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Title: The effects of mental fatigue on cricket-relevant performance among elite players

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Running head: "Mental fatigue in cricket players"

Abstract

This study investigated the effects of a mentally-fatiguing test on physical tasks among elite cricketers. In a cross-over design, ten elite male cricket players from a professional club performed a cricket run-two test, a Batak-lite reaction time test and a Yo-Yo-Intermittent Recovery Level 1 (Yo-Yo-IR1) test, providing a rating of perceived exertion (RPE) after completing a 30-min Stroop test (mental fatigue condition) or 30-min control condition. Perceived fatigue was assessed before and after the two conditions and motivation was measured before testing. There were post-treatment differences in the perception of mental fatigue ($P < 0.001$; $d = -7.82$, 95% CIs = -9.05 to 6.66; *most likely*). Cricket run-two ($P = 0.002$; $d = -0.51$, 95% CIs = -0.72 to 0.30; *very likely*), Yo-Yo-IR1 distance ($P = 0.023$; $d = 0.39$, 95% CIs = 0.14 to 0.64; *likely*) and RPE ($P = 0.001$; $d = -1.82$, 95% CIs = -2.49 to 1.14; *most likely*) were negatively affected by mental fatigue. The Batak lite test was not affected ($P = 0.137$), yet a *moderate* ($d = 0.41$, 95% CIs = -0.05 to 0.87) change was *likely*. Mental fatigue, induced by an app-based Stroop test, negatively affected cricket-relevant performance.

Introduction

Mental fatigue, caused by prolonged cognitive activity, has been characterized as a 'psychobiological state' and is associated with low levels of energy and feelings of tiredness (Boksem & Tops, 2008; Marcora, Staiano & Manning, 2009). Common neural networks for physical and mental activation have been suggested (Tanaka, Ishii & Watanabe, 2016), inferring a connection between mental and physical fatigue. Indeed, it has been established that mental fatigue negatively effects physical performance in simple continuous tasks, which have been attributed to higher perceptions of effort (Marcora et al., 2009; MacMahon, Schucker, Hagemann & Strauss, 2011). In this instance, perception of effort has been conceptualised as a centrally mediated efferent signal, referred to as 'corollary discharge', originating in the motor regions and innervating sensory areas of the cerebral cortex (Marcora et al., 2009). The negative effects of mental fatigue do not appear to reflect a greater development of either central or peripheral fatigue but, rather, are speculated to relate to alterations in regional brain activity, such as that of the anterior cingulate cortex (Pageaux, Marcora, Rozand & Lepers, 2015). There is now growing evidence to suggest that mental fatigue can affect more complex forms of exercise and skill-based tasks, which has a variety of implications for many other sports. For example, mental fatigue has been shown to impair sports-specific skill in soccer (Smith, Marcora & Coutts, 2015; Badin, Smith, Conte, & Coutts, 2016) and intermittent running performance (Smith et al., 2015; Smith, Coutts, Merlini, Deprez, Lenoir & Marcora, 2016), which has consistently been attributed to an increased perception of effort after repetitive, cognitively demanding tasks. Given the known deleterious effects of mentally-fatiguing tasks on cognitive ability (van der Linden & Eling, 2006), the reported effects on more complex, skilled sports performance might have been anticipated.

Cricket is a skilled sport and is characterized by prolonged low-intensity activity, interspersed by random periods of high-intensity movement (Petersen, Pyne, Portus & Dawson, 2009; Houghton, Dawson, Rubenson & Tobin, 2011; MacDonald, Cronin, Mills, Mcguigan & Stretch, 2013; Scanlan, Berkelmans Vickery & Kean, 2016). The physical demands imposed by cricket performance depend on field position and game format (Petersen et al., 2009). The external load (i.e. distance, speed and acceleration) of a game is typically lower for shorter formats (i.e. One-day), whilst longer multi-day games are more physically demanding (Petersen et al., 2009). Given its various formats (Test, One-day or Twenty20) and positional requirements (i.e. fielding batting and bowling), successful performance in cricket requires a variety of physical and technical abilities (MacDonald et al., 2013; Scanlan et al., 2016). However, there has been relatively less recognition of the mental challenges imposed by cricket (Gordon, 1990; Noakes & Durandt, 2000; Petersen et al., 2009; Macdonald et al., 2013). This is important because players must concentrate for prolonged periods, particularly in batting and fielding positions, where attentional focus could be required for an entire innings, lasting up to six hours per day in Test Match cricket (MacDonald et al., 2013). Furthermore, it is questionable whether the breaks provided to players during matches, or their activities during these periods, are sufficient to permit recovery from a mentally-fatigued state. It is therefore possible that mental fatigue could affect a cricket players' performance during games.

