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Global practitioner assessment and management of mental fatigue and mental recovery in high-performance sport: A need for evidence-based best-practice guidelines

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Abstract

Background: Mental fatigue and mental recovery have gained scientific attention in relation to sporting performance, yet best practice assessment and management methods are lacking. A greater understanding of current knowledge and practices in high-performance sport are necessary.

Objective: To understand the contemporary knowledge, beliefs, monitoring processes, management strategies, perceived responsibility, sources of evidence, and challenges, when assessing the mental fatigue and mental recovery of athletes in high-performance sport.

Methods: A mixed-methods survey approach obtained information from 156 multi-disciplinary high-performance sport practitioners. Descriptive outputs were reported and potential differences between key concepts were detected using Wilcoxon-signed rank analysis. Thematic analysis interpreted open-text responses.

Results: Only 11.5% and 5.1% of respondents indicated they were "very" knowledgeable about mental fatigue and mental recovery, respectively. Knowledge ($p < 0.001$) and confidence in application ($p = 0.001$) were significantly greater for mental fatigue than mental recovery. Nearly all respondents perceived mental fatigue and mental recovery impacted training and competition performance, with a greater negative impact during competition ($p < 0.001$). A limited number of respondents reported deliberate assessment (31.1%) or management (51.2%) of mental fatigue and mental recovery. A combination of sources of evidence were used to inform practice, with common challenges to implementation including staff knowledge, athlete-buy in, time-availability, and a lack of evidence. Practitioners reported that assessing and managing mental fatigue and mental recovery was multi-disciplinary in nature.

Conclusion: Practitioners reported that mental fatigue and mental recovery did impact performance, yet this was not reflected in the implementation of evidence-based assessment and management practices in high-performance sport.

KEYWORDS
athlete management, cognition, cognitive load, fatigue, high-performance, human performance

1 | INTRODUCTION

Mental fatigue and mental recovery have recently gained increasing scientific attention in relation to sport and exercise performance. Fatigue is complex and multifaceted,[1] and mental fatigue, also known as cognitive fatigue, refers to the exertion experienced as a result of prolonged demanding cognitive activity, that requires sustained mental efficiency.[2] While broad scope in the classification and identification exists, mental fatigue is typically indicated by a change in subjective, behavioral, or neurophysiological markers.[3] Mental fatigue is characterized in the domain of cognitive science, by feelings of exhaustion,[4] lack of energy,[5] and reduced motivation to sustain attention required for performance on a task.[6] Sports-specific descriptions of observed behaviors and symptoms have also been reported by athletes and staff.[7] Mental recovery relates to the process of regaining allostatic balance and replenishment of one's cognitive resource and capability through restorative processes.[8]

The potential negative effects of mental fatigue on physical, technical, tactical, psychological, and psychomotor aspects of sporting performance have been demonstrated.[9] Historically, mental fatigue research has been critiqued for a lack of ecological validity, with a large portion undertaken in laboratory or simulated settings.[10] However, despite its scarcity, recent evidence, that explores mental fatigue beyond the laboratory-based environment, indicates that athletes perceive mental fatigue to have a negative influence on their performance in daily training and competition environments.[7] Across sports, athletes experience fluctuations in mental fatigue and recovery, with elevated instances of mental fatigue during the pre-season training and in-season competition phases.[11–15] Differences between training camps and benchmark competitions (e.g., Olympic and Paralympic Games, World Cups), have also been reported.[16,17] As such, findings highlight the need for research to further examine mental fatigue and recovery, with a particular focus on the practical relevance to sporting performance.[18]

Foundational knowledge supports the influence of cognitive and psychological factors on performance under pressure in competition, and expert-consensus constructs have been identified across domains of attention, cognitive control, working memory, self-awareness, arousal, and shifting.[19] The complexity of mental activity and subsequent mental fatigue related to sporting performance presents challenges in definition, measurement, assessment, inducement, and management.[7] Despite these challenges, subjective self-report data indicates athletes differentiate mental fatigue from physical fatigue.[12,14] There is an abundance of research providing practitioners with knowledge and practices to monitor and manage physical load and fatigue in high-performance sport. The experimental research exploring approaches to monitor and manage mental load and mental fatigue and enhance mental recovery, using strategies that may be implemented by practitioners is slowly emerging. It is increasingly apparent that mental fatigue and mental recovery are important factors in sport, and practitioners should aim to appropriately manage symptoms.[11,18]

Laboratory-based evidence demonstrates the impact of mental fatigue on athletes' performances.[3,20] However, little is understood about the current practices of sports science and sports medicine staff regarding the assessment and management of athletes' mental fatigue and mental recovery in training and competition. Qualitative research approaches can provide insight and provide subsequent value to practitioners.[10,21] Accordingly, this research aimed to understand the knowledge, beliefs, monitoring processes, management strategies, perceived responsibility, sources of evidence, and challenges in assessing and managing mental fatigue and recovery of athletes in high-performance sport. The outcomes can advance the understanding of current knowledge and inform best practices, to optimize training, competition, and recovery of athletes.

2 | METHODS

2.1 | Study design

The study used a mixed-methods cross-sectional survey approach to obtain information from a multi-disciplinary sample of global high-performance sports practitioners. The electronic open public survey was delivered using REDCap (Research Electronic Data Capture, USA) software. Ethical approval was provided by the university's Human Research Ethics Committee (approval number: 2021-242E).

2.2 | Participants

Participants volunteered to complete the survey with inclusion criteria of *frequently working in high-performance sport in a performance support or sports science and sports medicine capacity*. The publicly accessible survey link was promoted through social networking (Twitter) and shared by recognized professional bodies, international

federations, and sporting organizations (including professional teams and intentional/national institutes). Distribution of the publicly shareable link by word-of-mouth between eligible practitioners may have also occurred. All participants provided informed consent.

