FINAL REPORT

THE EFFECTS OF MENTAL FATIGUE ON REPEATED SPRINT ABILITY AND COGNITIVE PERFORMANCE IN FOOTBALL PLAYERS

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INTRODUCTION

Rationale and aims of the study

Professional football is a game that is characterized by high stakes, a pressure to succeed and perform optimally, coupled with a celebrity life-style. This can, and often does, prove too much for players given the number and frequency of match performances during a football season in which optimal performance is required. As a results, football players often develop a state of mental fatigue that negatively affect their performance. Although no scientific evidence exists to prove this phenomenon, anecdotal evidence is overwhelming. For example, Arsene Wenger suggested that he believed his squad had shown “a bit of mental and physical fatigue” following an under par 1-1 draw with Fulham (November 2011) in the English Premier League that followed a midweek victory over Borussia Dortmund in the group stages of this seasons Champions League. Further, last season Manchester City manager Roberto Mancini (March 2011) spoke about his worry that mental fatigue would stop his side from gaining silverware due to the long and demanding English football season. During his interview with the Eurosport TV channel he suggested that the constant physical stress of preparation for matches, and mental stress of media scrutiny was taking its toll on his players. Mental fatigue is not just an issue that affects English football; at the start of the current football season in Germany, Borussia Dortmund coach Jurgen Klopp suggested that fatigue affected the performance of his team following a shock 1-0 defeat to Hoffenheim. He suggested that players were fatigued following the extra stresses of mid-week international matches and media attention on his players. When asked about the performance, Klopp is quoted as saying “I do not know how to measure mental fatigue, but we have found a physical tiredness." From the exemplary quotes provided above, it is clear that mental fatigue is an extreme condition that negatively affects the performance of professional football players. In some players, acute mental fatigue may develop into a medical condition called “overtraining” which is characterized by chronic symptoms of fatigue and reduced performance (Budgett et al., 2000). Nevertheless, research linking mental fatigue and sport performance is sparse. Therefore, there is an urgent need for further investigations on the impact and neurophysiological mechanisms of mental fatigue in football players.

Among scientists, mental fatigue is defined as a psychobiological state caused by prolonged periods of demanding cognitive activity, and characterized by subjective feelings of “tiredness” and “lack of energy” (Boksem and Topps, 2008; Ackerman, 2010). Experimental evidence from our research group has demonstrated that mentally tired individuals will reach physical exhaustion quicker than those who are not mentally fatigued during high intensity cycling exercise, meaning a suboptimal level of performance (Marcora et al., 2009). Not only is physical performance affected by mental fatigue, but research has also shown that cognitive performance is reduced in a state of mental fatigue (Boksem and Topps, 2008; Ackerman, 2010) Whether, mental fatigue has an impact on cognitive performance in football players and on football-specific physical performance is currently unknown. Similarly, the brain alterations associated with mental fatigue in football players have never been investigated. During strenuous exercise like repeated sprints, hyperventilation may reduce arterial partial pressure of CO_2 and impair blood flow/O_2 delivery to the brain with consequent impairment in physical performance (Nybo and Rasmussen, 2007). A reduction in brain oxygenation has also been associated with impaired performance during prolonged cognitive tasks (Li et al., 2009). Therefore, an interaction between strenuous exercise and mental fatigue on brain oxygenation is plausible.

The aim of the studies presented in this report was to fill these gaps in the literature by investigating the effects of mental fatigue on two football-specific physical performance tests (repeated sprint ability, RSA, and Yo-Yo intermittent recovery test), cognitive performance, and brain oxygenation in football players.

Study progression

In July 2013, UEFA kindly granted us funding for our study on the effects of mental fatigue in football players. However, one of the conditions was that we modified our experimental protocol so that RSA was tested with an exercise mode specific to football rather than on a stationary cycle ergometer. In our original experimental protocol, we proposed the stationary cycle ergometer to assess RSA because many of the measurement methods we were planning to use are sensitive to movement, particularly electroencephalography (EEG). Therefore, the stationary nature of the cycle ergometer was advantageous in this respect. Furthermore, RSA has been measured using a stationary cycle ergometer in many previous scientific studies on the mechanisms of fatigue (Girard et al., 2011). However, we understood the concerns of UEFA, and proposed to perform the RSA test on a non-motorized Woodway treadmill specifically designed to assess performance during sprinting in a stationary manner. Our proposal was accepted by UEFA, and this decision was communicated to us via email on the 16th of September 2013. After this approval, we purchased this special treadmill and started pilot testing with professional football players. However, during pilot testing, it became clear that professional football players did not like being tested on this special treadmill because they found the running pattern unnatural. Given that UEFA wanted us to assess RSA with an exercise mode specific to football, we thought that this poor tolerability in professional football players defied the original purpose of using this special treadmill to assess RSA. Therefore, we decided to modify once again our experimental protocol and use a RSA test we previously used to assess elite professional football players in the field (Rampinini et al., 2007).

Due to the non-stationary nature of this field test, using this RSA test posed many challenges to us. We had to modify our proposed measurement methods so that we could measure all the major physiological systems relevant to physical performance in football (brain function, cardiovascular function, muscle function and metabolism) in the field during high-speed running and changes of direction. Therefore, we need to use measures that are not extremely sensitive to movement, and that are portable so that can be carried to training pitches of Gillingham Football Club (FC) for testing.

Gillingham FC is based in Gillingham, a city very close to the Medway Campus of the University of Kent in which the School of Sport and Exercise Sciences is located. Gillingham Football Club is the only Kent-based club in the Football League and in 2013–14 they compete in Football League One, the third tier in the English football league system. In spite of some disruption due to a change of manager in October 2013, we managed to reach an agreement with the club and started to test their players in the last week of November 2013.

Unfortunately, in December 2013 and January and February 2014, England faced the worst weather since records began. Because of the field nature of this study and the big impact that poor pitch conditions can have on sprinting performance, we had to cancel most the programmed testing sessions because of heavy rain. Furthermore, the adverse weather made even more difficult to fit research testing in the busy training and competition schedule of professional football players as they did not have many opportunities to train in good pitch conditions, and the coach did not want to "waste" these opportunities. These logistical issues meant that, to date, we have only completed full testing of only three participants. The weather has now improved and we are planning to continue testing players from Gillingham FC over the next 3-6 months to complete this study (Study 1). We are sure the sport science experts of UEFA understands how difficult it is to complete data collection for a field study with busy professional football players in only four months even when the weather is good. Therefore, we hope that an extension will be granted for this study which also had a delayed start to refine the protocol according to UEFA recommendations.

However, we have included in this report the final results of an additional study (Study 2) we have conducted to avoid the negative impact of bad weather during the winter months. This study was based on the review of our interim report in which one of the reviewers made a very positive comment on our choice to use the Yo-Yo test. Therefore, we decided to use this test indoor to produce the very first experimental evidence that mental fatigue can affect physical performance in football players.

STUDY 1

METHODS

Subjects

A group of six professional footballers from Gillingham F.C. have been recruited so far. All six players completed the preliminary testing, but one player has since withdrawn from the study due to injury. Three of the remaining five players have completed all three testing sessions. Subjects were informed about the study protocol and gave written informed consent. However, subjects were informed that the study was about the effects of two different cognitive activities on the physiological responses during subsequent exercise to avoid nocebo effects on performance and subjective ratings. The present investigation was performed according to the Declaration of Helsinki and was approved by the local ethics committee.

Experimental protocol

This was a randomized, single-blind, crossover, counterbalanced study investigating the effects of mental fatigue on RSA and other dependent variables. Subjects were tested over three visits with at least 72 hours of recovery between them.

Visit 1

During this visit subjects performed the Yo-Yo intermittent recovery test (Level 1) and familiarize themselves with the RSA test and with all the devices and procedures used during the experimental sessions. The Yo-Yo test consists of repeated exercise bouts performed at progressively increasing speeds, interspersed with 10-s active rest periods and performed until the subject is exhausted. The Yo-Yo test has been fully validated (Bangsbo et al., 2008) and it is widely used to measure physical performance in football players, including professionals. The main parameter of this test is distance covered in metres.

