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Mind Games on the Court: Exploring Mental Fatigue in Simulated Badminton Matches

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Abstract: *This study examined the psychophysiological responses of players to mental fatigue (MF) during simulated badminton matches. Sixteen badminton athletes (age = 19.06 ± 1.29 years) participated in this study voluntarily. Before starting the measurements, the players were informed about the measurements, and anthropometric measurements were performed. Official badminton competition rules and formats were used. Brunel Mood Scale (BRUMS) responses were recorded before and after the games. At the end of each set, the players' perceived exertion (RPE), visual analogue scale (VAS), and enjoyment scale values were determined. Mental fatigue increased perceived exertion and mental fatigue levels during the match, and at the same time, the enjoyment of badminton players decreased ($p<0.05$). Based on mood responses, an increase in negative moods, such as anger and fatigue, was observed after MF, whereas a decrease in vigour mood occurred ($p<0.05$). However, no mood change was observed before or after the match without MF ($p>0.05$). After the game was played with MF, only a decrease in the feeling of vigour was detected compared to the game without fatigue ($p<0.05$). The results may help coaches and sports psychologists better understand their athletes and take appropriate measures when necessary. Understanding the effect of MF on athlete performance may help athletes direct their training programs directly.*

Keywords: *cognitive fatigue, psychophysiology, badminton, match, performance.*

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Introduction

Badminton is a highly demanding sport that requires physical and mental ability (Cabello-Manrique et al., 2022). Worldwide, badminton enthusiasts are approximately 150 million, with an estimated 10 million professional players (Zhang et al. 2022). The physical strain experienced during a badminton game, with its high number of strokes and short- and high-intensity activities, can significantly affect player performance (Shidiq, 2022). Competitive success in badminton depends on technical mastery, tactical cunning, mental toughness, physical power, and mental prowess.

Effort, an essential component of performance, is defined as the mediating situation between the characteristics of a specific task player's current information processing capacity and the appropriateness of the information processing process during task performance (Shenhav et al., 2017), Players' efforts during training or competition elicit physical fatigue, which causes a reversible decline in the force-producing capacity of the neuromuscular system and a reduced ability to perform physical tasks (Fry et al., 2017). Zhang (2020) found that fatigue leads to a decline in athletic performance and an increased risk of sports injuries. Fatigue is a complex condition defined as extreme tiredness or exhaustion that can affect physical, mental, and emotional functioning (Chaudhuri & Behan, 2000). Examining mental fatigue's (MF) effects on badminton performance is important for optimizing athlete training and competition strategies (Li & Ding, 2021).

MF is characterized by reluctance, a general feeling of tiredness, inhibited emotions, and poor cognitive performance caused by excessive mental or physical activity (Borghini et al., 2014; Ishii et al., 2014). The physical and mental demands of badminton matches can have significant effects on the psychophysiological responses of players, including changes in visual and auditory response times, psychological stability, and the ability to control the rhythm of a game (Zhang et al., 2022). Recent studies have shown that MF is an important mechanism that affects physical and mental demands (Soylu et al., 2022a; Le Mansec et al., 2018). However, MF prolongs visual and auditory response times in racket sports (Habay et al., 2021; Filipas et al. 2024). Van Cutsem et al. (2019) noticed that badminton players are mentally tired, and their visual and auditory response times increase. MF in simulated badminton matches is a relatively under-explored area of research. This gap in the literature makes it essential to investigate the effects of MF on badminton players to understand the psychological responses and improve training and match strategies. To our knowledge, no study has investigated the impact of MF on psychophysiological responses

during badminton-matching performance. Therefore, this study aimed to determine MF's effects on the psychophysiological responses of players to simulated badminton matches.

Methods

Study Design

Acute experimental research investigates the immediate effects on a specific outcome or variable, often involving a single session or exposure to an intervention. To examine the impact of MF on physical performance, this study employed an acute experimental research design to explore its direct effects on muscular endurance, motor performance, and exercise capacity. Studies have assessed physical performance immediately after inducing MF using cognitive tasks (Pageaux et al., 2013; Marcora et al., 2009).

Participants

Sixteen male badminton players were included in this study. The study consisted of an experimental group (age = 19.25 ± 1.49 years; height = 170.13 ± 3.56 cm; weight = 65.38 ± 7.01 kg; body mass index: 22.54 ± 1.80 kg/m2) and control group (age = 18.88 ± 1.13 years; height = 174.63 ± 1.85 cm; weight = 69.13 ± 6.71 kg; body mass index: 22.64 ± 1.87 kg/m2) were randomized into two groups. The participants were athletes of the same club trained five days a week. All players were physically healthy and had no psychological or orthopaedic problems. Before data collection, the participants provided written informed consent after being briefed on the study's benefits and risks. During this period, the layers maintained their normal dietary routines and did not ingest caffeine. The study was approved by the Tokat Gaziosmanpasa University Ethics Committee (2024/02.64) and was conducted following the Declaration of Helsinki.