2.3 | Data collection

Researchers ($n=4$) with expertise in mental fatigue, training and recovery practices, and sports psychology contributed to the initial design of the survey, followed by a qualitative expert review. A pilot of the online survey was completed ($n=9$) with refinements including question wording, structure, order, and number, made based on feedback. The final survey tool consisted of single-select, multi-select, and open-response questions. The survey link was active for a period of 3 months from the end of November 2021 to the end of February 2022.

2.4 | Analysis

Descriptive outputs and quantitative analyses were performed using RStudio (version 2022.02.1) the R statistical programming language (version 4.1.3, *One Push-up*). The Wilcoxon-signed rank test was used to determine differences between confidence and knowledge about mental fatigue and mental recovery; the impact on training and competition; whether mental fatigue and mental recovery were assessed; and whether mental fatigue and mental recovery were intentionally manipulated. All tests were done using the *wilcox. test* function within the *stats* package with the *paired* argument set to *true* to acknowledge the repeated measurements. Due to the exploratory nature of the study, significance was set to $p<0.05$. The Braun, Clarke[22] step-by-step guide and 15-point checklist were used to inform thematic analyses. Nvivo software (Version 12, QSR International Ltd) was used to identify patterns and interpret open-text responses. All open response data were included in the data corpus, with specific data set responses coded to answer prior-identified research questions.[22]

3 | RESULTS

3.1 | Survey respondents

The survey captured 156 complete responses. Participants identified as male (66%), female (33.3%), or preferred not to disclose (0.64%). Practitioners were aged between 30–34 years (27.6%), 25–29 (16.7%), 35–39 (1,4.1%) and 40–44 (14.1%), with 11 ± 8 years of relevant experience. Practitioners worked across 112 different sports, with athletes of varying high-performance levels, including solely elite (28.2%), a combination of elite and sub-elite (14.1%), elite, sub-elite and development/junior/academy (32.7%), elite and development/junior/academy only (3.2%), solely sub-elite (3.2%), sub-elite and development (10.3%) or solely development/junior/academy (8.3%). Most participants were associated with a professional accreditation body (79.5%). Respondents worked with both male and female athletes (66%), solely male (23.7%) and solely female (8.3%) athletes, and a combination of male, female, and self-described (1.9%) athletes. Further demographic information on participants is provided in Table S1.

3.2 | Practitioner knowledge and confidence

Practitioners reported having significantly greater knowledge about mental fatigue than mental recovery ($p=<0.001$). A small percentage of respondents indicated they were "very" knowledgeable about mental fatigue (11.5%) and mental recovery (5.1%). The majority reported being "somewhat" knowledgeable about mental fatigue (78.2%) and mental recovery (67.3%), or "not at all" knowledgeable about mental fatigue (10.3%) and mental recovery (27.6%). Practitioners reported they were significantly more knowledgeable about both mental fatigue ($p=<0.001$) and mental recovery ($p=0.008$), than they were confident in applying their knowledge. Only a minority reported being "largely confident" in applying their knowledge about mental fatigue (10.9%) and mental recovery (8.3%) to maximize performance. Most reported being only "somewhat" confident in the application of mental fatigue (61.5%) or mental recovery (51.9%) knowledge. The remainder reported to be "not at all" for confident for applying knowledge of mental fatigue (27.6%) and mental recovery (39.7%) to maximize performance.

Overall, with specific regard to confidence in applying knowledge, practitioners reported significantly greater confidence in the application of practice related to mental fatigue, than mental recovery ($p=0.001$).

Key themes identified from open response data defining mental fatigue included impact on performance, mental fatigue as a psychobiological state, and connection to athlete wellbeing. For mental recovery, concepts of replenishment, rejuvenation, restoration, and refreshment were identified as well as comments regarding return to baseline performance and function. Practitioners also provided insights on the importance of proactively scheduling recovery, reducing exposure to external stressors, and sports-specific stressors (e.g., complex drills), providing support, and encouraging fulfillment and enjoyment.

3.3 | Perceived impact of mental fatigue

Almost all (>96%) practitioners reported that mental fatigue and mental recovery impacted training and competition performance. Reports indicated mental fatigue to be perceived to influence training both positively and negatively (60.9%) or negatively only (37.8%). For competition, the impact was reported to be only negative (66.7%), both positive and negative (32.7%), or positive only (0.6%). Mental recovery was found to be perceived to have an only positive (53.8%), both positive and negative (39.1%), or negative only (4.5%) impact on training. For competition, mental recovery was reported to have an only positive (56.4%), both positive and negative (32.7%) or negative only (7.7%) impact. There was a significant difference between the impact of mental fatigue on competition compared to training, with a greater perceived negative impact during competition ($p = <0.001$). There were no significant differences between the impact of mental recovery on performance in training and competition ($p = 0.247$). Table 1 summarizes the effects of mental fatigue and mental recovery shared by practitioners.

3.4 | Assessment and management

Most practitioners did not assess mental fatigue (61.5%) and mental recovery (76.3%) of athletes. Of those who did assess mental fatigue and mental recovery, most did so for both training and competition (Figure 1A). Similarly, most respondents did not deliberately manage mental fatigue (55.8%), of those that did, most only managed it in training (38.5%). Mental recovery was reported to be deliberately managed by 54.4% of practitioners (39.9% in both training and competition, 11.5% in training only, and 3.8% during competition only), and not at all by 45.5% (Figure 1B).

