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SPORT AND EXERCISE PSYCHOLOGY

The impact of sprint, middle-distance, and long-distance orienteering races on perceived mental fatigue in national level orienteers

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ABSTRACT

Experiencing mental fatigue (MF) before an orienteering race can lead to a slower completion time. This study aimed to explore the changes in perceived MF, mood and other psychological responses during an orienteering competition. Sixteen national level orienteering athletes (20.8 ± 4.9 years) provided informed consent and completed the online surveys, before and immediately after each race, and 24- and 48-hours post competition (48POST). This study measured MF, physical fatigue, stress, tiredness and motivation using 0–100 Visual Analogue Scale, and the mood was assessed using The Brunel Mood Scale (BRUMS). A moderate to large increase in MF (ES = 0.93 [0.54 to 1.31]), BRUMS fatigue (ES = 0.61 [0.3 to 0.92]), and PF (ES = 1.21 [0.81 to 1.61]) was reported following orienteering races. A small increase in tiredness and BRUMS confusion, and a small decrease in motivation, stress and BRUMS vigour was also reported. There was a delay in recovering from the MF elicited by competition, with a small increase in MF (ES = 0.54 [0.08 to 1.15]) at 48POST compared to the pre-competition value. This study found that orienteers experience MF during competition and have a delayed recovery that can last up to two days after the competition.

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Cognitive fatigue; delayed recovery; mental exertion; well-being

Introduction

Mental fatigue (MF) has been defined as a negative psychobiological state that happens during a prolonged period of cognitively demanding task and results in an increased subjective tiredness and reduced endurance performance (Habay et al., 2021; Lam et al., 2021; Van Cutsem et al., 2017). Perceptions of MF may vary between individuals and sports (Lam et al., 2023; Russell et al., 2019). Consequently, this study adopted the revised definition from international orienteering experts which defined MF (Lam et al., 2023) – an inability to maintain concentration and process information for decision-making efficiently and effectively after a prolonged period of cognitively loaded activity. According to Martin et al. (2018), an increase in mental exertion can impair brain executive functions, resulting in impaired decision-making and self-regulation. This impairment subsequently contributes to poor endurance performance.

In contrast to the conclusion of previous systematic reviews and meta-analyses (Giboin & Wolff, 2019; Habay et al., 2021; Van Cutsem et al., 2017), a recent Delphi study with international orienteering experts agreed that MF exists in orienteering training and competition but disagreed that it has a negative impact on orienteer's speed or endurance running performance (Lam et al., 2023). The discrepancy between the views of orienteering experts and the literature may be attributed to the potential differences in the perception and interpretation of MF between practitioners/athletes and researchers, as reported in Russell et al. (2019). Previous studies have shown that MF induced via a computerized cognitively demanding task, such as the Stroop-colour task, can impair decision-making, reaction time and accuracy in open skill sports (Habay et al., 2021; Sun et al., 2021), and reduce efficiency in using environmental information during soccer small-sided games, thereby affecting the execution of tactical plans (Coutinho et al., 2018). Although Batista et al. (2021) observed that orienteers had a slower completion in a subsequent 3.1 km simulated orienteering race after performing a computerized cognitively demanding task for 30 mins, it has the same limitation as most of the investigations on MF, in which the MF induced was far from the reality of the sport. The fundamental nature of orienteering requires orienteers to gather as much information from the surrounding environment as possible in order to identify the most energy-cost-efficient and quickest route to each control point using a map and compass (Batista et al., 2020; Creagh & Reilly, 1997). It has been observed that mentally fatigued individuals may experience impairments in their visual search behaviour, resulting in a delay in responding to dynamic situations (Zeuwts et al., 2021). This suggests that mentally fatigued orienteers may have difficulties in effectively gathering environmental information, leading to slower completion times. This support previous findings with soccer players, who presented more conscious decision-making errors and poorer technical plan execution in a mentally fatigued state (Coutinho et al., 2017; Sun et al., 2021, 2022).

A recent systematic review found that the level of physical fitness level of individuals does not have an influence on susceptibility to MF (Habay et al., 2023). However, there is evidence indicating that well-trained athletes and

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individuals frequently exposed to highly cognitively demanding environment are least affected by the MF (Martin et al., 2016, 2019). Given the detrimental effects of elevated perceived MF on orienteering running performance were observed following MF protocol (Batista et al., 2021) and taking into account that orienteers were physically and cognitively trained to withstand exertion (Batista et al., 2020; Creagh & Reilly, 1997), it is crucial to investigate whether engaging in a complex sport such as orienteering could induce MF. Lam et al. (2023) also reported potential differences in perceived MF between orienteering training and competition, where the perceived MF should be investigated separately. This reinforces the importance of the need to examine the presence of MF in orienteering prior to assessing the effect it has on orienteering performance. Recent research has attempted to investigate whether participating in competition would induce MF in elite football players (Abbott et al., 2020; Thompson et al., 2020) and netballers (Russell et al., 2021). These findings have overcome the limitation of relying on a computerized MF induction method to explain MF in sports. The investigation of elite football players and elite netballers has reported that the MF elicited by participating in competition remains elevated for up to 48 hours after the competition (Abbott et al., 2020; Russell et al., 2019; Thompson et al., 2020). Although Lam et al. (2023) provides preliminary evidence that the international orienteering experts agreed that MF exist in orienteering, further investigation is needed to validate whether participating in an orienteering competition would induce MF. Taking into account the importance of individual characteristics in the extent of MF experienced in sports (Martin et al., 2016, 2019), It would be advantageous to understand whether orienteers suffer from MF when taking part in the sport of orienteering, which requires a high level of both physical and cognitive output.

Furthermore, it is acknowledged that the understanding of the development of MF in sport is limited (Martin et al., 2018; Smith et al., 2018). The mood state, which includes motivation, vigour, and fatigue ratings, is frequently measured alongside MF to evaluate the overall impact of MF on athletes' well-being (Van Cutsem et al., 2017). Considering that MF is a subjective experience, a similar observational study with elite netballers also examined other psychological responses such as physical fatigue, stress and tiredness of the individuals to observe how these variables change when they experience MF (Russell et al., 2022). These measurements could also provide additional information regarding the relationship between MF and other psychological responses (Abbott et al., 2020; Russell et al., 2019). Therefore, the inclusion of other subjective measures could be useful in justifying whether MF should be considered as other form of fatigue.

The effects of MF induced in an artificial way are evident in physical and sport-specific performance (Habay et al., 2021; Sun et al., 2021; Van Cutsem et al., 2017). no research has yet been conducted to explore the influence of an orienteering competition on MF. Consequently, the aim of this study was to explore the changes in MF and other psychological variables throughout an orienteering competition. Therefore, no hypothesis was formulated to allow for a thorough investigation.

Methodology

Experimental design

This research used an observational study design with repeated measures to investigate the changes in perception of MF and other psychological variables of national-level orienteers during orienteering races. Following institutional ethical approval, written informed consent of participants and consent from parents or guardians (for any athletes U-18) were obtained prior to the participation.

Participants

Sixteen national-level orienteers (20.8 ± 4.9 years, 1.77 ± 0.1 m, 63.7 ± 8.0 kg, 11.6 ± 5.5 years of experience in orienteering) from Australia ($n = 1$), Austria ($n = 1$), Estonia ($n = 1$), England ($n = 4$), France ($n = 1$), Scotland ($n = 4$), Sweden ($n = 1$) and Switzerland ($n = 3$) national teams participated. All participants had (1) received regular training in their national team; (2) previously represented their national team in an orienteering competition; and (3) were proficient in written in English. Based on the precision planning for a paired-sample design using the Exploratory Software for Confidence Intervals (Version 1) (Cumming, 2012), to achieve an average target margin of error of 0.4 for a confident interval when using $\rho = 0.70$, a sample size of 17 was necessary to achieve the desired level of precision. However, the sample size obtained in this study provides a target margin of error of 0.42 for a 95% confident interval.