Experimental Protocols

This acute experimental study employed a repeated stimulus design. All participants completed two simulated badminton matches (48-hour intervals between games) during a practical simulated competition under identical (official competition conditions). This study used the Stroop test for MF application, and the control group was shown as a documentary. A simulated competition program was used, with simulated matches every 24 hours (always at 4 pm). Anthropometric data (Tanita BC-418MA, Tokyo, Japan) and the Brunel Mood Scale (Terry et al., 1999, 2003; Soylu et al., 2022) were completed before the competition. The ratings of perceived

exertion (Foster et al., 2001), enjoyment (Raedeke, 2008; Soylu et al., 2023), and visual analogue scale for MF (Soylu et al., 2022) were applied during the matches. Official badminton rules were used, and a level 3 badminton coach monitored the competition. To ensure standardized conditions, participants abstained from physical exercise and alcohol for 48 hours preceding each visit. Additionally, caffeine was avoided for at least four hours before each simulated match.

Mental Fatigue Protocol

The participants were randomly assigned to either the MF (MF+BAD) group or the control group (MF-BAD), and two simulated badminton matches were performed. The MF+BAD group underwent MF induction by completing a 30-minute incongruent Stroop test before each match. Previous studies (Soylu et al., 2022b; Smith et al., 2016) have indicated that the Stroop test induces MF and impairs sports performance. The Stroop color-word task assesses cognitive control by presenting a visual and linguistic processing conflict. Participants must suppress the automatic tendency to read the word and instead focus on identifying the ink color.

Statistical Analysis

The analysis employed Paired t-tests to compare the mean ± standard deviation values between the MF+BAD and MF-BAD conditions to assess for significant differences. The coefficient of variation (CV) was used to measure inter-individual variability. Effect sizes (Cohen's d) were calculated for each dependent variable, with interpretations based on Hopkins et al. 's (2008) thresholds (insignificant, <0.2; small, 0.2-0.6; moderate, 0.6-1.2; large, 1.2-2.0; very large, >2.0). Statistical analyses were performed using the SPSS software (version 24.0), with a significance level of $p \leq 0.05$.

Results

This part of the study presents the statistical results of the psychophysiological responses of simulated badminton matches played with MF and simulated badminton matches without MF.

Table 1. Psychophysiological responses of MF+BAD and MF-BAD matches

	MF+BAD	MF-BAD			
	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	p	*d*	Magnitude
RPE	16.96 ± 1.05	14.67 ± 1.63	**0.023***	1.67	Large
VAS	4.79 ± 1.47	2.62 ± 1.70	**0.040***	1.37	Large
Enjoyment	39.83 ± 1.75	48. 33 ± 5.10	**0.004***	-2.23	Very Large

MF+BAD = Badminton match played with mental fatigue; MF-BAD = Badminton match played without mental fatigue; RPE = ting of perceived exertion; VAS = Visual analog scale; SD = Standard deviation; p = significance value; p<0.05

Table 1 shows the statistical results of the psychophysiological responses after the MF+BAD and MF-BAD. The groups differed significantly in RPE, GAS, and enjoyment responses. ($p<0.05$). Perceived exertion and MF levels increased, whereas pleasure decreased after the MF+BAD match.

Tablo 2. Brunel mood responses of MF+BAD and MF-BAD matches

	MF+BAD	MF-BAD			
	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	p	*d*	Magnitude
Anger	6.88 ± 5.96	7.38 ± 2.45	0.820	-	-
Confusion	4.00 ± 2.67	6.50 ± 2.45	0.165	-	-
Depression	3.63 ± 3.50	3.88 ± 1.73	0.831	-	-
Fatigue	9.25 ± 4.10	9.00 ± 3.25	0.913	-	-
Tension	5.25 ± 5.68	5.38 ± 2.88	0.964	-	-
Vigour	4.25 ± 3.20	8.00 ± 2.67	**0.030***	-1.27	Large

SD = Standard deviation; p = significance value; p<0.05

Table 2 shows the statistical results of the mood responses given after the MF+BAD and MF-BAD matches, and Vigour responses did not differ significantly between the groups ($p>0.05$). The state of vigour was higher after the MF-BAD match than after the MF+BAD match. The groups showed no significant differences in anger, confusion, depression, fatigue, or tension.

Discussion

This study examined the acute psychophysiological responses of MF to simulated badminton matches. According to the study results, while perceived exertion and MF level increased in matches with MF, the enjoyment of badminton players decreased. When the mood responses to MF+BAD and MF-BAD at the end of the game were compared, it was found that vigour

decreased after the match in which MF was experienced, but there was no difference in other moods. Examining the literature, it was observed that there are very few studies on MF and badminton performance.

