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CURRENT OPINION

Mental Fatigue in Football: Is it Time to Shift the Goalposts? An Evaluation of the Current Methodology

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Abstract

Research in football for a long time has focused on the physical nature of fatigue as opposed to its mental aspects. However, since 2016, six original articles have investigated the effects of induced mental fatigue in football on isolated physical, skill and decision-making performance tests, along with physical, technical and tactical performance outcomes in small-sided games. Whilst these studies have overall shown a negative impact of mental fatigue on task performance, this current opinion aims to critically examine the methodological approach to this problem, most notably the lack of ecological validity when inducing mental fatigue and the present approach to measuring mental fatigue using visual analogue scales (VAS). It is suggested that future research on mental fatigue in football may benefit from the use of surveys/interviews to understand the true cognitive demands of elite football players. Additionally, future research should aim to reduce the reliance on using VAS to measure mental fatigue as results from this tool may be confounded by several response biases. In conclusion, this article highlights the need for mentally fatiguing tasks that adequately represent football-associated mental fatigue and assessments of mental fatigue that minimise the confounding effect of response bias.

Key Points

Induced mental fatigue negatively influences physical, technical and tactical performance in football-specific tests.

There are shortcomings in the methodological approaches of current mental fatigue research.

Future research must seek to understand real-life causations of mental fatigue in elite football, and must also reduce the reliance on the visual analogue scale as a measurement of mental fatigue.

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1 Introduction

In recent years there has been a growing interest in the effects of mental fatigue on performance in football (soccer) [1]. In fact, it has been suggested that with the exception of military combat, team sport performance is more cognitively demanding than any other physical activity [2]. During the constantly changing environment of a football match, players are processing information (from the ball,

teammates and the opposition) and subsequently making decisions also influenced by team tactics, technical ability and physical capacity [3]. The high technical and tactical demands of football match play with the frequent pressure to meet internal and external expectations may well place a mental demand on an elite football player. Taken together, there is clear rationale for investigating the effects of mental fatigue on football performance.

To date, six original studies have been conducted to assess the influence of mental fatigue on football-related performance, and these were recently presented in a review article [1]. These studies found that induced mental fatigue negatively influences physical and technical performance, along with decision-making skill in laboratory settings [4–6]. Additionally, similar negative effects were reported for technical, but not physical, performance in small-sided games [7, 8]. Lastly, the most recent of these studies showed that induced mental fatigue resulted in a reduction in team synchronisation (i.e. collective movement of the team) and times spent at moderate to high running speeds in small-sided games [9], the latter being a contradictory finding to previous research [10].

Whilst there is some indication that mental fatigue may be detrimental to football performance, there are shortcomings in the methodological approaches of current mental fatigue research. More specifically, the aforementioned studies use mentally fatiguing tasks that have questionable ecological validity, and are completed by recreational or sub-elite level football players. In addition, the study designs often rely on subjective measures of mental fatigue that, despite their frequent use, are at risk of being confounded by self-assessment biases [11]. Therefore, this current opinion article aims to critically examine the current methodological practice focusing on inducing (current methods, limitations, ecologically valid alternatives) and measuring (current methods, impact of response bias and objective measurements) mental fatigue in football research. Recommendations for future studies in this field will be provided, which may have implications for further knowledge and practice.

2 Inducing Mental Fatigue

2.1 Limitations of Using a Modified Stroop Task

The Stroop task is a response inhibition/sustained attention task that causes an increased activation of the anterior cingulate cortex, which in turn may cause feelings of mental fatigue due to reduction in transmission of dopamine to the striatum and anterior cingulate cortex [12, 13]. At present, all but one of the research articles investigating the role played by mental fatigue in football performance has used either a computerised or paper version of the 30-min modified Stroop task to induce mental fatigue, in comparison with a control group that read magazines [4–6, 9] or watched a documentary [8]. The remaining study used a 20-min sport-specific motor task protocol to induce mental fatigue (see Sect. 2.3) [7].