Visits 2-3

As shown in Figure 1, during these two visits subjects were tested in two different conditions. In the mental fatigue condition, subjects performed a Stroop task for 30 min. The Stroop task is a mentally demanding cognitive task consisting in a list of printed words where words and the ink colour in which the words were printed were mismatched (e.g., the word “green” was printed in blue ink). Subjects were required to say aloud the colour of the ink in which the word was printed (e.g., for the word “green” printed in blue ink, they had to say “blue”). In addition, for words appearing in red ink, subject had to override the general instructions and say aloud the name of the printed word. In a recent study from our research group, this experimental treatment induced a significant reduction in physical performance (Pageaux et al., in press). In the control condition, subjects performed a non-demanding cognitive task (watching a documentary about the history of Ferrari) for 30 min.

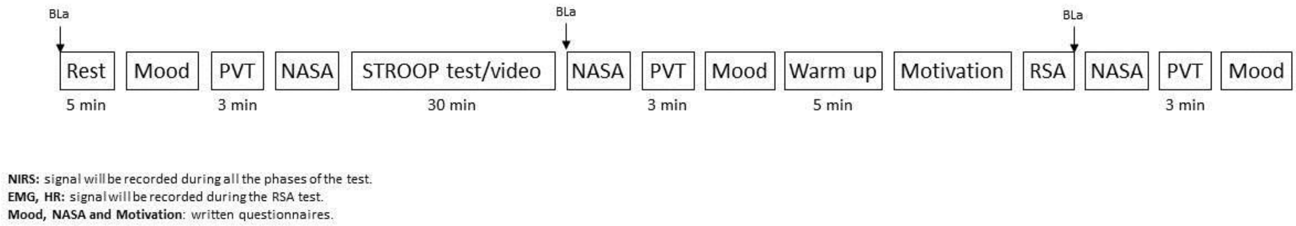

Figure 1. Diagram of the experimental protocol

Physical performance and physiological measures

RSA was measured after the cognitive tasks using a protocol consisting of 10 shuttle sprints of 40 m (20 + 20 m) at the maximal velocity possible interspaced by 20 s of passive recovery preceded by a light 5 min warm-up. During this RSA test, exercise intensity was quantified by HR and blood lactate concentration. HR was monitored continuously by a heart rate monitor (Polar RS800CX, Polar Electro Oy, Kempele, Finland), and a 20-µl sample of whole fresh blood was taken from the finger at rest and immediately after the RSA and then analyzed for lactate concentration using a portable analyser (Super GL2, Dr. Müller Gerätebau, Germany).

Brain oxygenation was assessed via near infrared spectroscopy in the bilateral prefrontal cortex using a portable device (Portalite, Artinis, Zetten, The Netherlands) emitting continuous wavelengths of 760- and 850-nm. Probes were symmetrically placed on the left and right prefrontal cortex, Fp1/Fp3 (left) and Fp2/F4 (right) respectively according to the international electroencephalographic 10-20 system. The distance between the emitter and detector was set at 4 cm. Sampling frequency was set at 10 Hz. Changes from baseline in concentration for oxyhaemoglobin (ΔO2Hb), deoxyhaemoglobin (ΔHHb), total haemoglobin (ΔtHb = O2Hb + HHb) and haemoglobin difference (ΔHb diff = O2Hb− HHb) were calculated during all the phases of the experiment. An age-dependent differential optical pathlength factor for cerebral cortex was used in this study. Data were averaged over the last minute for baseline and PVT tests, while for the cognitive tasks data were averaged over the last 5 min. During the RSA test data were averaged over the last 5 s for every sprint.

Electromyographic (EMG) signals were recorded during the RSA test from the right vastus lateralis and medialies muscle. Before placing the Ag/AgCl electrodes (Swaromed Universal, Nessler Medizintechnik, Innsbruck, Austria) the skin was shaved, cleaned with alcohol swabs and dried. The reference electrode was placed at the patella of the same leg. EMG signal was then acquired by a wireless portable device (MP150, Biopac Systems Inc, Santa Barbara, CA, USA) during the RSA test. EMG data will be analysed by an expert after completing data collection. A subject instrumented with the physiological recording devices used in this study is shown in Figure 2 A, B, C.

Cognitive performance and psychological measures

At the end of each sprint , subjects were asked to rate how heavy and strenuous the exercise was by using a 15 points rating of perceived exertion (RPE) scale (Borg 1998). Mood was measured before and after the cognitive tasks and again after the RSA test using the Brunel Mood Scale (BRUMS) developed by Terry et al (2003). Motivation related to the upcoming RSA test was measured using the success motivation and intrinsic motivation scales developed and validated by Matthews et al (2001) immediately before the warm-up preceding the RSA test. The NASA Task Load Index (NASA-TLX) rating scale (Hart and Staveland 1988) was used to measure the subjective demands of the cognitive tasks and the RSA test. Finally, the short version of Psychomotor Vigilance Test (PVT) (Basner et al., 2011) was performed before and after the cognitive tasks and after the RSA test in order to quantify the effects of mental fatigue and repeated sprint exercise on cognitive performance. In brief, visual stimuli were administered by red light on the screen of the portable apparatus (Figure 3). During this test the subject pressed a button as soon as the light appeared. The light turned on randomly every few seconds for 3 min. Performance in this test was assessed as the average response speed (inverse of reaction time).

Statistical analysis

The following are the most relevant results from the three subjects that completed the experimental protocol. Given the small sample size, inferential statistics are meaningless. Therefore, only descriptive statistics (mean ± SD) are provided and discussed. An addendum to this report containing the full results with inferential statistics will be provided after we completed this study.

Figure 2A. Front view of a participant instrumented with the physiological recording devices

Figure 2B. Lateral view of a participant instrumented with the physiological recording devices

Figure 2C. Rear view of a participant instrumented with the physiological recording devices