The physical demands of cricket performance are wide-ranging. For example, research has shown that prolonged bouts of intermittent bowling induces moderate metabolic perturbation, reporting blood lactate values of 4–5 mmol·l^{-1} (Burnett, Elliott & Marshall, 1995; Duffield, Carney & Karppinen, 2009), ratings of perceived exertion (RPE) of 11-15 (Devlin, Fraser, Barras & Hawley, 2001), with mean heart rates of 150 - 170 b·min^{-1} (Burnett et al., 1995; Devlin et al., 2001; Duffield et al., 2009; Petersen et al., 2009), depending on field position. Furthermore, cricket players have been shown to cover 2 km to 4.5 km·h^{-1}, with up to 60 high-intensity efforts across the same time period (Petersen et al., 2009). These data support the observed actions of bowlers, batsmen and fielders, who are frequently required to perform maximal sprints whilst approaching a delivery, performing runs or chasing balls in the open field, respectively. Finally, based on ball speeds in cricket of over 40 m·s^{-1}, batsmen or fielders have an approximate 2.5 ms window of opportunity to react to environmental cues and perform successful actions (Regan, Beverley & Cynader, 1979). These time-constrained conditions, coupled with numerous distractors during the game, place significant demand on the visual perception-action skills of cricket players (Müller, Abernethy & Farrow, 2006). It is therefore feasible that fatigue-induced errors may increase injury risk. Indeed, impact injuries and fractures are relatively common in key fielding positions (Stretch, 2003), thus highlighting the risks that fatigue-induced reductions in reaction times could pose.

It is common to use a battery of tests to measure the underlying qualities that are necessary to cope with the collective demands of cricket (ECB, 2016). Given the relationship between mental and physical fatigue, it is possible that mental fatigue could negatively affect performance in these tests. Accordingly, this study aimed to investigate the acute effects of a mentally-fatiguing task on cricket-relevant physical tasks among elite cricket players. It was hypothesized that the mentally-fatiguing task would negatively affect endurance capacity, intermittent sprint speed and reaction time.

Methods

Participants

Ten elite male cricket players (age = 21 ± 8 years; body mass = 77.1 ± 9.9 kg; stature = 184.9 ± 7.7 cm), with a minimum training age of two years, consented to take part in this study. The participants were selected from a professional county cricket club (CCC) in the UK. Based on the effect sizes reported in a recent comparable study (Smith et al., 2016), which were 'moderate' to 'very large' (Cohen's d = 0.48 – 2.37), a power analysis indicated that a sample size of seven would have been sufficient to identify differences between groups with a statistical power of 0.90 (G*Power, Version 3.0.10). Ten participants were selected to account for potential experimental mortality. During the study, the participants were instructed to maintain their normal diet and reported this on the day of each trial. All participants were instructed to avoid consumption of alcohol or caffeinated products, as well as abstaining from strenuous exercise in the 48-h before testing. Supplements, such as branched-chain amino acids and creatine were also restricted for seven days prior to the first trial. None of the participants were colour blind or vision-impaired. Institutional ethical approval was provided for this study, which was conducted in accordance with the 1964 Helsinki declaration.

Study design

The participants reported to the testing facility at the same time of day (1000 hrs) on three separate occasions, each separated by one week. The participants were familiarized to the testing procedures at visit 1 and, thereafter, were randomly assigned to one of the two conditions (mentally fatiguing task or non-mentally fatiguing task) in a randomized, cross-over trial. The cricket-based outcome measures were: a 'cricket run-two test'; a Yo-Yo-intermittent recovery test level 1 (Yo-Yo-IR1; Bangsbo, Iaia, & Krustrup, 2008) and a reaction-time and hand-eye co-ordination test (Batak Lite test; Gierczuk & Bujak, 2014). The study was performed during a pre-season period, when players were not competing in matches. The players training load was manipulated such that this didn't interfere the participation in this study.

Procedures

During familiarization (visit 1), participants were given verbal instructions and demonstrations on how to perform each of the tests. Whilst the participants were extremely familiar with the tests as part of their normal testing regime, every participant practiced each task until the investigators were assured of their familiarity. This included the partial completion of the mentally fatiguing tasks (see below) and the performance tests. The reliability for each test is stated in the following sections.