Despite frequently relating prolonged exposure to a modified Stroop task to a perceived state of mental fatigue, the Stroop protocol demonstrates little relevance to the ecological environment of football. During games, footballers are subjected to environmental, task and individual constraints that allow them to exhibit coordinated behaviour in highly dynamic and ever-changing contexts [14]. For example, players both with and without possession of the ball must constantly use information on the position, running direction and velocities of their teammates (and those of the opposition players), in relation to their own position. Whilst using this information, they are required to perform relevant defensive (e.g. committing to a tackle) or attacking (e.g. pass, shoot, dribble) actions under high or low amounts of pressure. A real-world football setting also consists of external factors such as quality and type of playing surface, crowd interaction and ambient light available during the game. Therefore, players constantly find functional movement solutions to movement problems posed by situations that involve varying and interacting constraints [15]. Tasks aimed at inducing mental fatigue should ideally include perception–action couplings representative of perceptual and information processing demands experienced during game play [16, 17]. Hence, researchers should acknowledge the value represented by representative task designs in inducing mental fatigue. With this in mind, the current mental fatigue in football studies may lack the ecological validity required to make inferences on how mental fatigue that originates from playing football affects sports performance.

2.2 Contextual Interference

While playing football is characterised by high degrees of contextual interference (CI), that is, high variability in the consecutive execution of skills, a 30-min modified Stroop task is more likely associated with much lower amounts of CI. High CI has been associated with high degrees of cognitive engagement and problem solving while low CI tasks are associated with less cognitive engagement and the repetition of a solution to the same problem from trial to trial. For example, a recent study compared the task engagement associated with high and low CI practice schedules (a key-pressing task with two goals: learning the relative timing dimension and learning the absolute timing dimension) and found that greater cognitive effort was associated with high CI than with low CI practice [18]. Furthermore, with increasing time-on-task, task engagement and mental workload decreased more in the low CI practice schedule.

These findings have important implications for research on mental fatigue. First, task engagement and cognitive workloads associated with a repetitive 30-min modified Stroop task are likely lower than those associated with the constant problem solving based on ever-changing individual, environmental and task constraints associated with football match play. Moreover, the perception of the modified Stroop task by elite football players may be that of boredom and reduced arousal, ultimately providing a different effect on performance in comparison with 'football-specific' mental fatigue. Therefore, research investigating the effect of mental fatigue in football should employ mentally fatiguing protocols using tasks with higher degrees of contextual interference that bear more relevance to football match play. In addition, breaking down these protocols into sections (i.e. a 30-min protocol into six 5-min bouts) may help to identify individual time responses to performance decrement and perceptions of mental fatigue.

2.3 Developing a More Ecologically Valid Mental Fatigue Protocol

To date, one known study has attempted to establish an ecologically valid mentally fatiguing protocol in football performance research. This consisted of a 20-min whole-body coordination task that consisted of juggling a tennis ball whilst completing agility ladders, and incorporated motor coordination, sustained attention, cognitive processing and perceptual skills to induce mental fatigue before competing in small-sided games [7]. Once the performance levels of a participant increased, a new exercise was selected to maintain a cognitive demand. This was compared with a control condition that consisted of light general aerobic exercises including skipping, jogging, running backwards and side stepping (selected due its low cognitive demand). Although commendable in its attempt to use a more ecologically valid fatiguing task, methodological considerations such as the differences in physical (heart rate) response between conditions, sport specificity and response bias must be considered. In another study unrelated to football performance outcome [19], 32 subjects participated in a 32-team tournament system featuring the popular franchise video game FIFA 15, with mental fatigue being assessed by performance on a mathematical test (paced auditory serial addition test). Whilst it was reported that FIFA 15 gameplay had no effect on mental fatigue, the findings of this study are difficult to interpret as there was no control group and the length and number of games played were not reported. This still points to a pivotal question—what is actually a real-life causation of mental fatigue in football?

2.4 Perceived Cognitive Demands of Elite Match Play

The perceived cognitive demands of elite football (despite the vast amount of decision making and information procession involved in match play) are currently an under-researched area limited to one study. Recent work [20] collected differential rating of perceived exertion (d-RPE) data that consisted of three components (breathlessness [RPE-B], leg muscle exertion [RPE-L] and technical/cognitive exertion [RPE-T]) measured 15–30 min post-match by an English Premier League team across one season. Significantly higher RPE-T scores were reported following matches against the higher ranked teams (top six), plus positional data showed that full backs reported substantially higher RPE-T scores than any other position in the team. This single case study, while beneficial, may only be reflective of that team and their style of play. In addition, the RPE-T does not appear to directly relate to mental fatigue (rather a rating of coping with the technical demand of the match), which may influence the interpretation of the question and ultimately elicit varied responses from the players. Furthermore, even with a clear mental fatigue element incorporated into future d-RPE, both the subjective rating and possible difficulty for players to accurately define mental fatigue may make it difficult to interpret the implications of the data.