Procedure

An initial recruitment email was sent to all orienteers with contact details on the 2021–2022 orienteering world ranking list (http://ranking.orienteering.org/?ohow=F) and British Orienteering national team practitioners, and a snowball sampling method was implemented, whereby eligible participants were asked to recommend others with a similar background using the same criteria. Two kinds of competition were recorded for this study: selection races for international events ($n = 8$) and competitions for world ranking points ($n = 8$). A total of 43 races from eight different orienteering competitions were recorded, with the number of competition days ranging from one to four (4-day: $n = 4$; 3-day: $n = 5$; 2-day: $n = 5$; 1-day: $n = 2$). An online survey was administered and distributed using the Qualtrics XM Platform (USA). Participants were asked to complete the survey within 30 minutes of waking each day (PRE) and within 30 minutes after competing on each day (POST) as identical to previous research (Russell et al., 2022). They were also asked to complete the survey one (24POST) and two days (48POST) after the final day of competition, as previous research has highlighted that MF remain elevated for 48 hours after competition (Abbott et al., 2020; Russell et al., 2019; Thompson et al., 2020). Due to difficulties in standardising equipment in similar field-based studies (Russell et al., 2021,

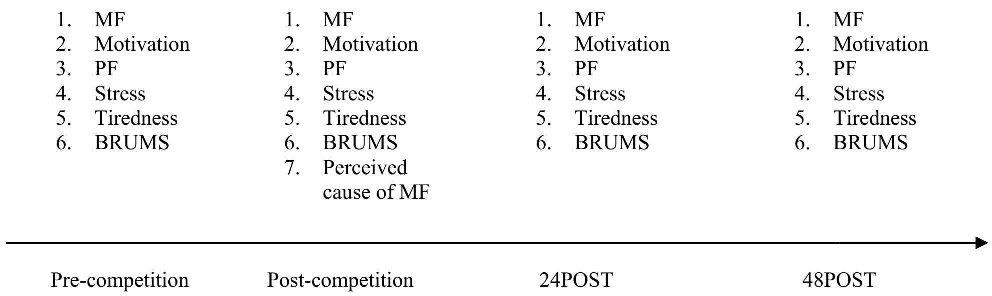

Figure 1. The schematic diagram of the experimental protocol.

2022), the survey was completed on athletes' own electronic devices.

Online survey design

We adapted the daily self-report measurements from Russell et al. (2022). The survey consisted of 20 items, including a closed-ended question asking "Did you compete in an orienteering race just now?" and an open-ended question to determine the perceived cause of MF during orienteering competitions. For open-ended question, a blank space were provided to the participants to type in response to the question "what do you believe are the cause(s) of mental fatigue during the orienteering race you completed just now?". Five sliding scales (0–100) for self-reported ratings on MF, motivation, physical fatigue (PF), stress, and tiredness, as well as twelve items from the vigour, fatigue and confusion subscales of the Brunel Mood State (BRUMS) from Brandt et al. (2016) using 0–4 numeric scale were also included. Furthermore, six additional items regarding the demographic characteristics of the participants such as age, gender, height, body mass, geographical location, and years of competitive orienteering experience were collected in the first survey. All participants completed the entire data collection process once during a competition as a familiarization trial. The timing and the overview of the self-report measurements are provided in Figure 1.

100-mm Visual Analogue Scale (VAS)

The 100-mm VAS has demonstrated high reliability and validity when assessing fatigue-related variables (Lee et al., 1991; Smith et al., 2019). In this study, the subjective MF and other psychological variables were adapted from Russell et al. (2022) and were measured using a 0–100 arbitrary unit (AU) sliding scale with similar anchors. Similarly, a recent investigation on MF in elite academy soccer, a 0–100 AU slider scale was also utilised to measure MF (Thompson et al., 2020). The standardised question and descriptor of each variable are shown in Table 1. Additionally, the definition of MF specific to orienteering, as developed by international orienteering experts (Lam et al., 2023), has been included along with the MF VAS question. This inclusion aims to prevent any confusion with other fatigue constructs.

Mood state

The BRUMS was employed to assess changes in mood state. The vigour and fatigue subscales were commonly used to determine the mood state in MF research (Pageaux et al., 2015; Van Cutsem et al., 2017). Moreover, this study included the confusion subscale of BRUMS as a recent investigation with orienteering experts highlighted the importance of measuring confusion during training and competition (Lam et al., 2023). Participants had to answer a 5-point Likert scale responding to a standardised question "How do you feel right now" for a total of 12 items from the vigour, fatigue and confusion subscales as identical to Brandt et al. (2016). The rating for each item ranged from 0 to 4 (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely). The four relevant items from each subscale were summed up to obtain a score between 0 to 16.

Wearable heart rate and GPS technology

The physical demand for the orienteering competition was measured using participant's self-selected smartwatches with both heart rate monitoring and GPS capabilities. The mean heart rate, total running distance and average running speed per kilometre were calculated from the GPS data on the smartwatches. Due to the geographical limitation of the researcher, there was no standardisation of the smartwatch and HR monitor models used. However, participants were advised to use a smartwatch that was compatible with either Strava (Strava, USA) or Garmin Connect (Garmin Ltd, USA). A systematic review showed that the majority of photoplethysmography devices worn on the wrist were of acceptable accuracy when measuring heart rate during

Table 1. The question and anchor for the 0–100 self-report slider scale.

Measure	Question	Anchor for 0	Anchor for 100
Mental fatigue	What is your current level of mental fatigue?	Mentally fresh	Mentally exhausted
Motivation	How motivated are you to complete your next orienteering race?	None at all	Highly motivated
Physical fatigue	What is your current level of physical fatigue?	Physically fresh	Physically exhausted
Stress	What is your stress level right now?	Very relaxed	Highly stressed
Tiredness	How tired are you right now?	Very alert	Extremely tired

physical activities, meaning that this data could be used for population-based investigations (Zhang et al., 2020). Consequently, the heart rate was recorded through either wrist or chest straps, depending on the participants' access to equipment. The participants were instructed to activate their devices at least 15 minutes prior to the competition and to use the same smartwatch for all data collection sessions to ensure consistency. Participants were requested to provide detailed information regarding the specific types of orienteering races they had completed when submitting their GPS and heart rate data to the researchers.