Treatment conditions

At visit 2 and 3, the participants completed one of the two conditions. During the mentally-fatiguing condition, 30 × 60-s Stroop tests were completed by each participant, with ~10-s separating each test (total of 35-min). The form of Stroop test used in this study is recognized as a mentally fatiguing, cognitively-demanding task (Pageaux, Lepers, Dietz & Marcora, 2014). The Stroop test was performed on a computer with a ~33 cm screen (MacBook Pro, Apple, US) and, in brief, required participants to manually select the colour of a word that appears on the computer screen by pressing a button, when it was printed in a colour not necessarily denoted by the name (i.e. selecting 'red' when the word 'green' is printed in red). The number of correct answers denoted the participants' score on the test. The task was completed in a quiet room, with sole supervision from the investigators. There was no interaction permitted with the investigator until the end of the 30 repeated tests. The test was performed under timed conditions, causing an interference effect known to be cognitively demanding for participants. The participants were instructed to respond as accurately and as quickly as possible to the on-screen cues throughout the entire testing period. Multiple repetitions of similar tests have been used previously to induce mental fatigue prior to soccer activities (Pageaux et al., 2014; Smith et al., 2016; Badin et al., 2016). The version of the Stroop test used was part of a free, publicly available app-based program called 'Brainiversity' (Version 1.0 for Mac). At the end of the test, the scores were recorded in Microsoft Excel to monitor the attainment on the Stroop tests prior to the performance tests. The results of each test were manually blinded from the participants. To provide additional motivation and limit boredom, the participants were told that the highest cumulative score would be deemed as the 'winner' at the end of the trial and that the final scores would be fed-back to them as a group, thus creating a level of competition. As previous studies have reported differences in cognitive performance after 15-min of a similar mentally-fatiguing task (Rauch & Schmitt, 2009), we reported the performance on the test after 15 attempts (~15-min or mid-way through the intervention) and after the second 15 attempts (~30-min). This permitted the ability of the app-based version of the Stroop test to adequately induce mental fatigue in the manner reported elsewhere (see Smith et al., 2016; Badin, Smith, Conte, & Coutts, 2016). In the control condition, the participants were asked to read magazines of a neutral, non-emotive content for 30-min. A 2-min period was given to the participants after completing the intervention, before starting the cricket-based performance tests.

Performance tests

All of the tests were completed within 2-min of completing one of the two treatment conditions and took a total of 45-min. After a standardised warm-up, the tests were completed in the following order: i) the run-two test; ii) the batak lite test and iii) the Yo-Yo-

IR1 test. The reason for selecting this order was because the Yo-Yo-IR1 was deemed to be too fatiguing to perform prior to any other test, whereas recovery from the other tests is entirely achievable in a short time-frame. A 5-min period was provided between tests, which was consistent between tests on all visits.

The cricket run-two test is an English Cricket Board (ECB) standard test. This required the participant to run a distance equivalent to one length of a cricket pitch (17.68 m) with a standard cricket bat in their preferred hand, touch the bat over the crease line, turn 180° and sprint back for one length (ECB revised testing protocols, *unpublished*). Infra-red timing gates (Brower timing gates, Brower TC athletic timing system, Brower timing systems, UK) were set up at a height of 1 m at one end of a 17.68 m line, which was painted onto the gym floor. The participants started from 50 cm behind the start line, on their preferred foot, and waited for a “3-2-1-GO” command before starting their trial. Time-splits were measured using the wireless transmitter and manually recorded into Microsoft excel. All participants performed five sprints in total, with 2-min recovery between attempts. One time-split (i.e. run-two = 35.36 m) was recorded for each trial and the average of all five sprints was subsequently reported. The test was performed on a rubber gym floor in an indoor sports centre. The players wore their indoor trainers, standard shorts, socks, and t-shirt provided by the club and kept this consistent throughout the testing. There were no instances where the participant did not touch their bat across the line. This test is performed on a weekly basis by the participants and has a reliability of 0.9 (CV%).

The batak-lite hand-eye co-ordination test was performed exactly 5-min after the final run-two test, using the batak lite reaction test apparatus (Batak Lite model, Batak.com, UK). The batak system is a transportable device (1143 cm × 1800 cm × 950 cm) that harnesses eight separate light emitting diodes (LED) or ‘buttons’ and a microcomputer, which controls the LEDs. The LEDs are evenly distributed in an ‘X’ pattern across the device. Once activated, the LEDs illuminate in a random sequence, the order and duration of which depends on the program selected. The participants stand in front of the device at arm’s length and used their hands to press the buttons (LEDs) as they are illuminated. In the program selected for this study, the participants were instructed to touch as many of the eight randomly illuminating buttons as possible in 30-s, and were given five attempts, interspersed by 2-min recovery. A point was awarded for each light being tapped and summated at the end. Average scores from all five tests were recorded and reported as the final score. This test has a coefficient of variation (CV%) ranging from 3.5 to 10% (Gierczuk & Bujak, 2014).