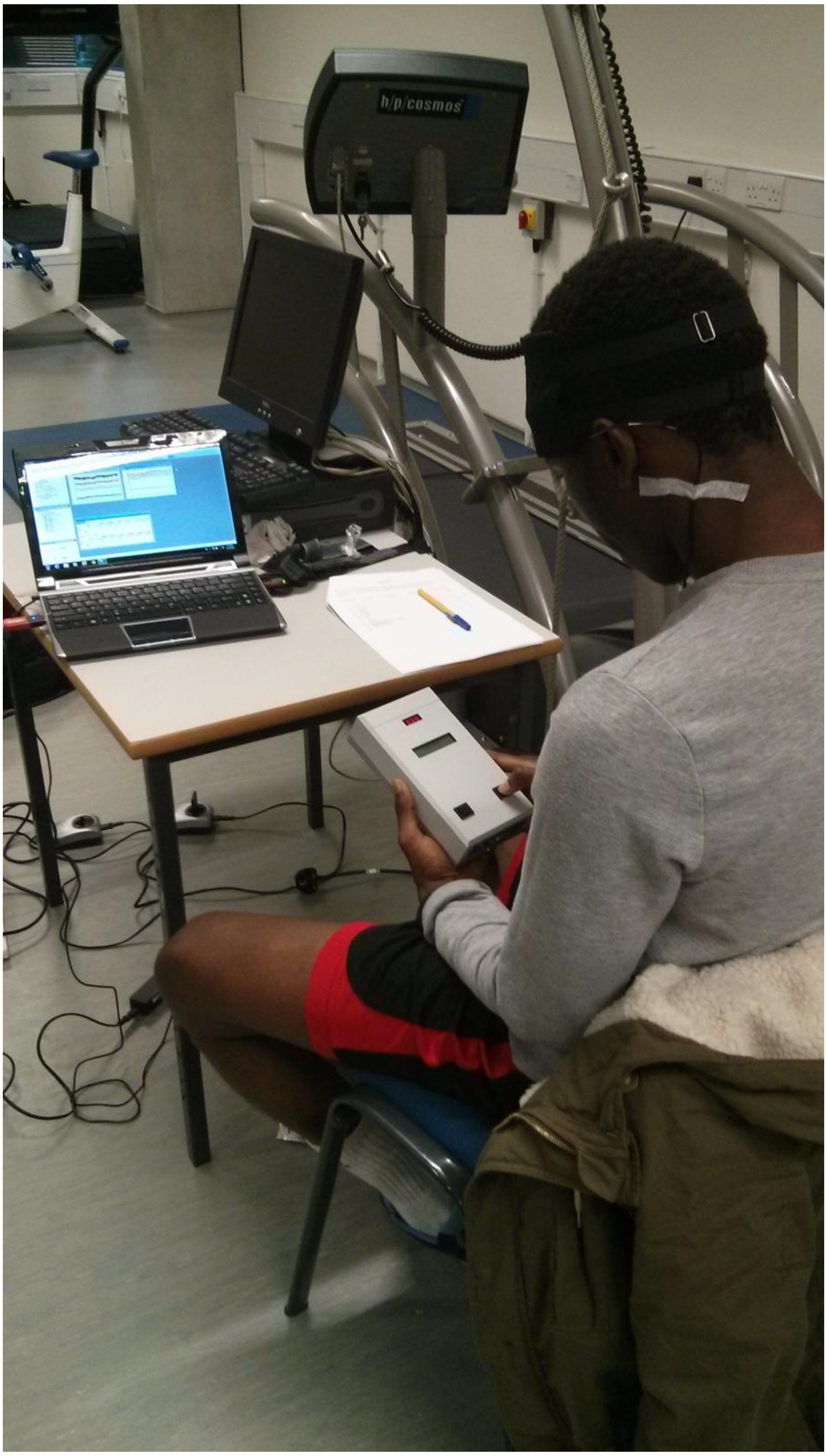

Figure 3. Participant performing a 3-min PVT test using a portable hand-held device

RESULTS

As shown in Figure 4, all six players tested so far have exceeded the performance top elite professional football players during the Yo-Yo intermittent recovery test (Level 1) (Bangsbo et al., 2008). This finding suggests that our sample is representative of professional football players in terms of physical performance.

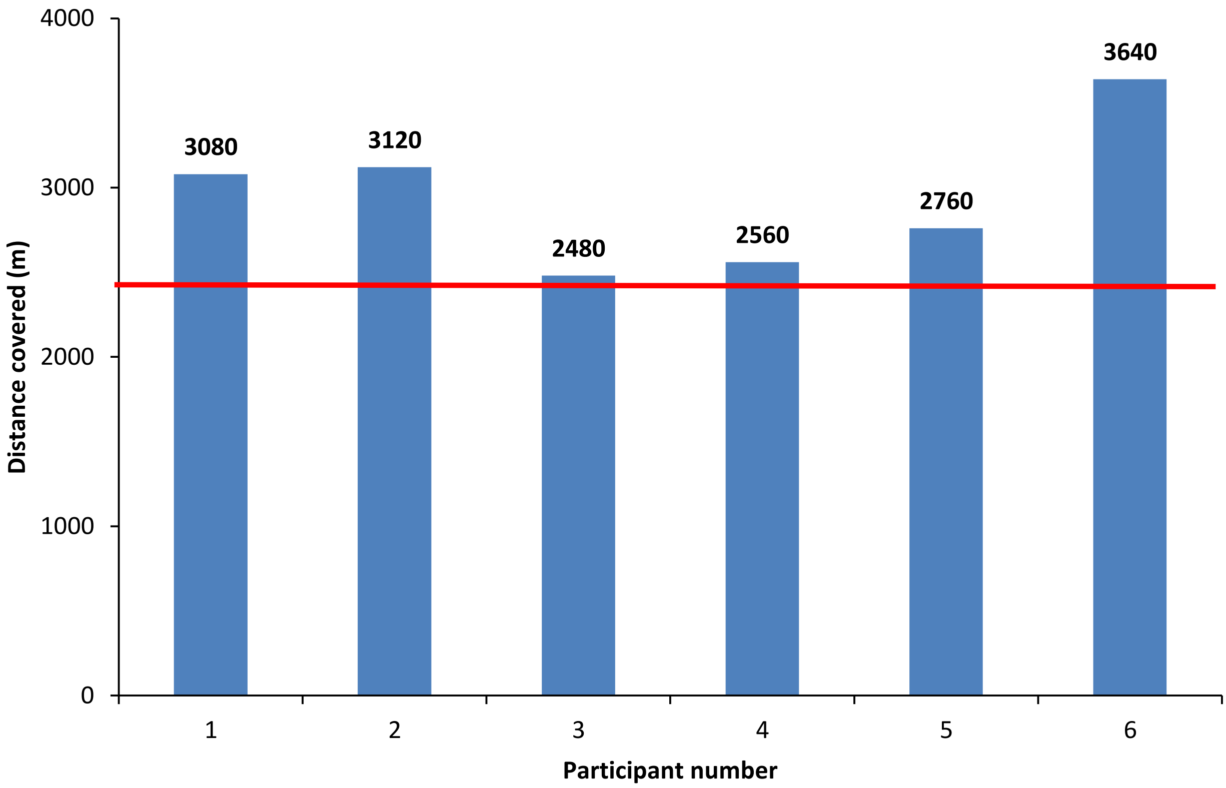

Figure 4. Gillingham F.C. football players performance in the Yo-Yo intermittent recovery test (Level 1). The red line indicates "top elite" performance

As expected, during the RSA test, we found a decline in speed over the 10 sprints in both conditions (Figure 5). After the first two sprints, subjects sprinted at a slower speed in the mental fatigue condition compared to the control condition. As a result, average RSA speed in the mental fatigue condition (17.9 ± 1.4 km/h) was slower than in the control condition (18.5 ± 0.8 km/h).

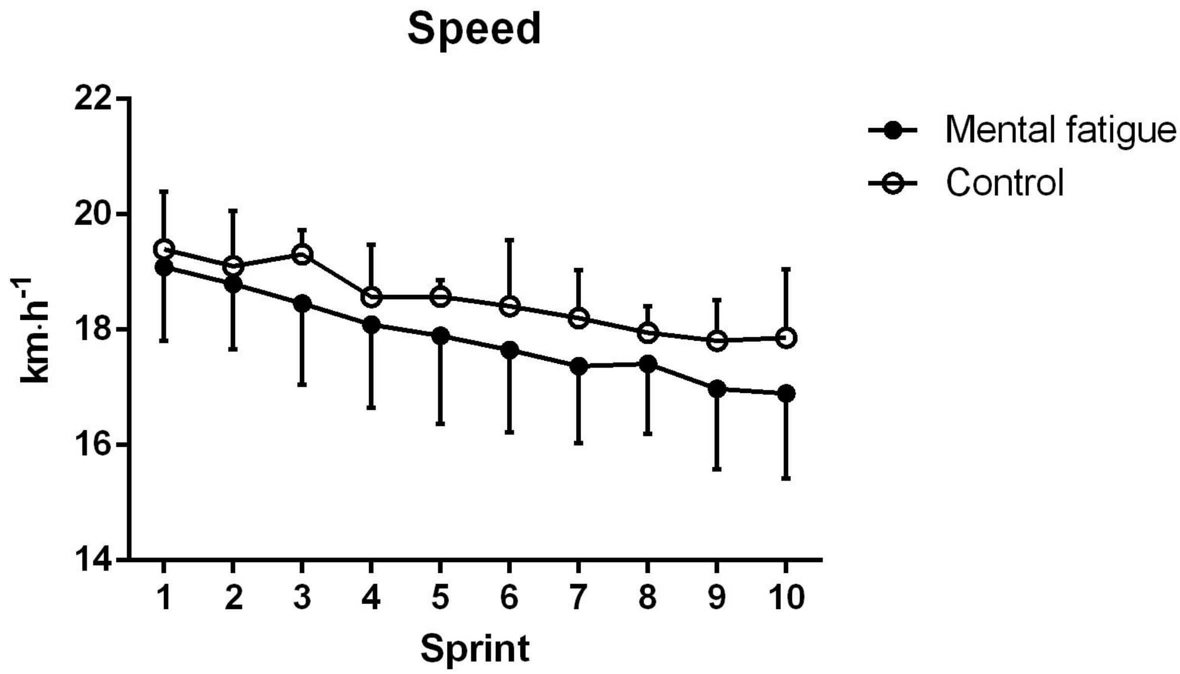

Figure 5. Effect of mental fatigue on sprint speed during the RSA test

Measures of exercise intensity such as HR during the RSA test (Figure 6) and blood lactate concentration after the RSA test (Figure 7) were lower in the mental fatigue condition compared to the control condition. This effect of mental fatigue was most likely due to reduced sprinting speed.