3.5 | Assessment approaches

Many different approaches were used by practitioners to assess mental fatigue and mental recovery (Table 2).'Other' free typed methods reported to assess mental fatigue largely indicated use of subjective tools including the Short Recovery and Stress Scale (SRSS), Rating of Perceived Exertion (RPE), Daily Analysis of Life Demands for Athletes (DALDA), Hooper Index, Total Quality Recovery (TQR) and self-designed wellness questionnaires. Observation of an athlete's skill and technical execution including performance on sports-specific tests, behavior, body language, effort, and activation, in addition to engaging in direct conversation with athlete's, were also reported by practitioners as approaches to assess mental fatigue. For mental recovery assessment, 'other' approaches were reported as per mental fatigue, as well as use of a word-association test.

3.6 | Management approaches

Practitioners indicated a variety of approaches to induce mental fatigue and enhance mental recovery (Table 3). Reports of 'other' approaches to induce mental fatigue included: withholding information on the session plan, deliberate scheduling, deliberate repetition, deliberate inducement of physical fatigue, manipulating exposure to recovery options in relation to specifically induced training stress, and performing cognitive tests when fatigued. Several 'other' strategies were reported for enhancement of mental recovery. 'Athlete self-selection' or 'athlete choice' of mental recovery strategies was commonly raised. Consultation with a psychologist and utilization of psychological strategies including meditation, self-talk, and well-being journals were also reported. Additionally, respondents reported use of floatation tanks, yoga, progressive muscle relaxation techniques, and listening to relaxing or upbeat music. Deliberate nutrition and fuelling strategies and engaging in social events and fun activities were also reported.

3.7 | Frequency of assessment and management

Practitioners reported how frequently they assessed mental fatigue and mental recovery of athletes. The frequencies were daily, around training sessions or competition, weekly, or two to four times per week. Assessment of mental recovery was undertaken daily or weekly. Reference was made to performing assessment only following specific (intense) training or competitions. The pre-season phase was when practitioners reported to plan and periodise mental fatigue and mental recovery. Weekly, or two to four times per week, was commonly indicated, yet sporadic or infrequent use was also reported. Inducement of mental fatigue when injured, during rehabilitation, or during the return to sport phase, was raised by a small number of respondents. Variables including competition, type of competition, intensity of training, scheduling, and travel demands were identified as key considerations influencing the use of mental recovery. Reactive or responsive application of mental recovery was also reported.

TABLE 1 Effects of mental fatigue and mental recovery on athlete(s) performance in training and competition shared by practitioners (frequency of responses).

Effects of mental fatigue in training	Effects of mental fatigue in competition
Increase learning, adaptation, development of tolerance, resilience, and capacity (57)	Limit physical capability, intensity, and performance (58)
Decrease session quality (52)	Detrimental to decision-making, concentration, focus, skill execution, technique, reaction time and attention to detail (52)
Decrease motivation, energy, enthusiasm, mood, willingness to exert effort, intention (40)	Impact motivation, mood, energy, enthusiasm, arousal, willingness to exert effort (26)
Limit physical capability, intensity, and performance (38)	Decrease emotional regulation, discipline, communication, and team cohesion, increase irritation, and frustration (26)
Diminish skill-development, decision making and concentration (36)	More apparent with pressure and importance of performance (18)
Representative, replicate competition demands (17)	Opportunity for learning, development, and adaptation (when appropriately prepared) (15)
Improve confidence, self-awareness, self-regulation (15)	Awareness of self- and opposition- mental fatigue important for optimisation of tactical execution (14)
Information on athlete state and capability (15)	Require preparation and planning, consideration of competition structure (10)
Injury, health, and wellbeing risk (15)	Increase risk of injury (3)
Effects of mental recovery on training	**Effects of mental recovery on competition**
Better able to perform in training (51)	Better able to perform in competition (71)
Improve adaptation to training, learning and growth (32)	Improve energy and mood (29)
Requires strategic management and effective individualized strategy identification (24)	Improve self-awareness, self-regulation, ability to manage-self, and cope with pressure (21)
Better information processing, response-time, decision-making, and skill execution (24)	Refresh and reset (13)
Improved motivation, willingness to exert effort, freshness, and energy (17)	Improve focus, decision-making, response-time, skill execution, information processing, and cognitive functioning (11)
Important for performance, health, and wellbeing (13)	Heightened importance for condensed fixtures (6)
Important for athlete self-awareness, reflection, autonomy, and confidence (12)	Influence on arousal (6)
Relevant to demanding competition structure (6)	Practitioner uncertainty regarding appropriate amount of mental activity and mental recovery (6)
Impact on athlete availability (6)	Improve tactical execution (3)

3.8 | Who is responsible?

Whilst the coach was the most important role responsible for inducing mental fatigue (Figure 2A) and enhancing mental recovery (Figure 2B), all roles were in some way responsible, highlighting the multi-disciplinary nature of assessing and managing mental fatigue and mental recovery.

3.9 | Obtaining evidence

Practitioners reported using a range of listed potential sources of evidence to inform their practice assessing and managing athlete mental fatigue and mental recovery (see Figure 3). Colleagues, peer-reviewed research, podcasts, websites and blogs, and attendance at conferences and seminars were reported as the five most frequently used sources of evidence.