The Yo-Yo-IR1 (Bangsbo et al., 2008) was performed last, 5-min after completion of the final Batak lite test. This test is a progressive shuttle-run, where the participants ran between two cones, placed 20-m apart on a rubber indoor surface. An additional 5-m area was marked out at one end, where the participants actively recovered for 10-s after each shuttle. Starting at pace of 10 km/h, the participants shuttled between the cones at a tempo dictated by an external ‘bleep’ sound until they failed to maintain the desired movement rate. The investigators observing the test provided one verbal warning to the participant if they failed to maintain the tempo. After two consecutive failures, the participant was withdrawn and their total distance covered (number of shuttles × 20-m) was recorded and reported as their final score. The CV% of the Yo-Yo-IR1 test has been reported as 4.9% (Krustrup et al., 2003)

Visual Analogue Scale (VAS) for pre-physical assessments

A paper-based 100 mm visual analogue scale (VAS) was used to collect the participants' level of mental fatigue before and after the two interventions (hereafter referred to as pre- or post-cognitive task). Fatigue was broadly described to participants as a process that might impair their perceived cognitive performance or motivation to perform independent of any physical weakness (Chaudhuri et al., 2000). In turn, it was explained that the perceived difficulty of quickly processing information and accurately responding to cues during the task could be negatively affected. Lines were anchored at either end of the VAS, with the word 'none' at one end (left-side) and 'maximal' at the other (right-side). Based on the description provided above, the participants were asked to mark on the line their perceived state of fatigue both before (marked as a '1') and after (marked as a '2') each intervention. Using the same scale, the participants were also asked to mark their perceived level of motivation after the tests (marked as a '3'), prior to completing the physical tests. The participants were asked to judge their motivation as the total level of effort they felt that they were willing to reach in order to perform on the task to the best of their ability (Brehm & Self, 1989).

Rating of Perceived Exertion (RPE CR-10)

The CR-10 Borg scale (Borg, 1982) was used at the end of the Yo-Yo-IR1 test to evaluate the participants' global rating of perceived exertion (RPE) (Smith et al., 2016). The participants were familiar with this scale and were encouraged to use the visual anchors to guide their responses.

Statistical analyses

After checks for normality, pairwise differences between the dependent variables were identified by using paired *t*-tests. Significance for the tests was set at $P < 0.05$ and all tests were conducted using SPSS, version 22 (Chicago, IL). All data are presented as means ± SD.

Secondary to traditional hypothesis testing, effect sizes (ES), using Cohen's *d*, and magnitude-based inferences (MBIs) were used to identify clinical differences in the dependent variables between the two experimental conditions (control or mentally fatiguing task). Effect sizes were defined as; trivial = 0.2; small = 0.21–0.6; moderate = 0.61–1.2; large = 1.21–1.99; very large > 2.0 (Batterham & Hopkins, 2006). Raw data were log-transformed to account for non-uniformity of effects. For the MBIs, threshold probabilities for a substantial effect based on the 90% confidence limits were: <0.5% most unlikely, 0.5–5% very unlikely, 5–25% unlikely, 25–75% possibly, 75–95% likely, 95–99.5% very likely, 99.5% most likely. Thresholds for the magnitude of the observed change in the dependent variables were determined as the within-participant standard deviation × 0.2 (small) 0.6 (moderate) and 1.2 (large). Effects with confidence limits across a likely small positive or negative change were classified as unclear (Hopkins et al., 2009). The uncertainty of effects was based on 90% confidence limits for all variables. A custom spreadsheet was used to perform all of the calculations (http://www.sportsci.org/.).

Results

There were no differences (P = 0.378; ES = -0.48, 95% CIs = -1.34 to 0.37; MBI = *unclear*) in the pre-cognitive task perception of mental fatigue between mentally fatigued (14.4 ± 2.1 mm) and control conditions (13.5 ± 2.7 AU) (Figure 1). There were post-cognitive task differences (P < 0.001; ES = -7.82, 95% CIs = -9.05 to 6.66; MBI = *most likely*) in the perception of mental fatigue between mentally fatigued (46.6 ± 5.86 mm) and control conditions (16.6 ± 3.6 mm) (Figure 1).

*********Insert Figure 1 near here*********

There were no differences (*P* = 1.000; ES = -0.02, 95% CIs = -0.53 to 0.49; MBI = *unclear*) in the VAS scores for perceived levels of motivation between mentally fatigued (82.2 ± 4.4 mm) and control conditions (82.2 ± 6.3 mm) (Figure 2).

*********Insert Figure 2 near here*********

There were differences (*P* = 0.002; ES = -0.51, 95% CIs = -0.72 to 0.30; MBI = *very likely*) in the cricket run-two test times between mentally fatigued (6.29 ± 0.17 s) and control conditions (6.19 ± 0.18 s) (Figure 3).

*********Insert Figure 3 near here*********

There were no differences (*P* = 0.137; ES = 0.41, 95% CIs = -0.05 to 0.87; MBI = *likely*) in the points scored for the batak lite test between the mentally fatigued (38 ± 8 points) and control conditions (42 ± 2 points) (Figure 4).

*********Insert Figure 4 near here*********

There were differences (*P* = 0.023; ES = 0.39, 95% CIs = 0.14 to 0.64; MBI = *likely*) in the Yo-Yo-IR1 distance covered between mentally fatigued (1732 ± 402 m) and control conditions (1892 ± 357 m) (Figure 5).