Statistical analysis

All data was presented as mean ± SD unless specified. It has been criticised that using null-hypothesis testing on a small sample size can lead to an overestimation of the results, and the p-value does not provide information on the magnitude or direction of the changes in measurements (Batterham & Hopkins, 2006). Therefore, the magnitude of changes and 95% confident interval (95%CI) in paired comparisons for MF, motivation, PF, stress, tiredness, BRUMS, and the changes between outcome variables were calculated using Exploratory Software for Confidence Intervals (Version 1) (Cumming, 2012). To prevent an overestimation of the effect of the results in studies with small sample sizes, the effect size (ES) was interpreted as the following: trivial (0.00 to 0.19), small (0.20 to 0.59), moderate (0.60 to 1.19), large (1.20 to 1.99), very large (2.00 to 3.99) and extremely large (≥4) (Batterham & Hopkins, 2006; Hopkins et al., 2009). Any 95% CI that does not encompass 0 would be deemed statistically significant. This study first combined all pre-post orienteering races completed by the participants to present the overall changes in all outcome variables. Previous research has highlighted the importance of using mixed models for the analysis of observational and longitudinal data in the field of sport science (Newans et al., 2022). In addition to addressing the estimation of uncertainty, linear mixed models (LMM) were adopted to overcome the assumption of independence among observations. To account for the non-independence of multiple observations in a repeated measures study design involving the same participants, the GAMj in Jamovi (Version 2.3, The Jamovi project) was employed (Sahin & Aybek, 2020). The participants' identity was selected as a random intercept. We then analysed the pre- and post-specific type of orienteering race together with the analysis on the day following the specific orienteering race (MD + 1). Additionally, this study examined the changes in all outcome variables immediately after the final competition of the participants, 24POST and 48POST. The perceived causes of MF in orienteering competition were evaluated using a summative content analysis with two-step analysis, as this technique was effective in recognising and analysing the most commonly-occurring keywords by counting the number of times they appeared in responses (Cote et al., 1993; Hsieh & Shannon, 2005). Descriptive statistic were used to present the GPS and HR data.

Results

Pre and post-orienteering competition

A total of 43 races were recorded across all participants. The mean change in all outcome variables pre- to post-orienteering competition for all participants is in Figure 2. There was a large increase in the ratings of PF and a moderate increase in ratings of MF and BRUMS fatigue scores after the orienteering competition. Ratings of tiredness and BRUMS confusion ratings showed small increases following orienteering. Ratings of motivation and stress and BRUMS vigour ratings showed a small decrement following orienteering. The Bonferroni post-hoc analysis in LMM revealed a significant difference in post-training tiredness and vigour between sprint and long-distance races. Significant difference was also identified in pre-training MF

Variables	PRE	POST	Mean Difference [95%CI]	Effect size [95%CI]
Mental Fatigue	29.7 ± 20	49.5 ± 26.7	19.9 [12.5 , 27.2]	0.84 [0.49 , 1.19]
Motivation	85.6 ± 17.9	76.3 ± 21.8	−9.3 [-16.5 , -2]	−0.47 [-0.83 , -0.09]
Physical Fatigue	39.3 ± 23.1	67.4 ± 23.2	28.1 [20.8 , 35.4]	1.21 [0.81 , 1.61]
Tiredness	40.7 ± 20.2	53.9 ± 29.5	13.3 [4 , 22.5]	0.52 [0.15 , 0.9]
Stress	42.3 ± 20.4	35.8 ± 25	−6.6 [-13.9 , 0.7]	−0.29 [-0.6 , 0.03]
BRUMS Vigour	8.3 ± 3.5	7.5 ± 4.1	−0.8 [-2.1 , 0.5]	−0.21 [-0.54 , 0.13]
BRUMS Fatigue	5.9 ± 4	8.3 ± 4.2	2.5 [1.3 , 3.7]	0.61 [0.3 , 0.92]
BRUMS Confusion	1.1 ± 1.7	2.8 ± 3.7	1.7 [0.6 , 2.8]	0.58 [0.19 , 0.97]

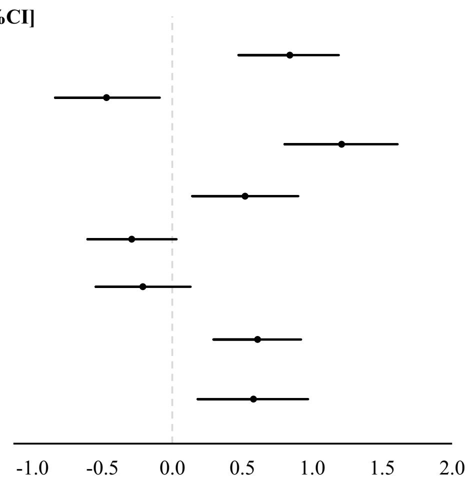

Figure 2. The magnitude of changes in all outcome variables before and after an orienteering competition. Data has been combined from all participants (43 races).

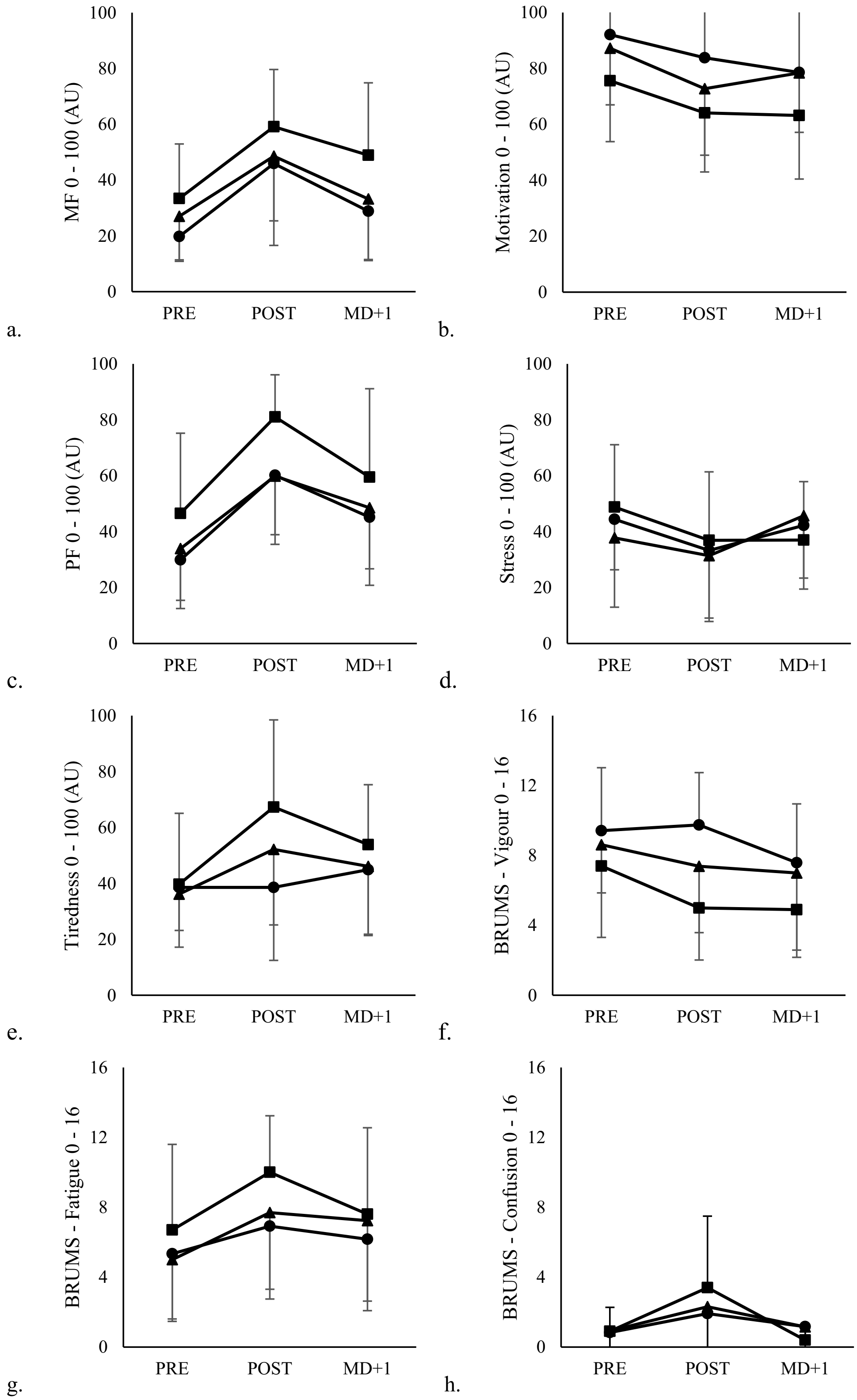

Figure 3. The changes in MF (a), motivation (b), PF (c), stress (d), tiredness (e), BRUMS – Vigour subscale (f), BRUMS – Fatigue subscale (g), and BRUMS – Confusion subscale (h). The circle represent the ratings in sprint orienteering competition, triangle represents the middle-distance orienteering competition and the square represents the long-distance orienteering competition.