3.10 | Challenges to implementation of mental fatigue and mental recovery assessment and management in practice

Practitioner-reported challenges to (a) assessing mental fatigue, (b) inducing mental fatigue, (c) assessing mental recovery, and (d) enhancing mental recovery are displayed in Figure 4. Athlete buy-in, staff knowledge, time availability, and evidence to support protocols were commonly

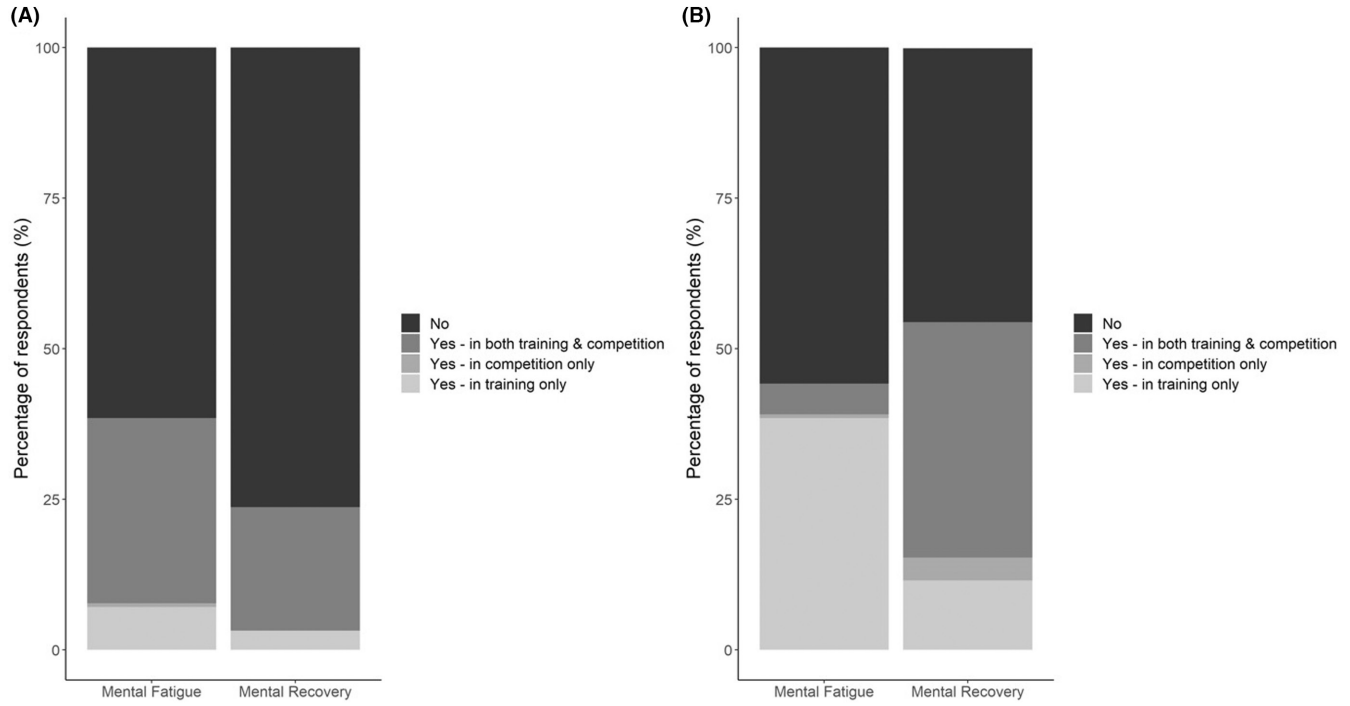

FIGURE 1 (A) assessment and (B) management of mental fatigue and mental recovery during training and competition by practitioners.

TABLE 2 Approaches used by practitioners to assess mental fatigue and mental recovery in athletes, displayed as a percentage (and raw number) of practitioners reporting assessment approach.

Assessment approach used	Mental fatigue	Mental recovery
Behavioral—response accuracy on cognitive task	6.8 (6)	8.6 (5)
Behavioral—response time on cognitive task	2.3 (2)	1.7 (1)
Physiological—HRV (used deliberately to assess mental fatigue)	11.4 (10)	15.5 (9)
Physiological—EEG	2.3 (2)	1.7 (1)
Physiological—fMRI	1.1 (1)	1.7 (1)
Physiological—cerebral haemodynamics (e.g. cerebral bloodflow, fNIRS)	0.0 (0)	0.0 (0)
Subjective—Likert scale format	26.1 (23)	25.9 (15)
Subjective Tool—other (e.g. ARMS, SRSS)	14.8 (13)	13.8 (8)
Subjective—100 mm VAS scale format	10.2 (9)	6.9 (4)
Subjective—NASATLX (or adapted)	2.3 (2)	1.7 (2)
Other	22.7 (20)	22.4 (13)

indicated by staff as perceived challenges. Open-text responses also identified the willingness for stakeholders to engage as an 'Other' challenge.

3.11 | Proposed future research for practical applications

Practitioners identified several areas for future research. Commonly proposed topics (and frequencies of responses) included, directly translatable research involving an interdisciplinary approach (17), mental recovery protocols (17), validation of practical and time-efficient assessment methods (15), and the specific impact of mental fatigue on aspects of training and competition (14). Practitioners also frequently expressed interest in research investigating training strategies to improve tolerance to mental fatigue (11), and understanding the potential influence of travel, scheduling, and hubs because of COVID-19 (11). The potential influence of factors such as performance level, gender, and age (7) and individual response differences (7) were described. The influence of various training and recovery modalities on mental fatigue (7), timeframes of mental recovery (6), nutritional protocols (4), and the influence of the coach-athlete relationship (3) were raised. Lastly, research investigating potential relationships with athlete well-being, injury, and concussion (3) were proposed.

TABLE 3 Approaches used by practitioners to manage mental fatigue and mental recovery in athletes, displayed as a percentage (and raw number) of practitioners reporting management approach.