*********Insert Figure 5 near here*********

There were differences (P = 0.001; ES = -1.82, 95% CIs = -2.49 to 1.14; MBI = *most likely*) in RPE between mentally fatigued (8 ± 1) and control conditions (7 ± 1) (Figure 6).

*********Insert Figure 6 near here*********

Discussion

The primary findings of this study were that mental fatigue, induced by a cognitively challenging task, acutely reduced performance in cricket-relevant tests. In agreement with previous studies (Rozand, Pageaux, Marcora, Papaxanthis & Lepers, 2014; Smith et al., 2016), the deterioration in the Stroop test scores across the trial (1st 15 attempts = 29 ± 4 *c.f.* 2nd 15 attempts = 27 ± 5) suggested that the thirty-minute app-based test was an effective method of inducing mental fatigue and could be used in future research for this purpose. Perhaps more importantly, our findings also support the suggestion that mental fatigue can be induced within fifteen minutes of task engagement (Rauch & Schmitt, 2009), questioning the need perform mentally fatiguing tasks of greater duration and identifying the 15-30 min period as the minimal exposure to Stroop testing that is necessary to induce mental fatigue and affect subsequent performance.

In support of the above findings, the differences in the perception of fatigue between bassline and immediately after the Stroop test was also higher in the mental fatigue condition and has also been reported in other research (Badin et al., 2016; Smith et al., 2016). However, the level of motivation reported immediately after the Stroop test was the same between conditions. This was unanticipated as a similar measurement tool has been used before to gauge acute changes in motivation following mentally fatiguing tasks (Smith et al., 2016). A theorised relationship between potential motivation (willingness to exert in order to complete a task) and fatigue is a key principle of the psychobiological model, which is the prevailing framework used to explain the effects of mental fatigue on performance (Smirmaul et al., 2013). Accordingly, one might have expected the motivation of the participants in the current study to decrease in the mental fatigue condition. This model also assumes that the level of conscious exertion (i.e. RPE) during an exercise task, which is ostensibly dependent on the degree of corollary discharge, gauges one's proximity to exhaustion (task disengagement) (Marcora, 2009). Therefore, an increase in RPE theoretically represents a progression towards exhaustion on a physical task, such as the Yo-Yo test, with a lower RPE permitting increased time to exhaustion (i.e. improved performance). Accordingly, we found that a lower RPE during the Yo-Yo-IR1 test in the no mental-fatigue compared to the mental fatigue condition permitted an increase in performance distance, but without any changes in motivation. This is similar to the findings of others (Marcora, 2009; Pageaux, Marcora & Lepers, 2013; Martin et al., 2016; Smith et al., 2016) and appears to suggest that the level of motivation did not affect the perception of effort. Others have attributed this to changes in goal orientation, from 'has to' to 'wants to' goals, which is dependent on the subsequent task to be performed (Smith et al., 2016). This is also a possible explanation for the current results and it is feasible that the elite level of the participants was sufficient to intrinsically motivate them to perform well in the subsequent physical tests that will have been naturally associated with increased fitness and squad selection. It is possible that the motivational characteristics of the elite participants in the study skew the possible relationship between mental fatigue and motivation but this requires further investigation. In addition, the lack of baseline testing of perceived motivation in the current study was a limitation and could have been included to confirm that the post-cognitive task motivation had changed as a result of the test.

Given the centrality of motivation to the psychobiological model and the consistency of findings between studies, this topic is worthy of further discussion. As well as the reasons discussed above, there are alternative perspectives that also relate to the nature of the participants in this and other studies. It is possible that the pre-existing relationship between the participants and the investigators, coupled with the competitive, elite team sport environment, could have resulted in participants underreporting their level of motivation before the physical tasks. Indeed, it is well-known that subjective reporting is affected by conscious bias (Baldwin, 2000). This describes a situation whereby participants, particularly elite athletes, can attempt to present themselves in a way that is socially desirable (Saw, Main & Martin, 2015). The degree to which their responses are affected by social desirability bias is related to its self-presentation potential or, in other words, the extent to which the participants believe their response is valued within a social system, such as the elite sports environment described above (Fisher & Katz, 2000). The VAS used in the current study did not account for social desirability bias and, as such, it is not known whether this affected the responses of the participants but we speculate that the environment might have promoted this effect. It is our suggestion that future research should account for the relationships between investigators and participants in studies of this type and that perhaps, visual analogue scales to measure motivation might not suitably control for social desirability bias in this elite sports environment. This is important as the concept of mental fatigue, and future interventions to prevent its deleterious effects, require further investigation in the elite sports.