and tiredness when comparing sprint and relay races. Additionally, post-hoc analysis showed significant differences in post-training PF for long-distance races compared to middle-distance races, and significant differences in pre-training MF ratings between relay races and middle-distance races. The remaining two types of orienteering competitions were excluded for further analysis due to the small sample size, relay ($n = 5$) and KO-sprint ($n = 3$) respectively.

Table 2. The extent of changes in all outcome variables immediately and one day after sprint (12 races), middle-distance (13 races) and long distance (10 races) orienteering competition.

	PRE vs POST				POST vs MD + 1			
			Changes between events (Effect size)				Changes between events (Effect size)	
Variables	Mean difference [95%CI]	Effect size [95%CI]	vs Middle	vs Long	Mean difference [95%CI]	Effect size [95%CI]	vs Middle	vs Long
Mental Fatigue 0–100 AU								
Sprint	26.2 [10, 42.4]	1.21 [0.36, 2.02]	0.2 [−0.42, 0.02]	−0.02 [−0.29, 0.25]	−17.1 [−36.5, 2.3]	−0.71 [−1.47, 0.08]	0.07 [−0.14, 0.29]	0.25 [−0.02, 0.51]
Middle	21.5 [9.1, 34]	1.09 [0.36, 1.79]		0.2 [−0.06, 0.47]	−15.3 [−25.3, −5.3]	−0.68 [−1.15, −0.19]		0.24 [−0.02, 0.51]
Long	25.7 [11.2, 40.2]	1.28 [0.41, 2.12]			−10.2 [−27.8, 7.4]	−0.44 [−1.11, 0.26]		
Motivation 0–100 AU								
Sprint	−8.3 [−17.6, 1.1]	−0.58 [−1.19, −0.06]	0.35 [−0.57, −0.13]	−0.12 [−0.39, 0.14]	−5.3 [−21.6, 11.1]	−0.21 [−0.79, 0.38]	0.49 [0.27, 0.71]	0.16 [−0.1, 0.43]
Middle	−14.5 [−26.7, −2.2]	−0.66 [−1.21, −0.08]		0.10 [−0.16, 0.36]	5.6 [−5.5, 16.7]	0.25 [−0.21, 0.7]		−0.28 [−0.54, −0.02]
Long	−11.5 [−36.7, 13.6]	−0.54 [−1.57, −0.52]			−0.9 [−20.7, 18.9]	−0.04 [−0.82, 0.74]		
Physical Fatigue 0–100 AU								
Sprint	30.3 [11, 49.5]	1.42 [0.4, 2.39]	−0.18 [−0.4, 0.04]	0.15 [−0.11, 0.42]	−15 [−29.7, −0.3]	−0.69 [−1.34, −0.01]	0.19 [−0.03, 0.40]	−0.22 [−0.49, 0.05]
Middle	25.9 [16.8, 35]	1.31 [0.64, 1.97]		0.41 [0.14, 0.67]	−11.3 [−21.1, −1.6]	−0.46 [−0.85, −0.05]		−0.37 [−0.64, −0.11]
Long	34.5 [16.1, 52.9]	1.51 [0.51, 2.46]			−21.5 [−46.5, 3.5]	−0.87 [−1.81, 0.11]		
Stress 0–100 AU								
Sprint	−11.2 [−26.1, 3.7]	−0.51 [−1.14, 0.14]	0.21 [−0.01, 0.43]	−0.04 [−0.3, 0.23]	9 [−6.2, 24.2]	0.37 [−0.22, 0.95]	0.23 [0.02, 0.45]	−0.37 [−0.63, −0.1]
Middle	−6.4 [−20.1, 7.4]	−0.27 [−0.8, 0.27]		−0.29 [−0.55, −0.02]	14.3 [1.5, 27.1]	0.64 [0.05, 1.21]		−0.62 [−0.88, −0.35]
Long	−11.9 [−22.7, −1.1]	−0.51 [−0.96, −0.04]			0.1 [−17.6, 17.8]	0 [−0.67, 0.68]		
Tiredness 0–100 AU								
Sprint	0 [−20.8, 20.8]	0 [−0.87, 0.87]	0.55 [0.33, 0.77]	0.82 [0.54, 1.09]	6.3 [−8, 20.6]	0.26 [−0.27, 0.77]	−0.51 [−0.73, −0.29]	−0.88 [−1.16, −0.61]
Middle	16 [0.8, 31.2]	0.68 [0.03, 1.32]		0.38 [0.12, 0.64]	−6.1 [−21.7, 9.5]	−0.24 [−0.79, 0.32]		−0.31 [−0.57, −0.04]
Long	27.6 [2.7, 52.5]	0.97 [0.07, 1.83]			−13.4 [−29.2, 2.4]	−0.50 [−1.05, 0.07]		
BRUMS Vigour 0–16								
Sprint	0.3 [−1.9, 2.6]	0.1 [−0.51, 0.7]	−0.4 [−0.62, −0.18]	−0.73 [−1, −0.46]	−2.2 [−3.7, −0.6]	−0.68 [−1.18, −0.16]	0.44 [0.22, 0.66]	0.66 [0.39, 0.94]
Middle	−1.2 [−3.8, 1.3]	−0.37 [−1.08, 0.35]		−0.28 [−0.55, −0.02]	−0.4 [−3.5, 2.7]	−0.09 [−0.77, 0.59]		0.06 [−0.20, 0.32]
Long	−2.4 [−5.2, 0.4]	−0.67 [−1.41, 0.09]			−0.1 [−2.7, 2.5]	−0.04 [−0.84, 0.77]		
BRUMS Fatigue 0–16								
Sprint	1.6 [−1.1, 4.3]	0.4 [−0.24, 1]	0.26 [0.04, 0.48]	0.43 [0.16, 0.7]	−0.8 [−2.6, 1.1]	−0.18 [−0.59, 0.23]	0.09 [−0.12, 0.31]	−0.49 [−0.76, −0.22]
Middle	2.7 [0.1, 5.2]	0.69 [0.03, 1.32]		0.15 [−.11, 0.41]	−0.5 [−2.4, 1.5]	−0.1 [−0.49, 0.29]		−0.55 [−0.81, −0.28]
Long	3.3 [0.6, 6]	0.8 [0.11, 1.45]			−2.4 [−5.1, 0.3]	−0.57 [−1.18, 0.06]		
BRUMS – Confusion 0–16								
Sprint	1.1 [−0.5, 2.7]	0.46 [−0.17, 1.07]	0.09 [−0.12, 0.31]	0.48 [0.21, 0.75]	−0.8 [−2.7, 1.2]	−0.28 [−0.94, 0.4]	−0.14 [−0.36, 0.08]	−0.62 [−0.89, −0.35]
Middle	1.4 [−0.9, 3.7]	0.5 [−0.27, 1.25]		0.31 [0.05, 0.57]	−1.2 [−2.7, 0.4]	−0.41 [−0.93, 0.13]		−0.54 [−0.80, −0.27]
Long	2.5 [0.1, 4.9]	0.82 [0.02, 1.59]			−3 [−5.9, −0.1]	−1.02 [−1.98, −0.02]		