Management approach used	Inducement of mental fatigue
Manipulation of technical or tactical drill demands	51.3 (60)
No taper into nominated competitions	17.9 (21)
Manipulation of video or performance analysis	12.0 (14)
Restriction of caffeine intake	5.1 (16)
Restriction of carbohydrate intake	5.1 (6)
Brain endurance training	3.4 (4)
Other	3.4 (4)
Sleep deprivation the preceding evening	1.7 (2)
Restriction of creatine intake	0.0 (0)
	Enhancement of mental recovery
Mindfulness	13.4 (58)
Directing time away from daily training or competition environment	12.4 (54)
Breathing techniques	11.8 (51)
Debriefing	11.8 (51)
Avoidance of social media	9.4 (41)
Exposure to restorative environments	8.3 (36)
Powernaps	8.1 (35)
Mental imagery	6.5 (28)
Avoidance of media engagement	5.8 (25)
Music—other	4.1 (18)
Mental detachment	3.9 (17)
Other	2.3 (10)
Psychological techniques—other	2.1 (9)
Music—binaural beats	0.2 (1)
Transcranial direct current stimulation	0.0 (0)

4 | DISCUSSION

This project examined practitioners' current knowledge, beliefs, and practices assessing, monitoring, and managing mental fatigue and mental recovery of athletes in high-performance sport. Findings confirm previous editorial comments, which propose a need for further research to rigorously examine best practice in the context of optimizing athletes performances in training and competition.[18] Attention should also be directed towards improving practitioners' scientific knowledge about mental fatigue and mental recovery.

4.1 | Impact on training and competition

When asked about mental fatigue in training, practitioners reported the benefits such as increased opportunity for learning, adaptation, development of tolerance, resilience, and capacity. This concept is supported by evidence demonstrating an adaptation response to mental fatigue, and potential improvement in an individual's tolerance to mental fatigue and subsequent improvements in physical and cognitive performance when fatigued.[23] Practitioners also reported mental fatigue decreased session quality of training, by way of reduced physical capability, skill execution, and response time, which is consistent with previous research.[9,10,24] The perceived reductions in session quality, motivation, energy, enthusiasm, willingness to exert effort and training intention also align with prior evidence, and self-reports from athletes and high-performance staff.[7] Practitioners also reported mental fatigue reduced physical capability, intensity, and performance, and impaired decision-making, concentration, skill execution, and technique in competition. Despite some practitioners indicating they perceived mental fatigue in training to be representative, or replicate, competition demands, there was a significantly greater perceived negative impact of mental fatigue on competition performance, than training performance. As such, the use of strategies which are currently employed by some practitioners to induce mental fatigue, and their subsequent adaptations, may not be adequality preparing athletes to perform during competition. With regards to pressure and importance of performance, time–pressure has recently been demonstrated to increase perceived mental load, likely mediated by increased cognitive complexity and requirement to emotionally regulate arousal.[25] Cognitive complexity may be experienced by athletes when elaborate score situations exist under time–pressure, or intricate tactical scenarios are presented for immediate implementation. Accordingly, situations where there is large importance of competition-outcome and small margins of difference, may increase perceived mental load. Reports of decreased emotional regulation, discipline, and increased irritation and frustration, when discussing mental fatigue in competition, indicate that athletes may not be prepared to adequately regulate emotions and arousal when mentally fatigued during competition.[19] Measurement of mental fatigue which replicates the cognitive complexity and arousal requirements of competition is a necessary next step in research. Periodizing training with appropriately designed drills which replicate competition stress experienced across a season or leading into events like the Olympic and Paralympic Games, which happen every 4-years, will benefit the performance of athletes in competition. Moreover, this would allow practitioners to dose training and recovery more effectively week to week.