The tests used in the current study were cricket-relevant and varied in their demand on motor skill proficiency. For example, the cricket run-two tests, which were negatively affected by mental fatigue, required the participants to control a cricket bat in one hand, whilst accelerating, running at maximal speed, decelerating and performing a 180° turn. Therefore, this test measured more than a single physical capacity and captured a series of skills that are a necessary part of cricket match play. In addition, the use of the Batak-lite test evaluated the reaction time of the participants using a timing sequence that closely replicated the fielding demands of cricket. Whilst there was no effect found between groups using hypothesis testing, the MBI approach revealed *moderate, likely* reductions in Batak scores in the mental fatigue condition. These findings were hypothesized as mental fatigue is known to decrease attentional focus and compromise cognitive processing (Lorist, Klein, Nieuwenhuis, De Jong, Mulder, & Meijman, 2000), such that performance on response-time tests, particularly those requiring the anticipation and processing of local features, is impaired (van der Linden & Eling, 2006; Duncan, Fowler, George, Joyce & Hankey, 2015). The lack of significance in the Batak scores between conditions might relate to the fewer gross motor demands and physical demands of the test, thus hindering the manifestation of mental fatigue on physical performance. Indeed, mental fatigue has also been shown to affect aspects of performance on sports-specific simulation protocols in soccer, impairing running, passing and shooting skills, which each pair cognitive demand with a gross motor response (Smith et al., 2016). Whilst the performance tests used herein were not sports-specific, the relevance of the tests are apparent for cricket players and are incorporated into the national governing bodies testing manual (ECB, *unpublished*). Therefore, for the first time, we have shown that elite cricket players' performance on these tests is also affected by a short (~ 30 min) cognitively challenging task. These findings might have further implications for players in close catching positions (i.e. wicket-keeping or the slip cordon) or batsmen with an increased likelihood of dropped catches or missed balls, respectively, from the delayed response time. However, our findings should be regarded as preliminary in nature until further research can be performed to verify the relevance of these findings during real-world scenarios. One must also acknowledge the multifactorial, task-dependent nature of fatigue, which will not easily be explained by singular mechanisms (Millet & Lepers, 2004). Future research should attempt to identify the realistic features of match-days that might induce similar states of mental fatigue and assess more specific types of cricket performance.

Conclusion

Mental fatigue, induced by an app-based Stroop test for 30-min, acutely affected cricket-relevant performance among elite cricketers. These findings concur with the conclusions of recent investigations regarding fatigue-related deficits in cognitive and physical abilities. Whilst further research is required to explore this phenomenon in greater depth, these findings might have wider implications for cricketers, who frequently endure prolonged periods of concentration during matches.

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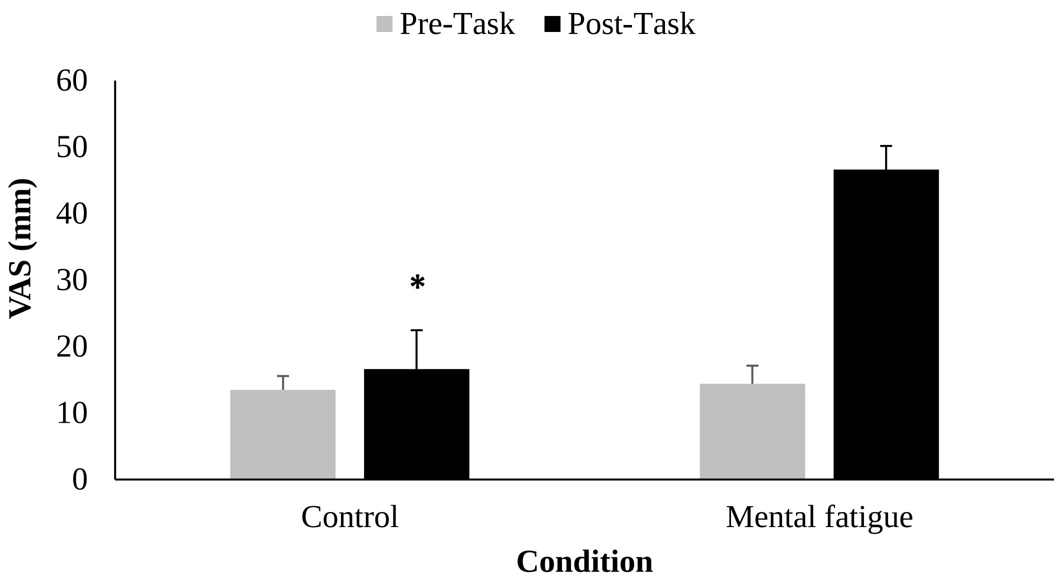

Figure 1. Perceived level of mental fatigue before and after the two conditions (n = 10). * = significantly different ($P < 0.05$) from the mental fatigue scores. Task = Stroop test.