Pre, post and 24-hour after sprint (12 races), middle-distance (13 races) and long-distance (10 races) orienteering competition

The mean change in all outcome variables before, immediately after, and 24 hours after (MD + 1) sprint, middle-distance, and long-distance orienteering competitions are shown in Figure 3, with the effect sizes and confidence intervals reported in Table 2. The differences in the outcome variables before and after the orienteering competition were mostly consistent across the three events, with the exception of ratings of tiredness and BRUMS vigour ratings in the sprint event. The extent of the changes varied in ratings of motivation, tiredness, BRUMS vigour, fatigue, and confusion ratings. Additionally, there was a moderate increase in tiredness ratings in middle- and long-distance competitions, with greater ratings observed in the long-distance orienteering competition, with no change in the sprint event. There was a small to moderate magnitude of changes when comparing sprint to middle- and long-distance competition. Although the sprint event showed a trivial increase in BRUMS vigour ratings, there was a small to moderate decrease in middle- and long-distance orienteering competitions, and a small to moderate difference in magnitude of change in BRUMS vigour ratings compared to middle- and long-distance competition as shown in Table 2. Regarding the other outcome variables in Table 2, changes of trivial to small magnitude between different races were observed. When comparing pre- and post-competition subjective outcome variables, the long-distance competition had the greatest changes, except for the ratings of MF and motivation when compared to sprint and middle-distance competitions.

According to Figure 3 and Table 2, the comparison between post-competition and MD + 1 demonstrates similar directions of change in the outcome variables, apart from the ratings of motivation in middle-distance and tiredness in sprint event. The directions of changes in the remaining outcome variables were similar, with the ratings of MF, PF, BRUMS vigour, fatigue and confusion subscales showing a decline from post-competition to MD + 1.

Compared to pre-competition value, the ratings of MF, PF, stress, tiredness, BRUMS fatigue and confusion were higher, and motivation and BRUMS vigour was lower in MD + 1 except the ratings of stress in middle-distance competition and BRUMS confusion ratings in long-distance competition, as shown in Figure 3. The stress ratings were higher than pre-competition values in middle-distance competition with a small effect size (ES = 0.34 [−0.21, 0.87]), and displayed a small to moderate difference when compared to the changes between sprint (ES = 0.52 [0.3, 0.74]) and long-distance competition (ES = −0.76 [−1.03, −0.49]). The BRUMS confusion ratings were less than pre-competition in long-distance competition (ES = −0.46 [−1.48, 0.59]), with a small difference when compared to the changes of sprint (ES = −0.4 [−0.67, −0.13]) and middle-distance competition (ES = −0.42 [−0.68, −0.15]) in MD + 1. When assessing the magnitude of changes between sprint and middle-distance competition in PRE vs MD + 1, a trivial difference was observed in MF (ES = −0.18 [−0.4, 0.04]), motivation (ES = 0.19 [−0.02, 0.41]), PF (ES = −0.03 [−0.25, 0.19], tiredness (ES = 0.14 [−0.08, 0.36]), BRUMS vigour (ES = 0.06 [−0.16, 0.28]) and confusion (ES = −0.05 [−0.27, 0.17]), and a small difference in BRUMS fatigue (ES = 0.37 [0.15, 0.59]). Similarly, a small difference in MF (ES = 0.41 [0.14, 0.68]), tiredness (ES = 0.29 [0.03, 0.56]) was seen between sprint and long-distance competition. Moreover, there was a trivial difference in the ratings of motivation (ES = −0.17 [−0.43, 0.09]), PF (ES = −0.08 [−0.34, 0.18]), tiredness (ES = 0.17 [−0.09, 0.43]), and a small difference in MF (ES = 0.55 [0.29, 0.82]), BRUMS vigour (ES = −0.21 [−0.47, 0.06]) and fatigue (ES = −0.34 [−0.60, −0.08]) when comparing the magnitude of changes between middle- and long-distance competition.

Immediately post-24-hours and 48-hours post the final competition ($n = 16$)

Data for all outcome variables immediately post- (POST), 24-hours (24POST) and 48-hours post (48POST) each participant's final competition are shown in Figure 4, with unstandardized and standardized effect sizes in Table 3.

All outcome variables presented a decrease from POST to 24POST. There was a trivial decrease in the ratings of tiredness, BRUMS vigour and fatigue ratings and a small decrease in the ratings of MF, motivation, PF, stress and BRUMS confusion ratings at 24POST. From 24POST to 48POST, there was a small decline in the ratings of MF and BRUMS confusion ratings, and a moderate decline in ratings of PF, tiredness and BRUMS fatigue. Conversely, there was a small increase in stress ratings and a moderate increase in BRUMS vigour ratings in 48POST. Compared to the pre-competition values, the ratings of MF (ES = 0.54 [0.08 to 1.15]), PF (ES = 0.72 [−0.01 to 1.41]), stress (ES = 0.1 [−0.49 to 0.7]), tiredness (ES = 0.31 [−0.39 to 1.01]), and BRUMS – fatigue subscale (ES = 0.3 [−0.03 to 0.63]) remained higher, whilst the ratings of motivation (ES = −0.63 [−1.3 to 0.06]), and BRUMS – vigour subscale (ES = −0.54 [−1.05 to −0.02]) remained lower than the pre-competition level at 48POST. However, at 48POST, BRUMS confusion ratings return to a level similar to pre-competition (ES = 0 [−0.6 to 0.6]). It is important to note that there was a noticeable fluctuation in individuals' rating of all self-report measures, with some ratings outside the standard deviation of the mean value. The wide 95%CI in effect size as presented in Figure 4 and Table 3 also indicate the high variability in individuals' ratings.

Perceived cause of mental fatigue during orienteering competition

Eight perceived causes of MF were identified based on the summary of 41 responses we received after every orienteering competition. The physical demand of the race (56.1%) was the most mentioned causes of MF during orienteering competition. Around one third of responses highlighted the stress from the race and/or mistakes (31.7%), technical demand and/or the difficulty of the race (29.3%) and weather condition i.e., heat or cold (26.8%). The remaining were the amount of concentration required for the race (24.4%), physical readiness for the race (17.1%), non-orienteering challenges e.g., travel or school (12.2%), and multiple race schedule (12.2%).