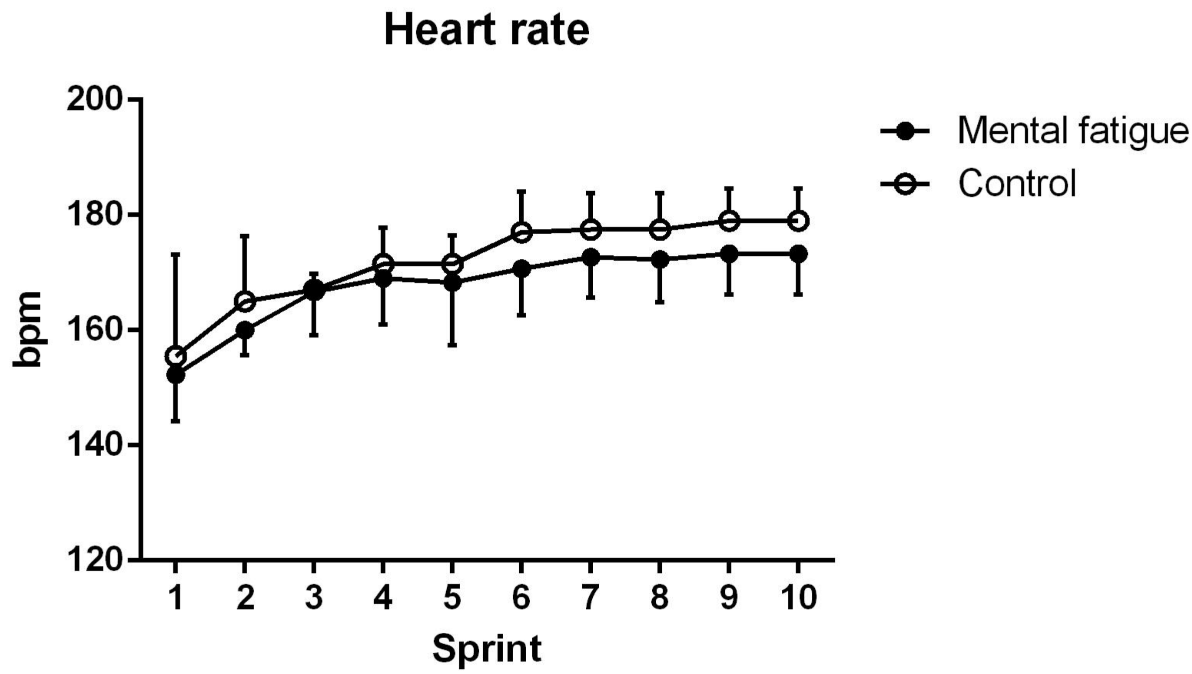

Figure 6. Effect of mental fatigue on heart rate during the RSA test

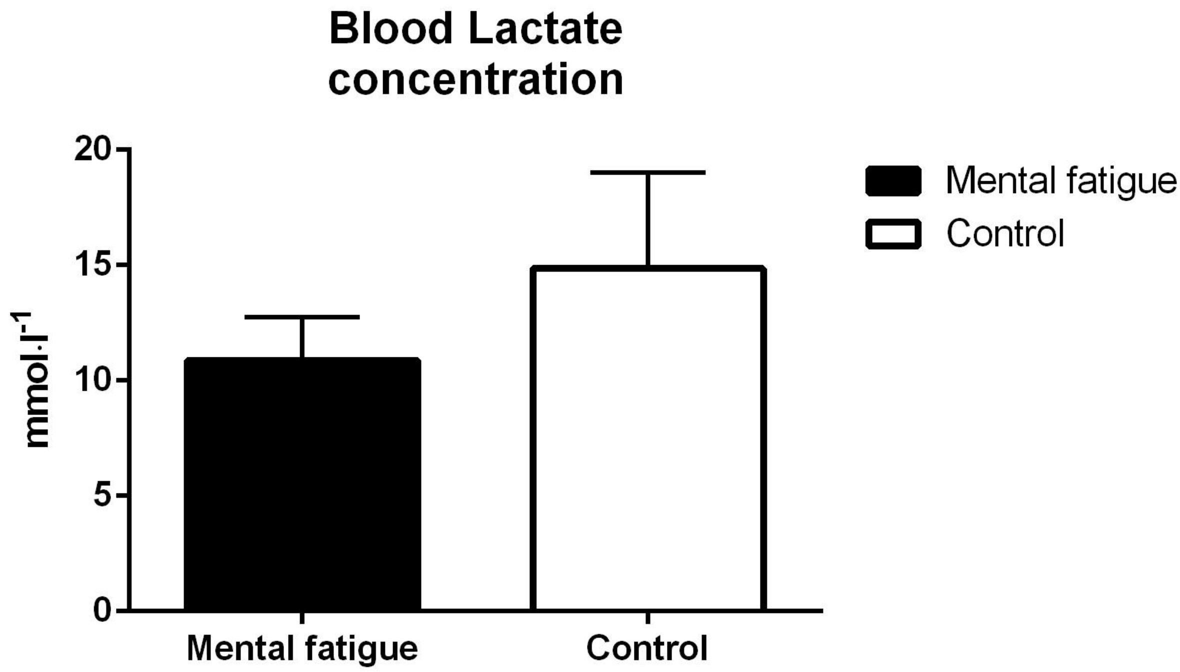

Figure 7. Effect of mental fatigue on blood lactate concentration after the RSA test

RPE, however, was higher in the mental fatigue condition during the first two sprints and similar to the control condition thereafter (Figure 8) despite lower exercise intensity. This effect suggests higher perception of effort during the RSA test in mentally fatigued subjects.