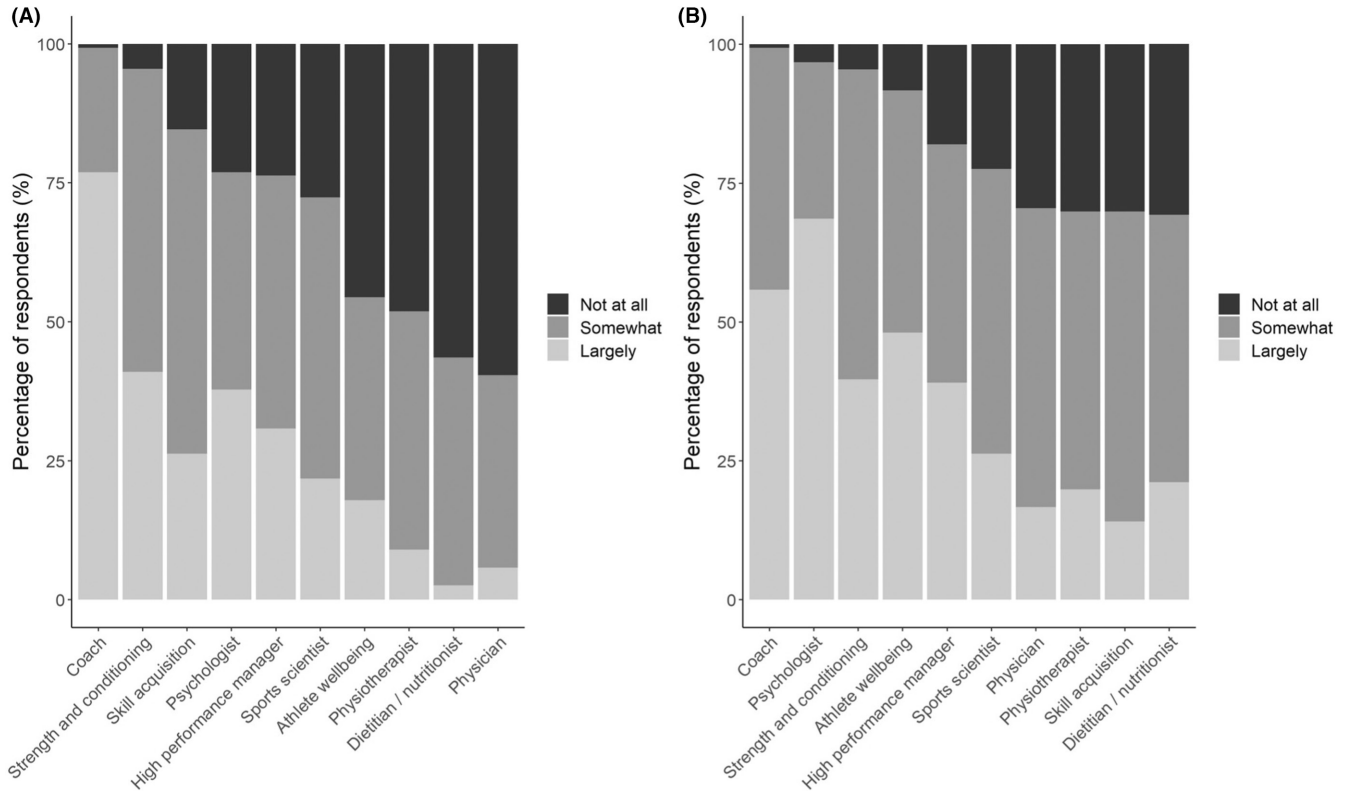

FIGURE 2 Practitioners responsible for (A) inducing mental fatigue (B) enhancing mental recovery of athlete(s) in training and competition.

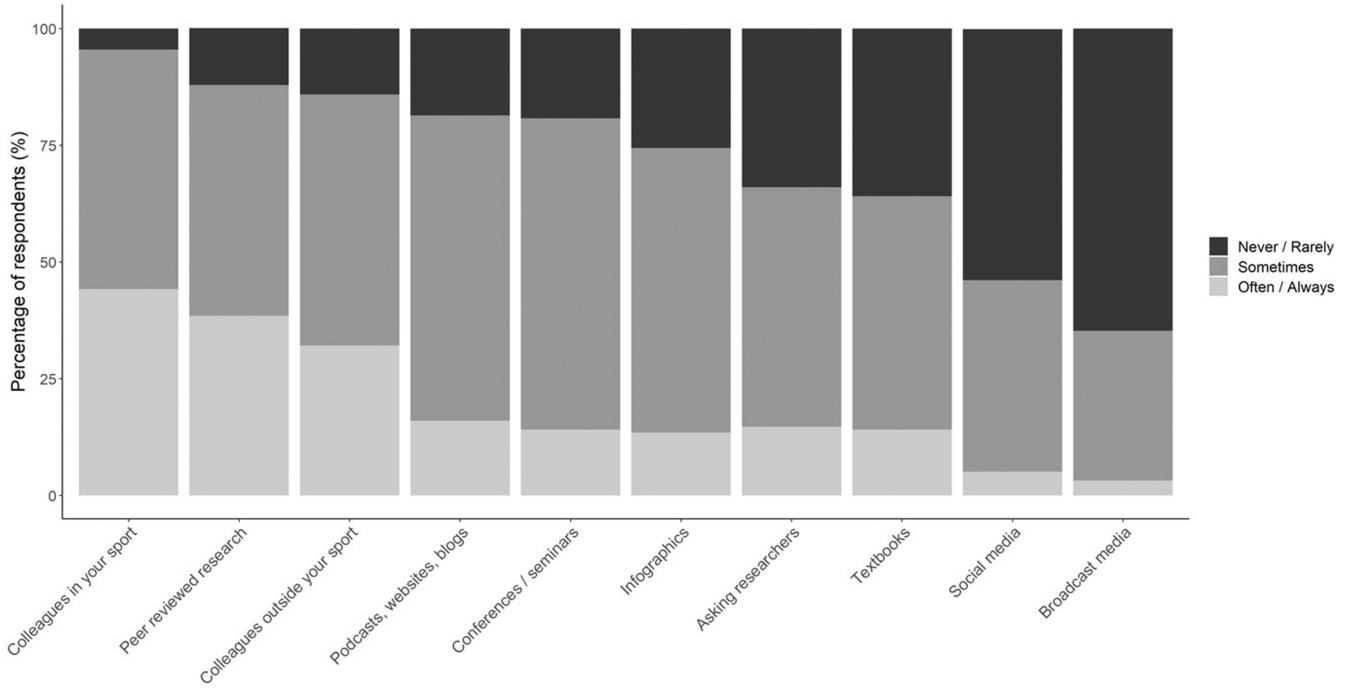

FIGURE 3 Practitioners means of sourcing evidence to inform assessing and managing athlete(s) mental fatigue and mental recovery.

Practitioners perceived that effective mental recovery helps athletes perform in training and competition. The influence of exposure to repeated bouts of mental fatigue, and its subsequent effects, such as disengagement and withdrawal, has previously been examined.[7] Present findings reinforce a perceived positive impact of mental recovery to manage, chronic cognitive adaptations, athlete availability, health, and wellbeing. Practitioners were