Physical demand of the orienteering competition ($n = 13$)

The GPS and HR data from 13 competitors was recorded during orienteering competitions; however, three individuals' HR data was not available because of some technical difficulties. The

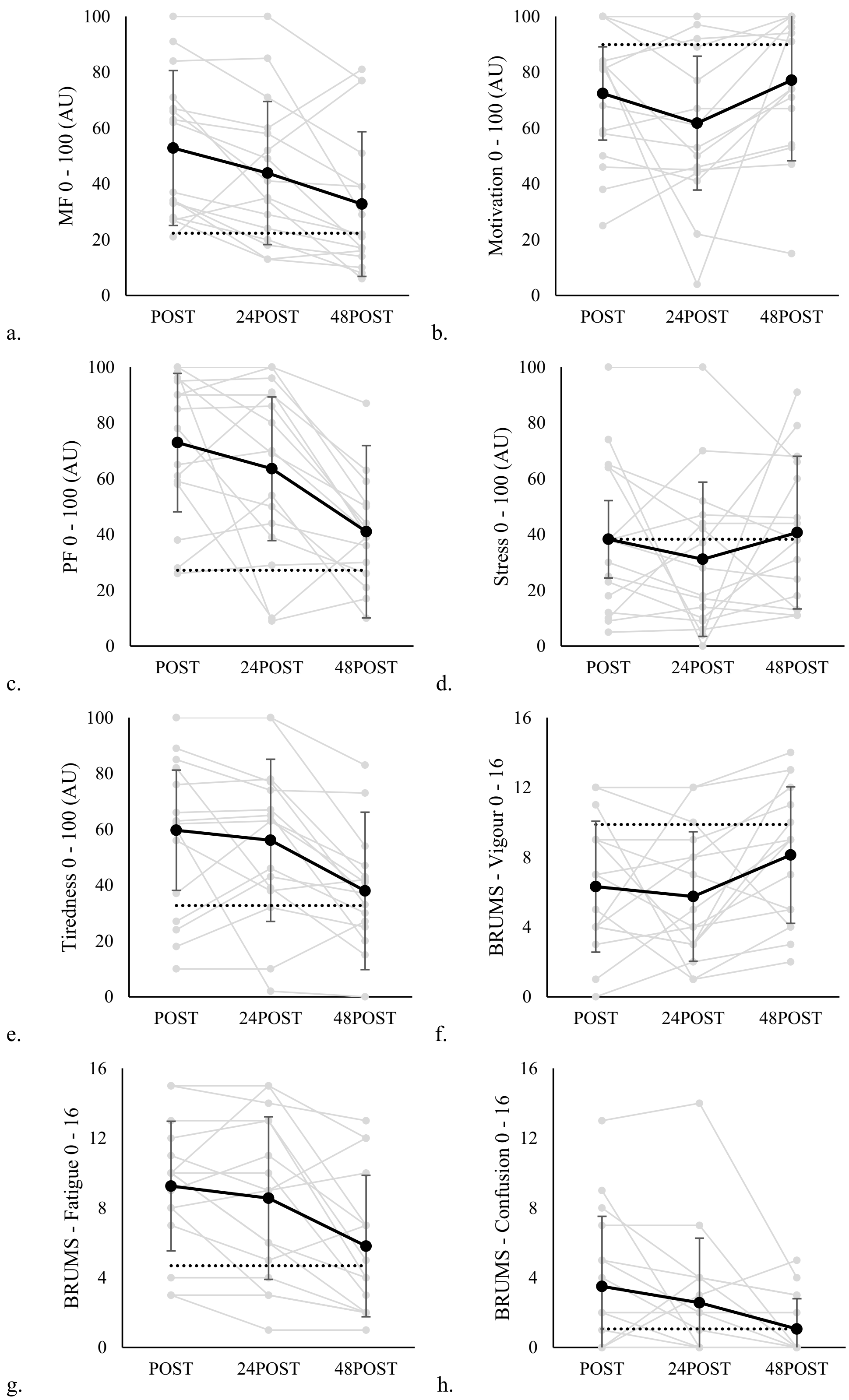

Figure 4. The changes in MF (a), motivation (b), PF (c), stress (d), tiredness (e), BRUMS – Vigour subscale (f), BRUMS – Fatigue subscale (g), and BRUMS – Confusion subscale (h). The black dash line represents the mean value immediately before the first day of competition and the grey lines represent the individual ratings.

physical demands of these races are presented in Table 4. There was a small difference in the amount of time taken to travel each kilometre between the middle- and long-distance competition, while a moderate to large difference was reported between the sprint and both the middle-distance and long-distance competitions.

Table 3. The magnitude of the changes in outcome variables for immediately after the last day of the competition, 24 hours- and 48-hours after the competition ($n = 16$).

	POST vs 24POST		24POST vs 48POST	
Variables	Mean difference [95%CI]	Effect size [95%CI]	Mean difference [95%CI]	Effect size [95%CI]
100-mm visual analogue scale				
MF	−8.9 [−17.1, −0.8]	−0.35 [−0.66, −0.03]	−11.1 [−21.6, −0.7]	−0.43 [−0.83, −0.02]
Motivation	−10.6 [−25, 3.7]	−0.4 [−0.91, 0.12]	15.4 [2.4, 28.4]	0.57 [0.08, 1.05]
PF	−9.4 [−25.2, 6.5]	−0.33 [−0.85, 0.2]	−22.6 [−34.5, −10.7]	−0.88 [−1.4, −0.34]
Stress	−7.2 [−22.3, 7.9]	−0.26 [−0.77, 0.26]	9.6 [−7.2, 26.3]	0.36 [−0.24, 0.95]
Tiredness	−3.6 [−15.3, 8]	−0.13 [−0.5, 0.25]	−18.1 [−28, −8.2]	−0.74 [−1.18, −0.27]
The Brunel Mood Scale 0–16				
Vigour	−0.6 [−2.8, 1.7]	−0.15 [−0.71, 0.41]	2.4 [0.4, 4.3]	0.62 [0.1, 1.13]
Fatigue	−0.7 [−2, 0.6]	−0.16 [−0.46, 0.14]	−2.8 [−4.7, −0.79]	−0.63 [−1.09, −0.15]
Confusion	−0.9 [−2.5, 0.6]	−0.24 [−0.63, 0.15]	−1.5 [−3.1, 0.1]	−0.52 [−1.06, 0.04]

Table 4. The physical demand of different orienteering competition from 13 orienteers.

Type of competition (number of races)	Distance Covered (km)	Climb (m)	Completion time (hr:min:s)	Average speed (km/h)	Time taken per kilometre (min:s.ms)	Difference in distance covered/ time taken per kilometre Effect size [95%CI] vs Middle	vs Long	Mean heart rate (bpm)*
Sprint (12)	3.54 ± 0.43	42.5 ± 22.51	0:17:19 ± 0:04:13	12.72 ± 2.41	04:53.3 ± 01:11.3	1.06 [0.77, 1.34]	1.28 [0.85, 1.72]	171 ± 12
Middle (10)	5.26 ± 1.29	102.8 ± 23.47	0:33:04 ± 0:07:34	9.79 ± 2.25	06:17 ± 01:26.3		0.25 [−0.17, 0.66]	171 ± 10
Long (6)	12.83 ± 2.91	310 ± 86.75	1:25:21 ± 0:19:45	9.04 ± 0.98	06:39.1 ± 01:32.4			169 ± 15

*Result were calculated using 10 orienteer's heart rate data (Sprint: $n = 10$; Middle: $n = 9$; Long: $n = 5$).

Discussion

The aim of this study was to investigate whether orienteering competition influenced perceived MF and other psychological variables. Our data reveals that orienteering competition caused a moderate increase in perceived MF, and the increase did not return to the pre-competition value 48 hours after the final competition had finished, with the perceived MF remains higher than pre-competition value with a small effect size. This study also found moderate increases in perceived MF after middle-distance competitions and large increases after sprint and long-distance competitions, with MF remaining elevated 48 hours after final day of competition.