In the psychophysiological responses of the present study, it was observed that the increase in RPE and VAS values and the decrease in the feeling of pleasure were due to the MF. MF is a state of cognitive exhaustion that can affect athletic performance (Soylu et al., 2022). Many studies have examined the effects of MF on sports performance; however, research focusing specifically on badminton athletes is limited. Badminton matches are known for their high-intensity games, short-duration rallies, and frequent breaks (Shidiq, 2022). However, Slimani et al. (2016) noted that the negative effect of MF on endurance performance was due to an increase in the perceived degree of exertion. Kosack et al. (2020) investigated the acute effect of MF on the performance of a specific badminton test in elite players. The study found that, although they felt more mentally fatigued after a Stroop test, badminton performance had no negative impact, as measured by a badminton-specific test. This suggests that MF may not significantly impair the badminton performance of elite players. Van Cutsem et al. (2019) found that both badminton players and a control group showed decreased accuracy in a visual-motor task over time, indicating increased difficulty. In terms of MF, both groups perceived MF similarly, but higher levels of MF were found in the badminton players. In the visual-motor task, both groups responded more slowly to complex stimuli during the MF. Badminton players performed better in the visuomotor task, but badminton players and controls performed similarly in the Stroop and Flanker tasks. Limited research exists on the influence of MF on badminton performance. The results of existing studies support the current study, and it has been determined that MF negatively affects players during physical tasks.

There are reports in the literature on how MF affects various racket sports. Le Mansec et al. (2018) investigated the effect of cognitive and muscle fatigue on table tennis performance. MF is created by completing a specific task, whereas muscular fatigue is created by exercising particular muscle groups. After the fatigue protocols, stroke parameters and fatigue were evaluated. The feeling of fatigue increases, muscle fatigue affects stroke accuracy, and MF changes speed. However, muscle fatigue has a negligible effect on table tennis performance. Habay et al. (2021) examined the effects of MF on table tennis performance and found that MF negatively affected performance, particularly in visual-motor tasks. Research shows that EEG measurements and subjective feelings confirm participants' MF, although participants are evident in behavioural indicators. These results provide

further insight into the effects of MF on human performance. Vincze and Jurchiş (2022) found that high physiological load in badminton did not significantly impair anticipation skills in expert players. This finding suggests that physiological factors may not considerably affect anticipatory skills during badminton matches. Understanding the effects of MF on badminton matches is crucial for players and coaches. This knowledge can help make informed decisions during training sessions, manage injury risks, and support players returning to sports after injury.

The current study revealed that MF negatively affected vigour after a simulated badminton match. MF is a common problem among athletes during training and competition (Van Cutsem et al., 2017), leading to mood disorders, poor performance, and reduced cognitive function (Clark & Mach, 2016). Several factors may contribute to MF in athletes, including exercise-induced stress behaviour, gut microbiota-brain axis dysfunction, sleep deprivation, nutritional deficiencies, and psychological stressors (Clark & Mach, 2016; Troynikov et al., 2018; Enoka & Duchateau, 2016; Meeusen and Decroix, 2018). Psychological stressors, such as the pressure to perform well or cope with competitive demands, can increase MF in athletes (Van Cutsem et al., 2017). In their study of soccer players, Soylu et al. (2022) stated that MF had a negative effect on vigor and mood in game-based soccer training. Athletes use various non-drug approaches to challenge MF. Exercise interventions, such as aerobic exercise, have proven effective in reducing fatigue symptoms and improving sleep quality (Nédélec et al., 2021). These interventions can help athletes develop coping strategies, improve self-regulation, and enhance overall psychological well-being. Schiphof-Godart et al. (2018) examined the effects of MF on endurance performance. It has been suggested that mentally fatigued athletes perceive exercise as more demanding and may choose to perform at lower intensities, which affects their emotional states during endurance activities.

This study has some limitations. First, the small sample size restricted the generalisability of our findings. Future research should include a larger participant pool to strengthen our conclusions. Second, the relationship between physiological, technical, and psychological performance, such as the physiological response to heart rate and lactate, can provide more accurate responses. Further studies are needed to identify the factors contributing to these variations in in-game performance.

Conclusion

This study showed that MF increased the perceived exertion and level of MF in simulated badminton matches while decreasing badminton players' enjoyment. Based on the players' responses, MF increased negative moods, especially anger, and fatigue, and reduced vigour. These results help us to understand better MF's effects of MF on badminton performance and mood. Consequently, researchers should consider developing practice and guidance tools that can be used to assess and manage MF based on athlete feedback. Further studies should be conducted to understand the factors influencing athletes' performance and how these fatigued athletes can be managed. The results of this study provide important clues for sports psychology and performance researchers to understand how athletes respond to MF and how these responses can be managed.

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