2.5 Lifestyle Factors

Aside from football-specific cognitive demands, it could be suggested that lifestyle factors may also contribute to mental fatigue. For example, many elite football players are likely to use a car as their mode of transport to and from the club's training facilities, a task that has been frequently reported to induce mental fatigue subjectively and objectively [21–23]. However, in these studies the driving protocols lasted between 90 min and 2 h, and the prevalence and duration of car driving are unknown amongst football players. Another task that may be performed by elite football players is playing video games, which require sustained attention, rapid reaction times and decision making. Despite no impact of FIFA 15 on mental fatigue reported in the study by Aliyari et al. [19] (see Sect. 2.3), further work in this area with a more robust methodology is required. Personal issues such as domestic stress, moving to new environments and contract issues are also important aspects to consider in elite football. A study of academy football players collectively highlighted such mental stressors as making errors, family issues and receiving a renewed contract [24]. An evaluation of the prevalence of these and other potential mental stressors and their relation to mental fatigue in senior elite football is warranted.

2.6 Future Research

To further understand mental fatigue in elite football, several steps are suggested. Firstly, the use of surveys/interviews to chart the mental demands of high-level football, on and off the field, will allow researchers to understand which tasks, if any, players find mentally fatiguing. To date, no known research has been conducted on elite players, and the prevalence of mental fatigue therefore remains unclear. Such topic areas of interest could be the perceived mental demands of fixture congestion, travel and acute match-play demands, and understanding the common pre-match activities and rituals performed by players. These topic areas could also be linked together with different playing standards, playing positions, experience levels and age groups to determine individual differences. This will enable the design of more ecologically valid studies to investigate the effect of these 'mentally fatiguing' tasks on performance, providing a more realistic understanding of the real-world impact of mental fatigue on football performance. Additionally, future research should attempt to use tasks with high levels of CI to induce feelings of mental fatigue in participants (with the inclusion of appropriately selected physically matched control conditions), as these may better reflect the potential levels of mental fatigue experienced by football players during a game. Examples include isolated performance tests (i.e. passing, dribbling) or decision-making trials that are accompanied by audio and/or visual distractions to replicate match-play scenarios. It is also imperative to understand the individual response to mentally fatiguing protocols, as the current 20- to 30-min tasks may be too short for some individuals. Furthermore, another unknown quantity is the amount of time required to recover from feelings of mental fatigue, and how motivation/arousal may impact on this.

3 Measuring Mental Fatigue

3.1 What Has Been Used to Measure Mental Fatigue So Far?

All but one of the current studies investigating mental fatigue in football [4–6, 8, 9] have utilised a 100-mm visual analogue scale (VAS) [25] to assess subjective mental fatigue. The only exception to this is the remaining study, which only used RPE to measure perceived workload [7]. In the mental fatigue in football literature, participants completed a VAS before and after the mentally fatiguing/control conditions, plus immediately after the small-sided games [4–6, 8, 9]. Whilst recognising the VAS as a valid way to measure subjective mental fatigue, there are some shortcomings with this method as the primary measurement of mental fatigue in football research. In this section, issues related to bias of the VAS, respondents' uncertainty over the definition of 'mental fatigue' and the difficulties associated with masking the aims of mental fatigue research studies using this measurement tool will be discussed. In addition, the use of objective methods as an alternative to measuring mental fatigue will be examined.

3.2 Response Bias and Defining 'Mental Fatigue'

In mental fatigue research, the response bias and the difficulty participants have in personally defining the meaning of 'mental fatigue' should not be underestimated. The participants in these studies may be prone to different types of response bias. More specifically, participants in studies using VAS to assess mental fatigue may suffer from acquiescence bias, a response bias related to a tendency to agree with questions posed by investigators [11]. Furthermore, participants in these studies may also provide altered responses because they understand they are part of an experiment investigating mental fatigue and therefore want to exhibit behaviour that is suitable in such an experimental context. This type of response bias has been termed 'demand characteristics' [26]. Moreover, participants in studies that investigate mental fatigue may be prone to self-assessment bias, especially if participants lack the ability to truly understand what is meant by 'mental fatigue' (in other words, they may lack metacognition). Consequently, it is likely that participants with relatively high or low levels of actual mental fatigue asked to self-report their perceived mental fatigue will over- or underestimate their actual mental fatigue, especially when they lack a clear understanding of the term.