Acute changes in perceived mental fatigue after orienteering competition

Perceived MF moderately increased following an orienteering competition. Analysis of the combined data revealed that the mean change in MF from pre- to post-orienteering competition was similar to that reported in previous research on academy to premier league soccer players (mean difference: 18 to 47 AU) (Abbott et al., 2020; Thompson et al., 2020) and elite netballers (mean difference: 13.7 AU) (Russell et al., 2019). This study adopted a remote data collection method to measure MF, which was similar to that of Russell et al. (2022) and Thompson et al. (2020), but distinct from Abbott et al. (2020). However, similar mean values and mean changes of MF were observed, indicating that both remote and in-person data collection methods are capable of capturing perceived MF from pre- to post competition. Importantly, our data showed a large standard deviation in the mean value of MF in pre- and post-competition, reflecting broad inter-individual perceptions of MF. It is important to bear in mind that MF is described as an alteration in psychobiological state, and its presence and effects on performance can differ from one individual to another (Giboin & Wolff, 2019; Van Cutsem et al., 2017). There is no clear evidence defining the absolute extent of changes in MF that would have a negative effect on sport performance; however, as concluded in previous systematic reviews (Habay et al., 2021; Sun et al., 2021; Van Cutsem et al., 2017), individuals with increased MF are likely to have an impact on subsequent endurance and decision-making performance.

This study also compared the changes in MF following orienteering races of various lengths (sprint, middle- and long-distance). Trivial to small differences in the mean change of perceived MF were observed between the sprint, middle and long-distance competitions, with the greatest increase in MF being noticed in the sprint event. Nevertheless, irrespective of the type of race, the MF ratings at MD + 1 remained higher than the pre-competition value, with the largest difference observed in the long-distance competition. A small difference in the mean change in MF was identified between long-distance and the other two competitions when comparing PRE and MD + 1. Although both sprint and long-distance competition reported a large increase in perceived MF from pre- to post-competition, the delayed recovery from the long-distance race implies that the MF elicited from a longer duration spent in a physically and mentally demanding environment could have an effect on perceived MF the day after a long-distance competition, even if the change in perceived MF from pre- to post-competition is small compared to the sprint events.

This study supports the findings from previous research into academy to elite soccer players (Abbott et al., 2020; Thompson et al., 2020) and elite netball players (Russell et al., 2019) that MF can increase acutely after taking part in a competition, and can be sustained up to 24 hours after the task has ended. Nevertheless, this study cannot determine which factor is the most important in causing an acute increase in MF in orienteering competition, as long-distance competitions with a relatively longer duration and distance did not present the highest MF ratings after the competition. This aligns with the results from the Delphi study (Lam et al., 2023) and Giboin and Wolff (2019), which suggest that the extent of MF experienced during orienteering competition may be associated with the amount of effort needed to complete the task rather than the duration of the task. Interestingly, though those competing in a sprint competition had the greatest change in MF, and those in a long-distance competition had the greatest MF at MD + 1. Our data also support the findings in Smith et al. (2019) that MF induced by different cognitive tasks can have varied lasting effects on perceived MF.

Acute changes in perceived motivation, physical fatigue, tiredness, stress and mood state after orienteering competition

Our findings revealed a small decrease in motivation to undertake an impending competition after completing an orienteering competition, while MF was moderately increased. This is in line with previous research, which has suggested that mentally fatigued individuals are likely to have lower motivation towards the impending task (Abbott et al., 2020; Giboin & Wolff, 2019; Martin et al., 2019; Russell et al., 2022). According to the proposed mechanism of MF by Martin et al. (2018), the rise of cerebral adenosine in the brain after performing a cognitively demanding task could reduce the motivation to complete further work due to the interaction with dopamine in the anterior cingulate cortex, which could explain the decreased motivation ratings. Despite systematic reviews suggesting that motivation is unlikely to be affected by MF (Habay et al., 2021; Van Cutsem et al., 2017), strategies like increasing the rewards and listening to music can help reduce the effects of MF on physical performance (Boksem et al., 2006; Lam et al., 2021). Moreover, monitoring motivation can give additional evidence to show whether the decrease in physical performance caused by MF is related to the changes in motivation (Inzlicht et al., 2013). Nevertheless, it has been observed that mentally fatigued individuals would have higher ratings of perceived exertion when completing subsequence endurance tasks (Van Cutsem et al., 2017), implying that mentally fatigued individuals experience difficulty in completing the exercise. Associating increased MF with decreased motivation in a cause and effect fashion might overlook other variables that could be relevant to the changes in motivation such as perceived exertion. Previous research has reported that monetary incentives as a motivator can alleviate the adverse effects of MF, as mentally fatigued individuals who are financially incentivised tend to select a more difficult task (Brown & Bray, 2017; Harris & Bray, 2021). Furthermore, sport-specific studies have shown that the timing of the season and the outcome of the competitions can have an effect on psychological responses (Abbott et al., 2020; Russell et al., 2022). The present study did not assess the perceived importance of the competition or the outcome of the competitions in relation to each participant's prior expectations. However, Lam et al. (2023) revealed that the perceived importance of orienteering competition was not deemed to be an important factor in the extent of MF that athletes experience during orienteering. Future work may consider recording the perceived importance of the competition to validate these perceptions and further explore the relationship between motivation and MF.

The PF, tiredness, BRUMS fatigue and confusion ratings all increased after the orienteering competition, with the extent of changes varying from MF. Conversely, the stress and BRUMS vigour ratings decreased. In agreement with the previous investigation on the changes in psychological variables during netball competition (Russell et al., 2021, 2022) and international orienteering experts' consensus (Lam et al., 2023), the changes in both MF and PF followed a similar pattern yet the degree of changes between the two variables varied, which reflects the close association between them. Comparing pre- and post-competition in both combined and specific race types, we found that the perceived stress ratings decreased after the competition. According to Lam et al. (2023), the high perceived stress before the competition could be attributed to pre-competition nerves, as international orienteering experts have reported that external stress can be the cause of MF in orienteering competition but the stress might not occur when they are mentally fatigued (Lam et al., 2023). Furthermore, the mean value of stress ratings was higher at MD + 1 than post sprint, middle- and long-distance competitions. Therefore, it might be reasonable that the participants experience higher stress when their perceived MF is low before the competition. Our findings indicate that perceived stress and perceived MF should not be used interchangeably.

Previous research has defined MF as an acute increase in subjective ratings of tiredness (Habay et al., 2021; Martin et al., 2018), however the present study discovered that the magnitude of changes in MF and tiredness following orienteering competition were not the same. Therefore, it appears that tiredness, as measured in this study, may not be a consistent symptom of MF. It is noteworthy that the difference between MF and other psychological variables i.e., PF, stress and tiredness shows that athletes are able to distinguish MF from other similar terminology. Furthermore, the BRUMS mood state measured before and after competition showed a decrease in vigour and an increase in fatigue scores, which is similar to previous research using laboratory-based MF protocols (Van Cutsem et al., 2017). Lam et al. (2023) suggested that confusion should be measured together with MF, as the international orienteering experts agreed that orienteers may experience confusion when they are mentally fatigued. Our data reported a small increase in BRUMS confusion following orienteering competition. With regard to the magnitude of differences in the ratings of MF, motivation, PF, stress, tiredness and BRUMS among race distances, we found the mean differences of tiredness, BRUMS vigour, fatigue and confusion increased, with the longest orienteering competition having the largest changes apart from MF and motivation ratings. The changes in the remaining outcome variables (MF, motivation, PF stress) do not seem to be related to the race distance, with a trivial to small difference presented between race distances. Taken together, we cannot rule out the possibility that these variables are interlinked but providing a clear distinction between them is beyond the scope of this study. The present study found that orienteering competition would elicit a small to very large negative change in MF and other psychological responses, emphasising that MF should be monitored separately.