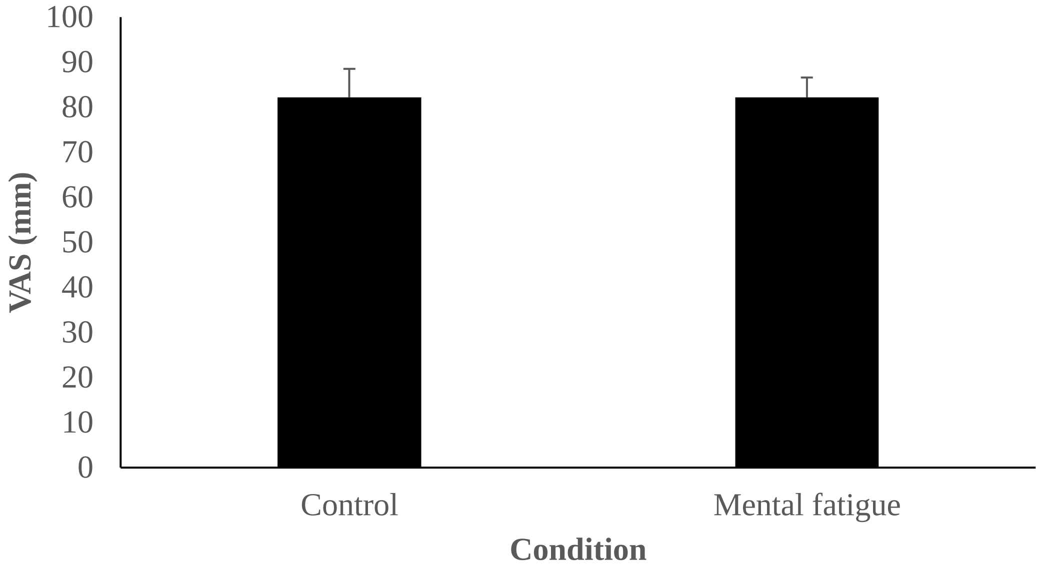

Figure 2. Perceived levels of motivation after the two treatment conditions (*n* = 10).

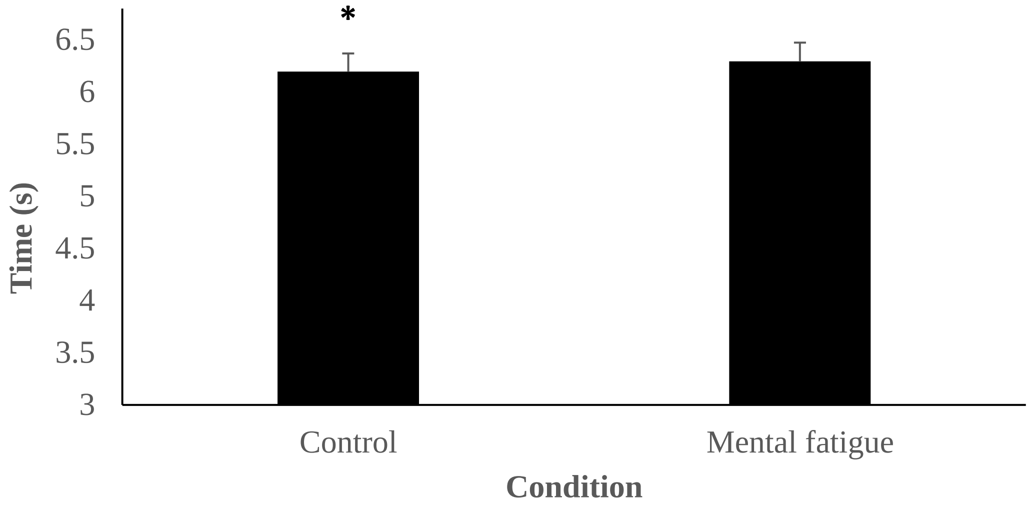

Figure 3. Cricket run-two times after the two treatment conditions (n = 10). * = significantly different ($P < 0.05$) from the mental fatigue scores.