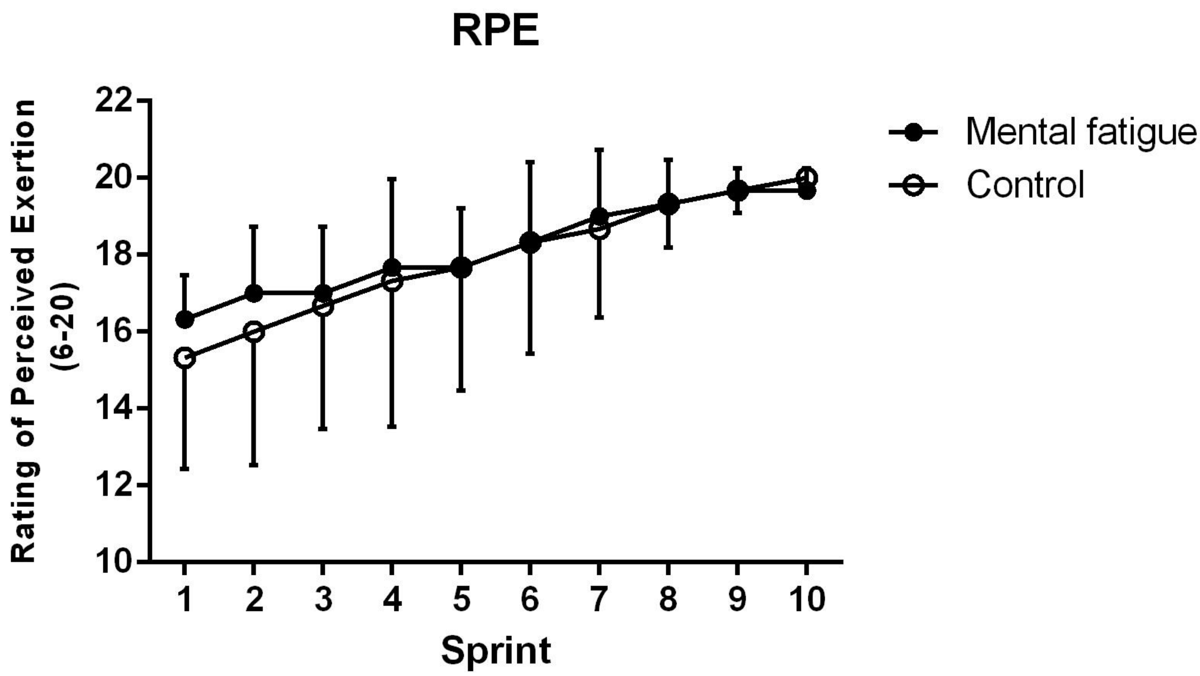

Figure 8. Effect of mental fatigue on RPE during the RSA test

The tissue oxygenation index data from NIRS of the prefrontal cortex suggest that subjects in the mental fatigue condition started the RSA test with a lower brain oxygenation compared to the control condition (baseline values in Figure 9). In both conditions, brain oxygenation declined during the RSA test.

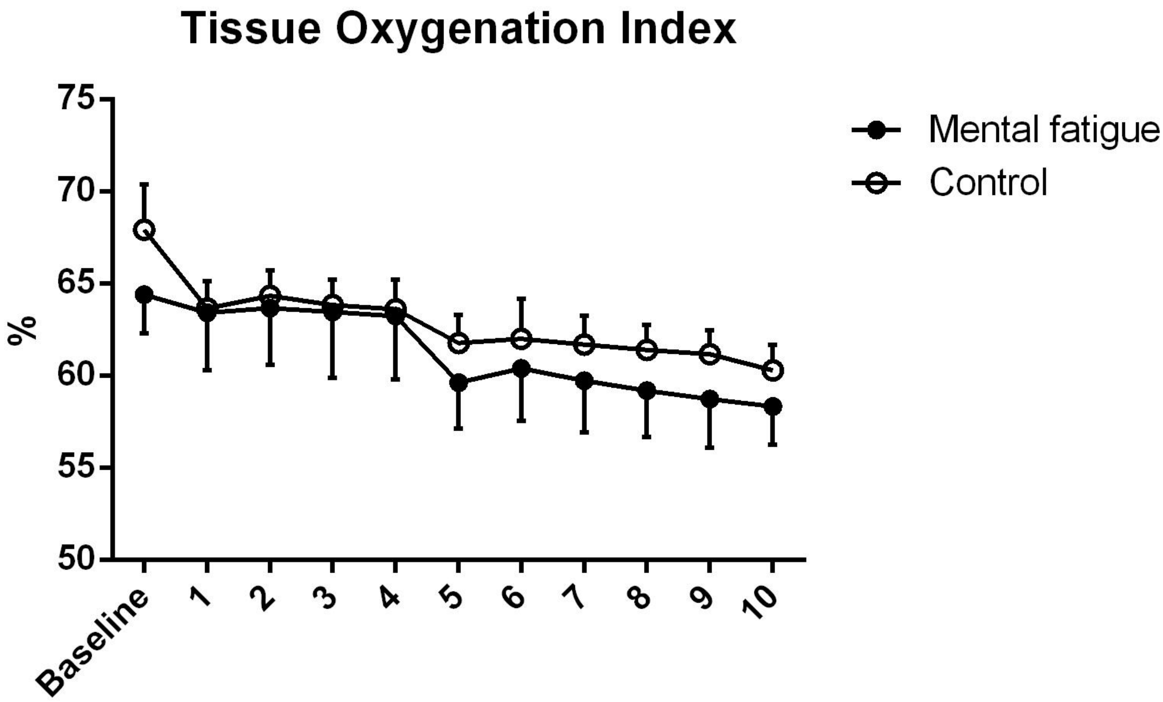

Figure 9. Effect of mental fatigue on brain oxygenation during the RSA test

With regards to the cognitive tasks, the subjects perceived the Stroop task (mental fatigue condition) to be more mentally demanding than watching the video (control condition) (Figure 10). However, subjective fatigue measured by our mood questionnaire was not higher in the mental fatigue condition compared to control (Figure 12). Subjective fatigue increased after the RSA test in both conditions probably because of the high physical demand of this test (Figure 11). Similarly, mean response speed in the PVT test was not affected by the cognitive task but was lower after the RSA test (Figure 13).

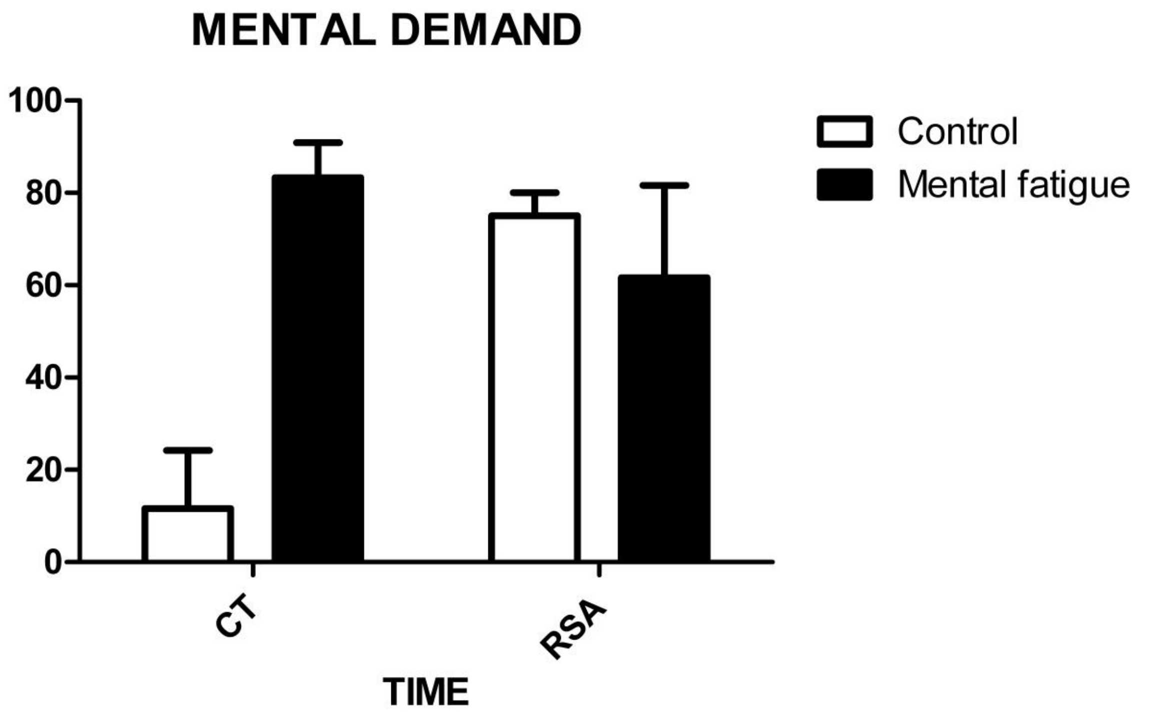

Figure 10. Effects of mental fatigue on mental demand of cognitive task (CT) and RSA test