While response bias is inevitable in scientific research, steps can be taken to minimise its effects. Response bias resulting from demand characteristics can be reduced by limiting the exposure participants have to the VAS aimed at assessing mental fatigue, as repeated exposure to these subjective ratings might increase the likelihood of participants identifying the true intentions of the experiment. Incorporating a control condition task with greater cognitive engagement (in comparison with reading magazines) and which more closely resembles the mentally fatiguing task (e.g. congruent vs incongruent/low practice variability vs high practice variability tasks) may also aid in minimising response bias. In addition, a potential solution may be to adopt a matched group design, rather than a crossover design. However, when adopting this design, researchers should be aware that larger sample sizes are required, and groups must be well matched. Finally, it has been indicated that self-assessment bias can be overcome by increasing participants' metacognitive skills [27]. Therefore, the potential assessment bias associated with the self-reporting of mental fatigue can be overcome by providing a clear and uniform

operational definition of mental fatigue and any other subjective measures.

3.3 The Use of Objective Methods to Measure Mental Fatigue

Future research on mental fatigue in football may benefit from the use of objective methods that measure psychophysiological (i.e. neural, optical and cutaneous) responses to cognitive tasks. Many examples exist, such as galvanic skin response, functional near-infrared spectroscopy and pupillary response, which have all assessed mental workload during cognitively demanding tasks [28–30]. However, the most common psychophysiological objective method used to assess mental fatigue is electroencephalography (EEG), a measurement of spontaneous electrical activity in the brain. Across the sport science literature, EEG activity has been measured in treadmill endurance performance [31], knee extension exercises [32], golf [33, 34], and physically active computer games [35]. Conducting studies in this field has proven difficult due to issues caused by excessive movement and sweat, in addition to noise and light disturbances, which can negatively influence the data collection [34, 36]. Despite the aforementioned findings in a challenging research area, all of these studies were completed in a static motion or with minimal head movement to enhance the quality of the EEG signal, questioning their practical value for a sport with the dynamic nature of football. With the current technology, research in football using EEG may be restricted to measuring the mental demands of zero to minimal movement quantity tasks such as football-specific decision-making trials [37] or virtual reality technology.

Aside from psychophysiological measures, cognitive task performance is another common measure of mental fatigue. Previous investigations that have examined time on task performance across general populations have shown mental fatigue causes a decrement in goal-directed attention, impairs performance adjustments after making errors and disturbs anticipation timing [12, 38, 39]. Based on the high quantity decision-making and rapid information processing demands of team sports, these findings may transfer into a football environment [3]. However, further research is required, as the only football-specific study to investigate this reported that cognitive performance (i.e. football decision making) was negatively influenced by induced mental fatigue [6]. Such research may in fact be simpler to implement in an elite football environment in comparison with psychophysiological objective measurements because of its less invasive nature.

Overall, further research is required to elucidate the effects of football-specific tasks on mental fatigue using various objective methods. It must be noted, however, that studies using psychophysiological objective methods (i.e. EEG) may only be possible to conduct in a laboratory setting with non-elite football players based on the practical difficulties in elite settings, which does not provide ecological validity. The equipment set-up times required, invasive properties of the protocol and frequent need to remove elite players from a congested playing and training schedule may collectively prove too difficult to overcome. These considerations not only highlight the challenges inherent in conducting objective measurements in elite football settings but also raise questions about the impact of these findings in the field. Developments in technology and/or the emergence of other objective methods (ecologically valid cognitive task performance protocols) may help to allow future research projects to better integrate, particularly with elite environments, plus also help to differentiate feelings of mental fatigue and boredom, which is currently challenging when using solely subjective measurements to measure mental fatigue.

4 Conclusions

To date, available studies suggest induced mental fatigue negatively influences physical, skill, decision making, technical and tactical aspects of football performance, both in isolated performance tests and small-sided games. However, these studies are limited by tasks with low ecological validity to induce mental fatigue and the use of the VAS to measure mental fatigue, which must be addressed in future research. Future research should use surveys/interviews with elite football players to better understand the source of mental fatigue. These findings inform the development of mentally fatiguing protocols with greater ecological validity than the existing options. It is also imperative to understand individual variation in susceptibility to mental fatigue from these protocols and the amount of rest required to recover from them.

Future study designs may also benefit from reduced reliance on VAS to measure mental fatigue and participants being provided with a clear definition of mental fatigue, which may lower response bias. Whilst objective measurement technology has proven effective in measuring mental workload during cognitively demanding tasks, the current likelihood of its involvement away from a laboratory setting is minimal due to its invasive nature and the inevitable time constraints in (elite) football settings. Therefore, we recommend further studies investigating objective responses to mentally fatiguing protocols in football to consider the use of more practical and less time-consuming protocols to help bridge the gap between research and applied settings.

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