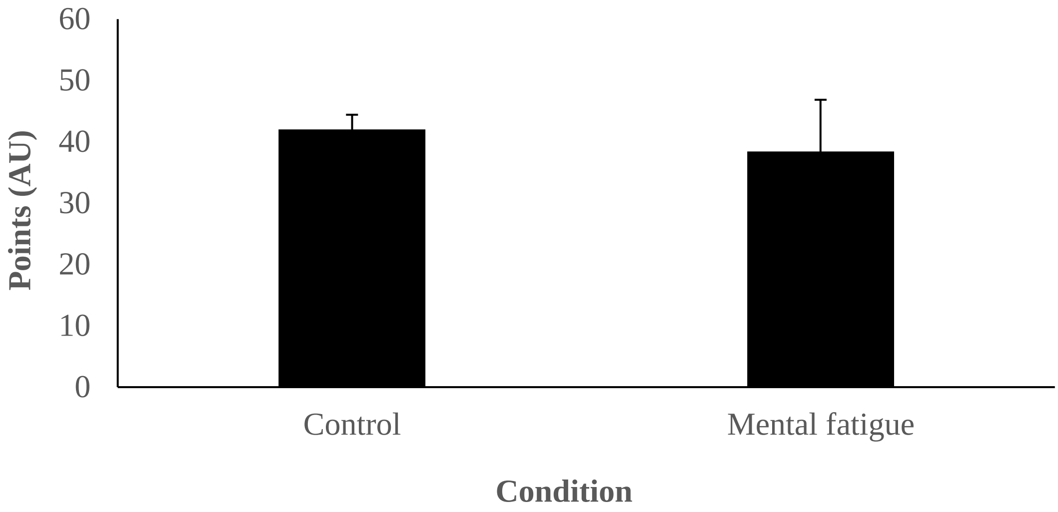

Figure 4. Batak lite test scores after the two treatment conditions (*n* = 10).

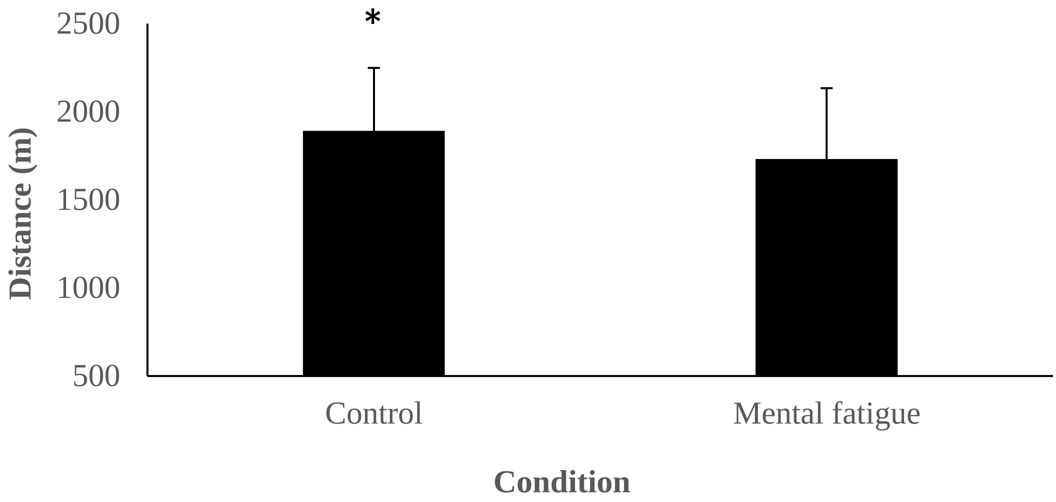

Figure 5. Yo-Yo-IR1 distance covered after the two treatment conditions (*n* = 10). * = significantly different ($P < 0.05$) from the mental fatigue scores.

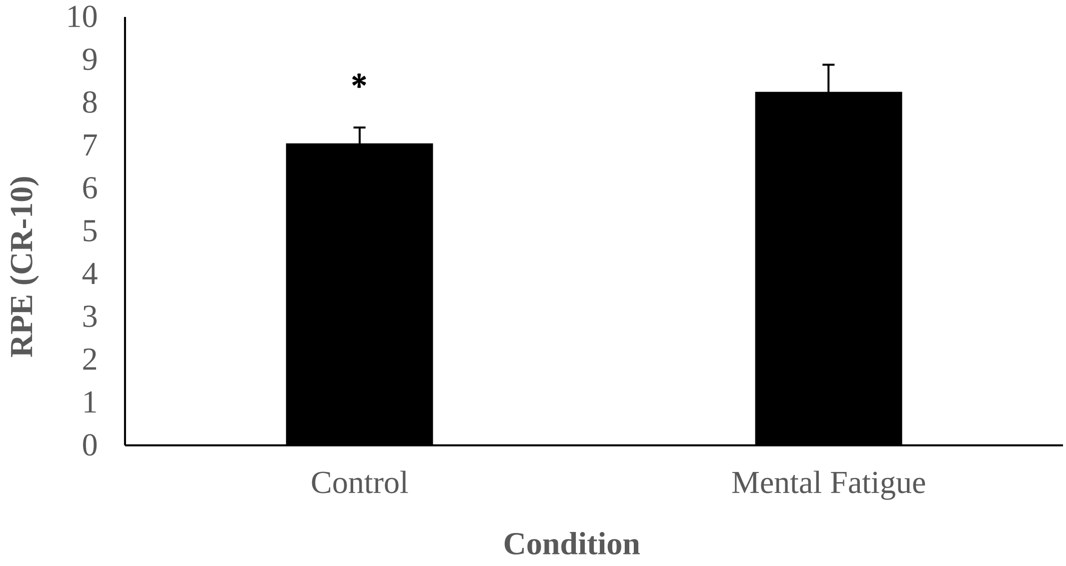

Figure 6. RPE scores after the two treatment conditions (n = 10). * = significantly different ($P < 0.05$) from the mental fatigue scores.