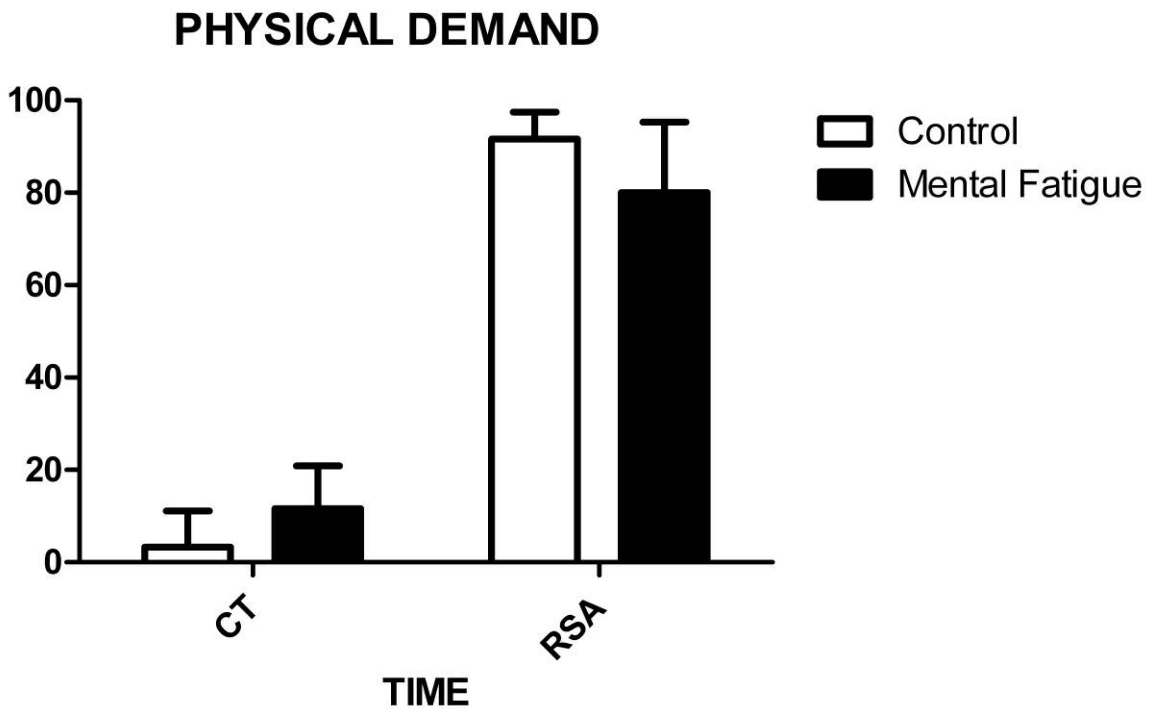

Figure 11. Effects of mental fatigue on physical demand of cognitive task (CT) and RSA test

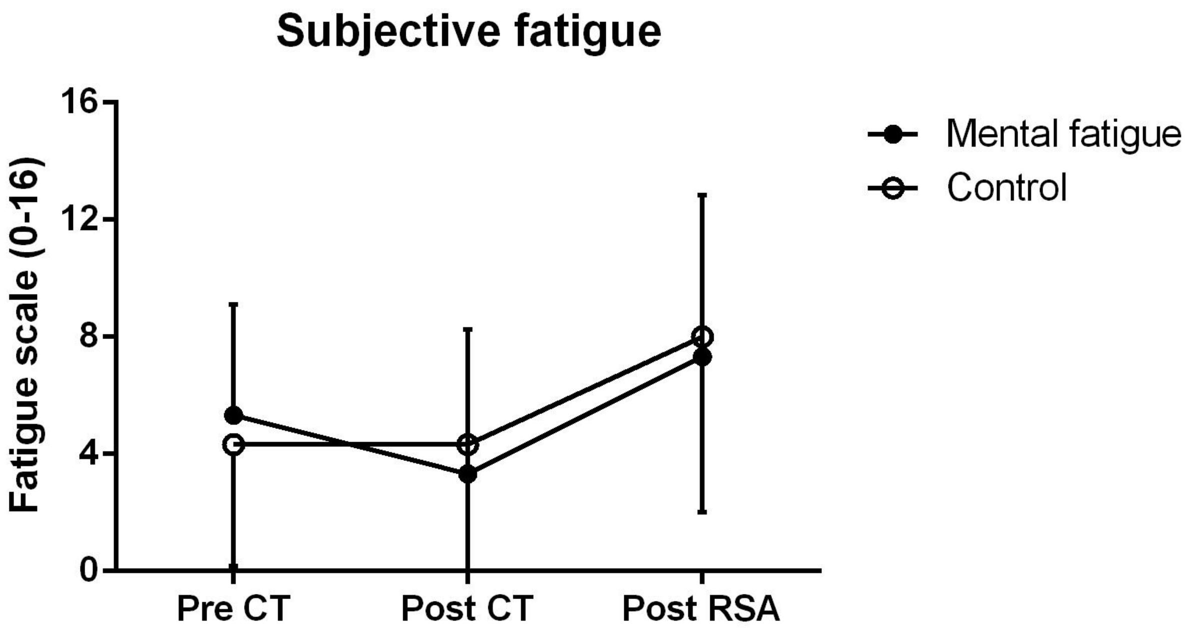

Figure 12. Effects of cognitive task (CT) and RSA test on subjective fatigue

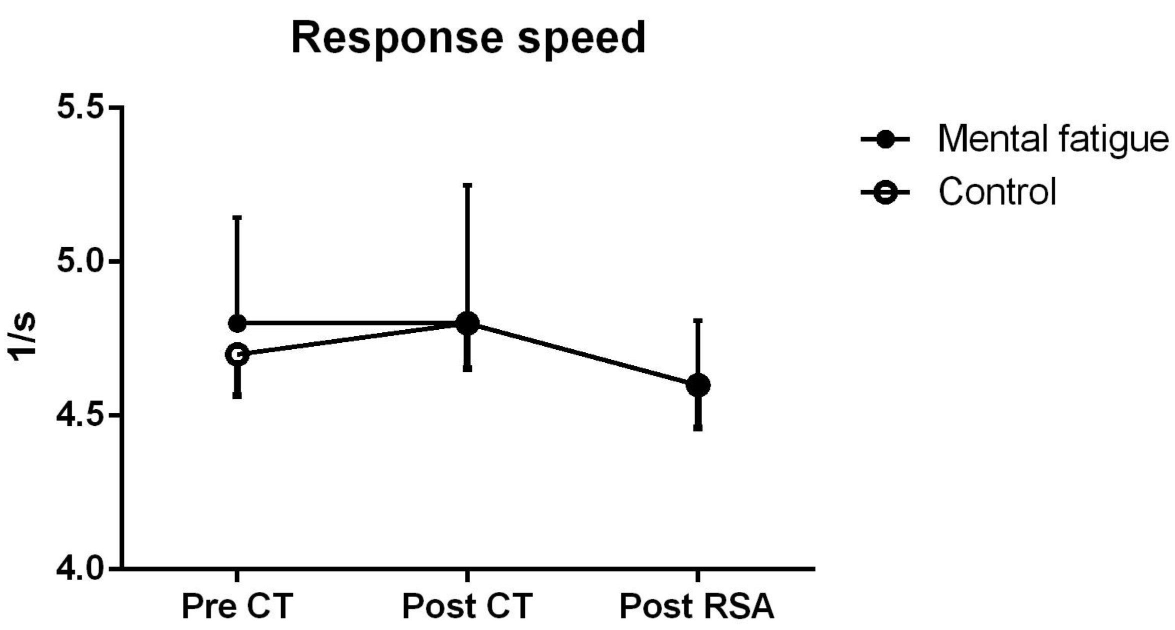

Figure 13. Effects of cognitive task (CT) and RSA test on PVT performance

STUDY 2

METHODS

Subjects

Twelve university level football players were recruited for this study. Subjects were informed about the study protocol and gave written informed consent. However, subjects were informed that the study was about the effects of two different cognitive activities on the physiological responses during subsequent exercise to avoid nocebo effects on performance and subjective ratings. The present investigation was performed according to the Declaration of Helsinki and was approved by the local ethics committee.