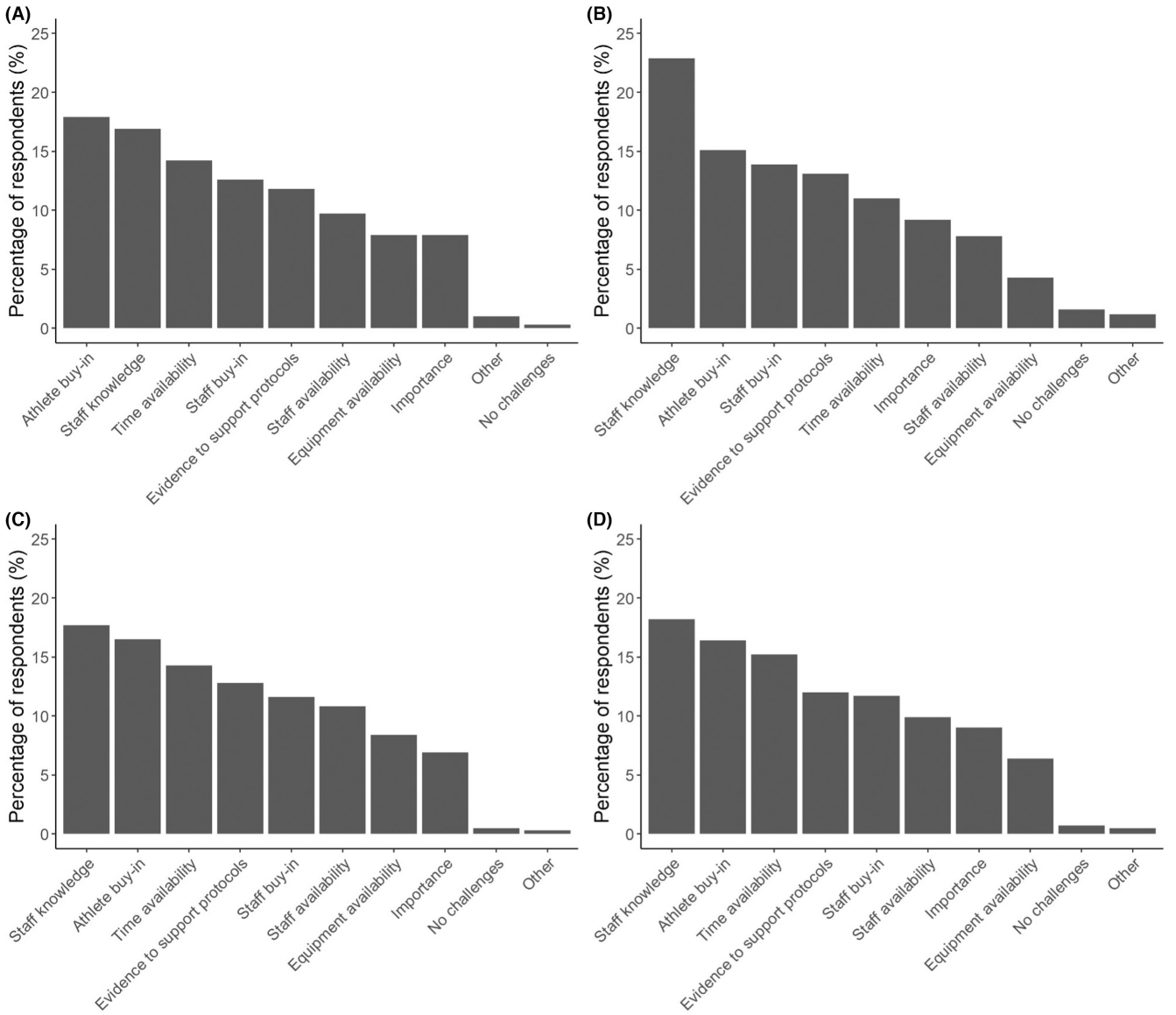

FIGURE 4 Barriers to (A) assessing mental fatigue, (B) inducing mental fatigue, (C) assessing mental recovery and (D) enhancing mental recovery in athletes reported by practitioners.

aware of the need for strategic and intentional management as previously proposed in the literature.[11,12] Open response comments regarding the elevated importance of mental recovery during congested fixture periods is supported by prior evidence demonstrating elevated mental fatigue with condensed scheduling and warrants further exploration.[17]

4.2 | Knowledge, confidence, assessment, and management

4.2.1 | Knowledge and confidence

Findings demonstrated that practitioner's knowledge about mental fatigue and mental recovery was limited. Despite fatigue and recovery being given much consideration in both research and practice, physical, biomechanical, and nutritional aspects of fatigue have been the focus.[10] Open responses to defining mental fatigue and mental recovery did not extend beyond a basic comprehension, yet aligned with published definitions[9,26] and athlete and practitioner self-report.[7] Further, practitioners reported extremely limited confidence in applying their knowledge of mental fatigue and mental recovery. The infancy of research which explores the efficacy of strategies and evaluates the applied impact is a likely contributor.[18,27] Moreover, differences were observed with practitioners reporting greater knowledge and confidence in applying their knowledge for mental fatigue, compared to mental recovery. This aligns with the concept that despite the proportion of time athletes spend recovering, the focus is

typically placed on training and the development of capacity and capability, with less attention given to recovery protocols. Additionally, whilst this area has emerged as a 'hot topic' the majority of the literature available to date has focused on mental fatigue as opposed to mental recovery.[3] Research about the mental recovery strategies of athletes is lacking thus further work is necessary to establish the evidence-base for practitioners [18].

4.2.2 | Assessment

Only a small percentage of respondents reported actively assessing or managing mental fatigue. Further, practitioners reported a variety of methods of assessment, reflective of the diverse approaches used in literature and the feasibility of such techniques.[10] Mental fatigue is typically assessed using changes in subjective (i.e., perceptual), behavioral (i.e., performance on a cognitive task), and (neuro) physiological markers (i.e., brain activity).[3] Traditionally a change in one, or more, of the three domains has been used to indicate a state of mental fatigue. However, it is recommended, where practically possible, to include markers from multiple domains for thorough assessment. Subjective approaches were reported to be most frequently used by practitioners, likely due to their practicality. A number of practitioners indicated use of validated subjective tools such as a 100 mm VAS,[28] NASA-TLX,[29] Short Recovery and Stress Scale (SRSS),[30] and Rating of Perceived Exertion (RPE).[9,31] A large portion of practitioners however reported use of self-designed subjective assessment methods and Likert scales. Likert scales have demonstrated changes in mental fatigue, and can aid in distinguishing mental fatigue from the majority of other athlete self-report measures using ordinal regression analyses.[12] However, it is strongly recommended that validated scales, or those which demonstrate strong relationships with behavioral and (neuro) physiological indicators are used for assessment of mental fatigue and mental recovery. Future research may establish which scale, or combination of scales, offer the most valid, reliable, and feasible methods of assessment during training and competition.

