolonged specific intermittent task, the higher-order cognitive functions (decision-making and executive functions) deteriorated only in the maze task. The time and accuracy of simple tasks remained without notable changes.

The decision-making of soccer players was not affected by cycling ergometry at different intensities [40]. In this study, players had to recognize sport-specific situations shown on the immersive screen while cycling at 70 and 90% of their heart rate reserve (HRR). Acute high loading caused the decline of players' visual attention accuracy in the object-detection task compared to rest condition (12.6 ± 13.5% *; d = 0.64) as well as moderate loading (12.6 ± 14.7% *; d = 0.79). Detection ability in the feature-recognition task, where participants had to detect the running direction of shown players, did not deteriorate significantly among the intensities. Furthermore, a moderate effect was observed between intensities of 70 and 90% HRR (d = 0.52). Physical exercise at different intensities can temporarily affect the attention and perception of players but does not alter their sport-specific decision-making ability. It is questionable if the cycling ergometry used in the previously described study [40] is an adequate fatigue-inducement method for further cognitive assessment of team sports players.

A new method of soccer-skill assessment was observed in the study of Vogt et al. [41]. "Footbonaut" is the system developed for training and diagnostics of reactive skills and passing accuracy in soccer. Participants performed a standardized practice (i.e., 20 balls randomly drawn at 50 km/h each). Pre-post differences in mentally and physically demanding tasks were evaluated by speed of action (time) and ball control (score). Exercise-induced fatigue caused by soccer-specific courses (i.e., four sets of various soccer-specific tasks with active recovery jogging between sets) did not result in a significant alteration in the speed of action time (−1.1 ± 10.3%) and ball control score (1.8 ± 4.5%). Specific exercise-induced fatigue did not have a significant impact on complex sport-specific skills with decision-making and attention requirements. Engagement of both motor and sensory components of movement in the evaluation procedure of this study was relevant to sport-specific performance. Although previous findings showed a significant deterioration of decision-making in the maze task ($p \leq 0.05$), there were no changes in the level of cognitive abilities in other psychological-based tests [38].

### *3.2. Mental Fatigue Inducement and Cognitive Performance*

Mental fatigue was exclusively induced by the standardized Stroop color-word task (ST) in most of the reviewed studies [41–46]. The duration of ST was generally 30 min; however, in one study, the authors used protocol with 10 min only [41]. Except for Veness et al. [43], all of the other reviewed articles in this field were dedicated to soccer. For the evaluation of soccer-specific skills, some authors [36,37] used the Loughborough soccer passing test (LSPT) adapted from Ali et al. [48]. 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%) [45]; however, a significant difference was observed in the under-18 youth players (17.5 ± 12.3% ***) [44]. 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%) [44]. 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% * [45]. 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% ***). We assume that mentally fatigued players tended to make more errors in sport-specific performance assessment, which includes the cognitive component. Furthermore, Smith et al. [45] did not observe alterations of movement speed in LSPT, though intermittent running performance in a different study [44] 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 [41] 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 [42]. 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 [43]. 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.

A predominantly synergic effect of both mental and physical fatigue was observed in studies [46,47] that used in-game performance analysis of players known as a Game Performance Assessment Instrument (GPAI). This approach, concomitantly with the equation for decision-making index (DMI), was adapted from Memmert and Harvey [49]. Players' performance was analyzed in simulated soccer games, which provided the additional sport-specific load. GPAI analysis showed a decrease in passing decision-making performance (DMI) following 30 ST compared to 15 ST (d = 0.31 *) and CON (d = 0.30 *). No significant difference was observed after 15 ST ($p > 0.05$). Fortes et al. [47] used smartphone application exposure (SMA) to induce mental fatigue in professional soccer players. Stroop task assessment immediately after SMA pointed to the significant deterioration of accuracy (30 SMA: −3.7 ± 0.7% *; 45 SMA: −3.8 ± 0.7% *) and response time (30 SMA: 6.2 ± 1.4 s *; 45 SMA: 7.0 ± 1.8 s *). No significant alterations were observed in CON and 15SMA groups. In comparison to the control group, DMI decline in simulated games occurred after 30 SMA (−4.2 ± 8.9% *; d = 0.6) and 45 SMA (−6.6 ± 9.7% *; d = 0.6). Changes in DMI were not observed in 15 SMA (1.9 ± 9.6%). According to these findings, passing decision-making performance can be impaired after at least 30 min exposure to smartphone applications. Consequently, both studies showed a significant decline in the decision-making ability of professional soccer players. In addition, at least 30 min of mental fatiguing task exposure is needed to influence decision-making ability directly in soccer matches [46,47].

Based on previous results in reviewed studies, soccer players' cognitive performance deteriorates in mental fatigue conditions [41,42,44–47]. A decrease in youth players' cognitive performance seems to be unprobeable [41,44].

## 4. 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 analyzed 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 of our review is mainly soccer players as only three studies were related to other sports (i.e., Australian rule football, field hockey players, cricket). The limitations of our research are heterogeneity and, in some cases, small sample sizes of selected studies.

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.

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