Experimental protocol

This was a randomized, single-blind, crossover, counterbalanced study investigating the effects of mental fatigue on Yo-Yo test performance and other dependent variables. Subjects were tested over three visits with at least 72 hours of recovery between them.

Visit 1

During this visit subjects were familiarised the Yo-Yo test and the other procedures used during the experimental sessions.

Visits 2-3

During these two visits subjects were tested in two different conditions. In the mental fatigue condition, subjects performed a Stroop task for 30 min. The Stroop task is a mentally demanding cognitive task consisting in a list of printed words where words and the ink colour in which the words were printed were mismatched (e.g., the word “green” was printed in blue ink). Subjects were required to say aloud the colour of the ink in which the word was printed (e.g., for the word “green” printed in blue ink, they had to say “blue”). In addition, for words appearing in red ink, subject had to override the general instructions and say aloud the name of the printed word. In a recent study from our research group, this experimental treatment induced a significant reduction in physical performance (Pageaux et al., in press). In the control condition, subjects performed a non-demanding cognitive task (watching a documentary about the history of Ferrari) for 30 min.

Measures

Physical performance was measured after the cognitive tasks using the Yo-Yo intermittent recovery test (Level 1). This test consists of repeated exercise bouts performed at progressively increasing speeds, interspersed with 10-s active rest periods and performed until the subject is exhausted. The Yo-Yo test has been fully validated (Bangsbo et al., 2008) and it is widely used to measure physical performance in football players, including professionals. The main parameter of this test is distance covered in metres.

During the Yo-Yo test, HR was monitored continuously by a heart rate monitor (Polar RS800CX, Polar Electro Oy, Kempele, Finland). At the end of each level, subjects were asked to rate how heavy and strenuous the exercise was by using a 15 points rating of perceived exertion (RPE) scale (Borg 1998). Visual analogue scales (VAS) were used to measure motivation related to the Yo-Yo test ("how motivated are you to perform well in the Yo-Yo test?"), mental fatigue ("How mentally fatigued do you feel right now?") and the effort exerted during the cognitive tasks ("How effortful was the cognitive task?"). Subjects were asked to answer these questions by marking a point on a 10 cm line with two anchors: "Not at all" (0) and "Extremely" (10).

Statistical analysis

All data are presented as mean ± SD. The effects of condition (mental fatigue vs. control) and time (first 6 levels of Yo-Yo test) on HR and RPE were tested using 2 x 6 fully repeated-measures ANOVAs. The effects of condition and time (pre and post the cognitive task) VAS mental fatigue were tested using 2 x 2 fully repeated-measures ANOVAs. The effects of condition on distance covered, VAS motivation, VAS mental effort, and RPE at exhaustion were analyzed using paired t-tests. For all analyses, statistical significance was set at $P < 0.05$.

RESULTS

Subjects rated the Stroop task (mental fatigue condition) to require significantly more effort than watching the video (control condition) (7.0 ± 2.0 vs 2.3 ± 2.0) ($p < 0.001$). As a result, ratings of mental fatigue increased significantly in the mental fatigue condition but not in the control condition (condition x time interaction $p < 0.001$) (Figure 14). After the Stroop task subjects reported moderate levels of mental fatigue (5.2 ± 1.1).

Motivation to perform well in the Yo-Yo test was not significantly affected by this mental fatigue (mental fatigue condition = 5.6 ± 2.1, control condition = 5.75 ± 2.7). Distance covered, however, was significantly lower in the mental fatigue condition (1203 ± 402 m) compared to the control condition (1410 ± 354) ($p < 0.001$).

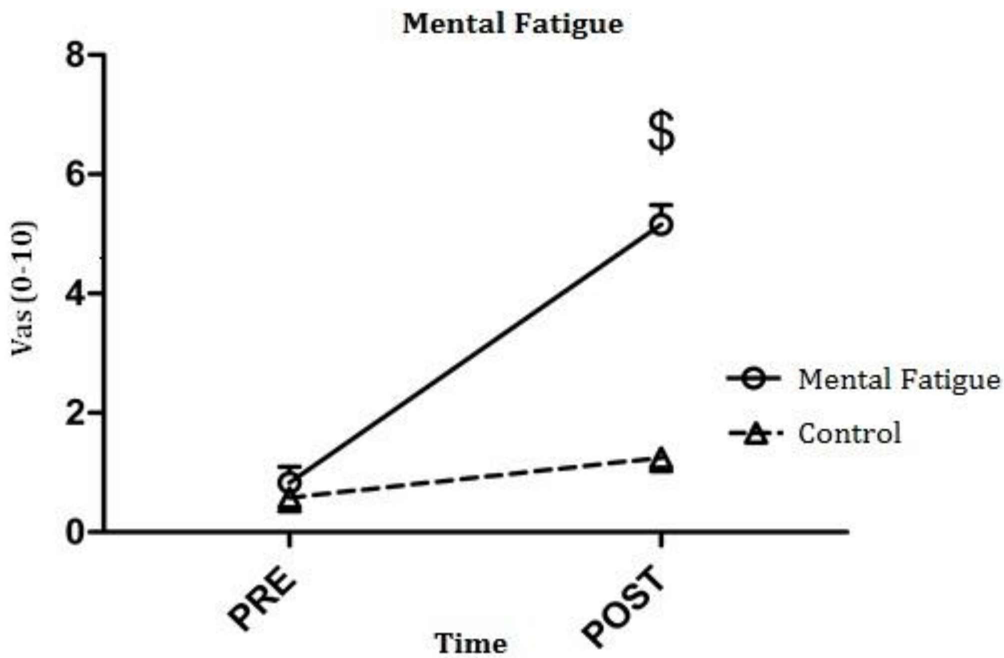

Figure 14. Effects of condition and time on subjective fatigue.

$ = condition x time interaction P < 0.001

HR and RPE increased over time in both conditions (Figures 15 and 16).