Changes in subjective outcome variables at 24- and 48-hours after the final competition

The comparison between the last day of the post-competition value and 48POST shows that, apart from BRUMS confusion ratings, all variables failed to return to the PRE1 value in 48POST. Previous evidence has reported that mood, fatigue (MF) and stress remain elevated 24- to 48 hours after a soccer match (Abbott et al., 2018, 2020; Thompson et al., 2020), which is similar to our findings. A study of 11 under 23 elite football players showing that the elevated subjective ratings of stress and mood could last up to 3 days after the competition, particularly if the match was played away from home or lost (Abbott et al., 2018). Collectively, it appears that the changes in subjective psychological responses induced by orienteering competitions can be sustained for at least 48 hours after the competition. Although most of the outcome variables remained negatively affected 48 hours following the competition, this study observed a gradual improvement as the days progressed. Therefore, based on these findings, it is postulated that the outcome variables could continue to improve over time. This suggests the need for future investigations to extend the observation period in order to provide a more comprehensive understanding of the overall recovery process. By extending the duration of the study, researchers can gain insights into how athletes' well-being and performance evolve beyond the initial 48 hours following a competition. The present study supports that MF can be acutely induced and accumulate at MD + 1. Furthermore, research into the effects of a sustained MF should be prioritised as previous investigation involving 63 Olympic-level open and closed skill sports athletes found that a greater MF rating may not significantly affect the ratings of perceived exertion in a single training session, but the failure to recovery from the increased MF would affect the total perceived exertion of the training week (Coyne et al., 2021). Thus, based on our findings, the MF and other psychological responses acutely affected by the competitions have a delay of at least 48 hours in recovering to the pre-competition value, suggesting that future research should take this delay in recovery into consideration when optimising performance following an orienteering competition.

It is unclear whether the elevated outcome variables in 24POST and 48POST are due to poor sleep quality or fatigue from competitions or the long-distance travel home. Fullagar et al. (2016) found that reduced sleep quality and perceived recovery are associated with the time of the day, however, our study did not measure sleep quality, perceived recovery and the timing of the competition to use justify the changes in outcome variables. The current study implies that attention should also be given to the days prior to and after the competition to enhance the recovery management of orienteers. This information is particularly important for orienteering practitioners since orienteering competitions are often held in the countryside where long journeys are unavoidable. Moreover, none of the participants are full-time athletes and the workload of their professions could also contribute to the changes in MF and psychological responses outside the competition period as non-orienteering tasks (Lam et al., 2023) and education (Thompson et al., 2020) have been perceived to be associated with the subjective feelings of MF.

Physical demand of the orienteering competition

A recent systematic review has provided an overview of the physiological demand of orienteering (Batista et al., 2020); however, it was unable to differentiate between various types of the race due to a lack of evidence. Though the sample size of this study was small, it included three different types of orienteering races with national-level orienteers of a similar age, which overcame the limitation of using competitors of varying ages (Larsson et al., 2002; Smekal et al., 2003). It was found that sprint had the fastest running speed, with a moderate to large difference compared to middle- and long-distance competition. Nevertheless, the similar HR and small difference in running speed between middle- and long-distance competitions reflects that the physical demands of these two races may be similar.

Perceived causes of mental fatigue during orienteering competition

The top three perceived causes of MF in the present study were "physical demand of the race", "stress from the race and/or mistakes", and "technical demand and/or the difficulty of the race". Similar research exploring the descriptors of MF in academy elite football players, elite netball players and international orienteering experts identified the following: "difficulty in reacting to mistakes" (Thompson et al., 2020), "inconsistency of the competitive environment" (Russell et al., 2019), "internal stress to succeed" (Thompson et al., 2021), "external pressures/ stress" and "complexity of the task" (Lam et al., 2023), which is similar to our findings. Although the international orienteering experts did not fully agree that the physical demands of the race directly caused MF, they did concur that being physically fatigued may heighten the perception of MF (Lam et al., 2023). This is in line with the current finding that physical demand may be a pivotal factor in the perceived cause of MF during orienteering, as it is believed to be interconnected with the level of MF experienced by orienteers during the activity. This reinforces the importance of defining MF for athletes and practitioners so as to improve the validity of MF research.

Limitations

It was difficult for participants to complete the survey immediately after the competition due to an unstable connection in some rural areas. This suggests that the timing of post-competition measurement might vary between rural and urban races. Previous research highlighted, however, that the perception of MF did not subside 60 minutes after completion of a cognitively demanding task (Smith et al., 2019). Therefore, even if the survey was not completed immediately after the competition, the measurement should still be considered valid. Furthermore, it is nuanced how meaningful the observed changes in the measured variables are, as the measurements were only taken during an orienteering competition, unable to reflect the day-to-day variation. Perhaps utilising a longitudinal research design may be useful to explain the potential differences in cognitive load and changes in MF between orienteering training and competition. It is important to note that all the competition data in this study were collected during a daytime orienteering competition, and the data may be insufficient to reflect those who participate in a night orienteering competition due to the noticeable difference in terrain visibility between daytime and night-time. Regarding the cumulative effects of orienteering competition on the rating of the outcome variables, the outcome variables were only recorded during one competition weekend, so the current study was unable to provide an overview of the changes in the measured outcome variables during a weekend without competition for comparison. We acknowledge the variation in the number of competition days participants engaged in, which may contribute to extreme ratings due to accumulated effects. This variability is inherent to orienteering, where athletes specialize in different race types, resulting in varying competition days. Considering this natural occurrence in the sport, it is important to consider the impact of competition days when interpreting the results. Although the study did not record the competition outcomes, which could be a confounding factor affecting the ratings on subsequent days, previous research has shown lower subjective well-being after winning a match (Abbott et al., 2018, 2020). Our study accounted for potential changes in subjective ratings by measuring the mood state of participants. Additionally, it is important to note that there was no control over the activities participants engaged in on the day following the competition weekend. These activities, such as educational pursuits, have been reported as potential contributors to MF (Lam et al., 2023; Thompson et al., 2020). Lastly, regarding the statistical analysis, even though there was no significant random effect observed for individuals in most of the analysed variables, future research needs to consider the inclusion of potential random effects of the athletes when conducting similar analyses with this type of data.

Conclusion

This study provides the first evidence that taking part in an orienteering competition will acutely increases orienteer's subjective ratings of MF, PF, tiredness, BRUMS fatigue and confusion, while reducing their ratings of motivation, stress, and BRUMS vigour. Additionally, we discovered that orienteers experienced MF immediately after sprint, middle- and long-distance orienteering competitions. Nonetheless, all outcome variables remained negatively affected by sprint, middle-distance, and long-distance orienteering competitions one day after the competition, apart from the subjective ratings of stress and BRUMS confusion in long-distance orienteering. Following the final day of the competition, most variables did not recover to their pre-competition level 48 hours after the orienteering competition except for stress and BRUMS confusion ratings.

Practical application

This study demonstrates that orienteers experience MF and take up to two days to recover from the fatigue induced by orienteering competition. This highlights the importance of measuring MF in order to improve the management of fatigue in orienteers, as it has been reported that MF reduces endurance capacity and decision-making performance. Consequently, it is essential to ensure there are effective fatigue management strategies in place, since delayed recovery from MF can have a negative effect on performance over multiple days of racing.

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Authorship Contribution

HKNL: conceptualization, manuscript writing (first draft), participant recruitment, data collection, data analysis, manuscript review and editing.
JS: research project supervision, manuscript review and editing.
AT: research project supervision, manuscript review and editing.
SP: research project supervision, manuscript review and editing.

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