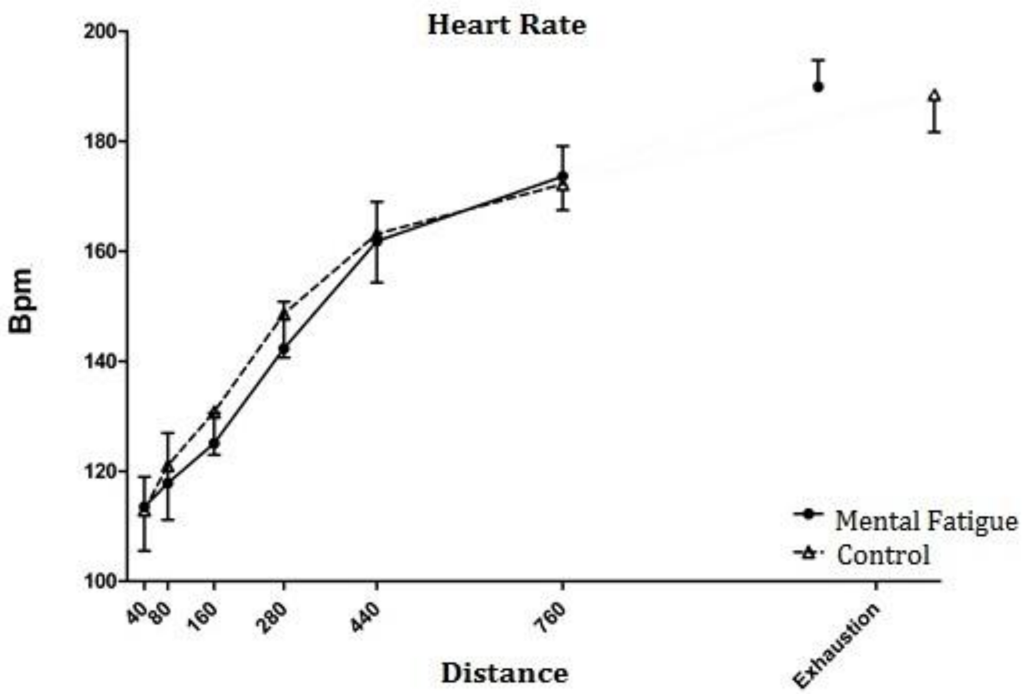

Figure 15. Effects of condition and time on heart rate

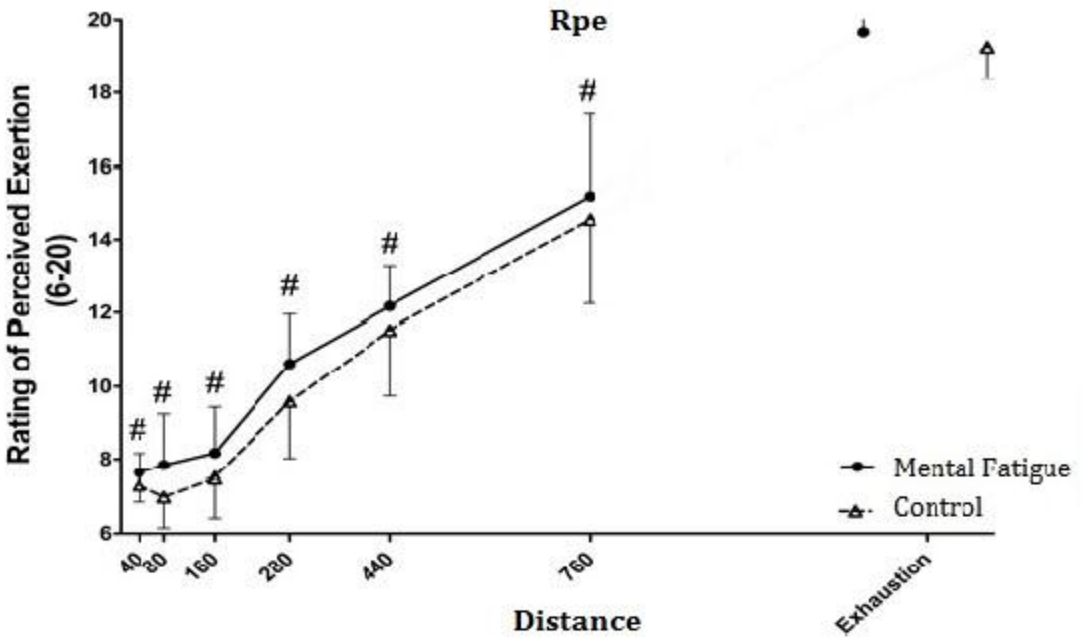

Figure 16. Effects of condition and time on RPE. # = main effect of condition P < 0.01

Although mental fatigue did not have a significant effect on the HR response, subjects in the mental fatigue condition reported significantly higher RPE during the first six levels of the Yo-Yo test compared to the control condition (main effect of condition, p <0.01). RPE at exhaustion was not significantly different between conditions.

DISCUSSION

We have reported here the very first experimental evidence that mental fatigue can affect the physical performance of football players. In fact, in Study 2, we measured a significant 15% reduction in distance covered during the Yo-Yo test. Because this test is positively correlated with measures of physical performance during real football matches (Rampinini et al., 2007), this finding suggests that mental fatigue may indeed affect performance on the pitch as anecdotally reported by many coaches and players in professional football. Interestingly, the 15% reduction in physical performance we found in Study 2 is similar to the effect of mental fatigue on time to exhaustion during high-intensity cycling exercise, a more generic test of physical performance (Marcora et al. 2009). This is not surprising as both the Yo-Yo test and high-intensity cycling exercise requires a high degree of exercise tolerance.

We have recently proposed that exercise tolerance in humans is primarily limited by perception of effort and motivation, and that any factor that decrease/increase perception of effort would result in an improvement/decrement in exercise tolerance (Marcora and Staiano, 2010). The results of Study 2 extend this psychobiological model to football. In fact, mental fatigue significantly increases RPE during the Yo-Yo test. As a result, subjects in the mental fatigue condition reached their perceived level of maximal exertion and stopped the Yo-Yo test earlier than in the control condition. This reduction in performance cannot be explained by an effect of mental fatigue on motivation because motivation ratings before the Yo-Yo test did not differ between conditions and because subjects exerted the same level of perceived effort at exhaustion.

Although the results of Study 1 should be considered preliminary because of the small sample size and consequent lack of statistical power, the slower average speed during the RSA test observed after the Stroop task is also consistent with the hypothesis that mental fatigue has a negative effect on physical performance in football players. Once again, motivation was not affected by mental fatigue. Our interpretation of the results is that subjects sprinted normally during the first two sprints (Figure 5) but perceived that they required significantly more effort to do so (Figure 8). Therefore, during subsequent sprints, they slowed down to maintain RPE within tolerable limits and complete the RSA test. There is no doubt that the reduction in speed over repeated sprints is primarily caused by cardiovascular, neuromuscular and metabolic processes leading to muscle fatigue (Girard et al., 2011). However, there is evidence that the brain also plays an important role as subjects pace themselves during repeated sprint exercise (Billaut et al., 2011). If we consider pacing during exercise as an effort-based decision making process (Renfree et al., 2014), then it is plausible that the negative effect of mental fatigue on perception of effort can lead to impaired performance even in physical performance tests where muscle fatigue plays a major role.

We believe that the negative effect of mental fatigue on perception of effort and physical performance is caused by alterations in the brain neurobiological state. Although the results of Study 1 should be considered preliminary, the lower level of brain oxygenation observed in the mental fatigue condition before the RSA test (baseline value) is consistent with the hypothesis that the negative effect of mental fatigue on perception of effort and exercise tolerance is psychobiological rather than just psychological. A negative effect on mental fatigue on brain oxygenation has been reported previously (Li et al., 2009), and there is evidence from various studies that a reduction in brain oxygenation may be linked with impaired physical performance (Nybo and Rasmussen, 2007). If confirmed after study completion, the effect of mental fatigue on brain oxygenation we found in Study 1 may provide a neurobiological mechanism for the negative effect of mental fatigue on physical performance in football players.

With regards to cognitive performance, the present results do not show a clear effect of mental fatigue on psychomotor vigilance. This is not surprising given the small sample size of Study 1 and the very complex relationship between mental fatigue and cognitive performance. In fact, over 100 years of research, cognitive performance has been shown to decrease, increase or remain stable in mentally fatigued subjects most likely because of compensatory effort and other motivational effects (Ackerman, 2010). What seems clearer is the negative impact of repeated spring exercise on psychomotor vigilance. In fact, response speed during the PVT was lower after the RSA test (Figure 13). This finding is in contrast with the findings of a recent meta-analysis on the acute effects of exercise on cognitive function (Chang et al., 2012). This review shows that when the exercise is hard, very hard, or maximal, there is no significant effect on cognitive function immediately after exercise. However, most studies included in this meta-analysis investigated the acute cognitive effects of continuous rather than intermittent exercise. If confirmed after study completion, the finding that high-intensity intermittent exercise can negatively affect psychomotor vigilance may have significant implications for performance of professional footballers. Clearly, high levels of physical fitness as those demonstrated by the six players recruited for Study 1 (estimated VO_{2max} 61.1 ± 3.6 ml/kg/min) do not prevent significant cognitive impairment during high-intensity intermittent exercise. Therefore, in addition to physical training, other strategies should be employed to reduce acute cognitive impairment during football matches. For example, caffeine in high doses is known to improve cognitive function in conditions of fatigue (Lorist and Tops, 2003) and the optimal use of this natural psychostimulant in professional football players should investigated not only in terms of improved physical performance but also in terms of cognitive performance and their interaction. Another possible strategy is Brain Endurance Training, a novel form of training that combines mentally fatiguing tasks with aerobic exercise. We have recently developed this kind of training in collaboration with the British Ministry of Defence, and found that it reduces fatigue in conditions in which physical and mental exertion is combined. Future studies should investigate whether Brain Endurance Training can improve physical and cognitive performance in football players.

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