Practitioners reported HRV as the most commonly used physiological measure for assessment of mental fatigue and mental recovery, and is commonly used in athletic populations. The sensitivity of HRV metrics such as low and high frequency power ratios and root mean square of successive interval HRV outputs, to detect changes in mental fatigue and mental recovery in athletes may provide a non-invasive and practical measure. The reliability of HRV metrics to measure mental fatigue and mental recovery requires further evaluation. Established markers of electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) were also reported by a very small percentage of respondents. Despite the feasibility of using these tools being low, there is importance in gaining understanding of brain changes whilst performing physical tasks, thus practitioners may be seeking robust physiological indicators.[10,24] A promising objective tool which has demonstrated sensitivity in a semi-elite training environment is ocular metrics, such as pupil diameter, saccade accuracy, number of saccades, saccade velocity and latency.[32] Behavioral indicators of response time and accuracy during cognitive tasks was reported by only a very small percentage of practitioners. This is surprising given the feasibility of a validated short cognitive task, such as a 3-min psychomotor vigilance test (PVT).[33] Overall, the knowledge and application of measurement approaches by practitioners can be improved.

Responses shared as 'other' assessment approaches, demonstrated that practitioners commonly use observation of an athlete's skill and technical execution to identify changes in mental fatigue or mental recovery. Behavior, body language, effort, activation, and conversation may be useful tools to indicate an athletes state of mental fatigue, which is supported by previous athlete and staff self-report.[7] These findings demonstrate the potential value of observational techniques as an informal assessment approach to indicate athlete mental fatigue or mental recovery. Future research should explore the potential to validate practitioner observations as sport-specific signs and symptoms of mental fatigue and mental recovery and evaluate the potential use as a practical assessment.

4.2.3 | Management

A greater percentage of practitioners reported management of mental fatigue and mental recovery than assessment. Manipulation of technical or tactical drill demands was a commonly reported management approach, in-line with evidence demonstrating increased technical and tactical complexity to be mentally fatiguing, and the consensus that mentally fatiguing tasks should be avoided close to competition.[24,34] Similarly, manipulation of video and performance analysis sessions, and media engagement to induce mental fatigue was used to induce mental fatigue by practitioners.[7,35] However, the impact of performance analysis on athlete mental fatigue is plausibly context-specific and should be assessed and evaluated within the specific sport. Open responses indicated use of 'other' techniques including withholding information on session plans, deliberate scheduling, repetition, inducing physical fatigue, and adding a training stress and mental load using cognitive tasks. The small percentage of reports of brain endurance training (BET) demonstrate opportunity for applied research using specifically

designed cognitively fatiguing protocols to improve athletes' tolerance to performing with additional mental fatigue.[23,36,37] In line with this, practitioners should consider the deliberate application of ecologically valid cognitively fatiguing protocols, to manipulate training outcomes. Accordingly, further research should seek to compare the benefits of traditional BET protocols to sport-specific tasks and translate the concept into applied practice.

A range of mental recovery strategies were reported by practitioners and several of the approaches were supported by recent evidence, such as mindfulness,[38] time away from the training or competition environment,[7] breathwork,[39] debriefing,[26] avoidance of social media,[40] and exposure to restorative environments.[26] Practitioners reported athletes having an active role in the selection of mental recovery strategies was of high importance. Belief in the sports science interventions chosen by athletes to optimize their performance is acknowledged by experienced coaches and scientists.[41] Future research should seek to include athlete input and agency in the design and evaluation of the available strategies they adopt as part of their mental fatigue and mental recovery processes in and around training and competition.

4.2.4 | Frequency of assessment and management

Timing and the optimal frequency of assessment and management of mental fatigue and mental recovery in the sporting environment is under-researched, with a lack of available evidence to inform practice. Practitioner perspectives indicated an understanding of the need to manage mental fatigue and mental recovery across differing training and competition phases. Practitioners demonstrated awareness of the multitude of factors to be cognisant of including session intensity, scheduling, travel demands, and competition type.[17] The current reactive, rather than proactive, management of mental recovery was highlighted, indicating practitioners are not prioritizing mental recovery in their planning and periodisation. Exploring the concept of front-loading mental recovery for athletes prior to high levels of mental activity, in a similar way that physical recovery, sleep extension or banking is used, may provide benefit around periods of high mental fatigue.

4.3 | Research translation

4.3.1 | Challenges to practice

A major challenge for assessment and management of both mental fatigue and mental recovery was practitioner knowledge. There is a need to share relevant evidence and find effective ways to communicate current knowledge and best practice through targeted education. Accordingly, the integration of information about mental activity, fatigue, and recovery, into educational modules and position statements may be important. Athlete buy-in, to assess and manage mental fatigue and mental recovery, was perceived as challenging, thus athletes may also benefit from targeted education about the effects of mental fatigue and mental recovery on performance in training and competition. Availability of time, or time constraints, to implement sports science interventions, is a barrier more broadly acknowledged in the daily training environment and competition setting and not unique to mental fatigue and mental recovery management.[42] However, the findings place additional importance on research evaluating the validity and sensitivity of time-efficient evidence-based approaches, such as short cognitive-tasks or easily implemented neuro-physiological techniques.

4.3.2 | Sources of evidence

The present findings indicate a combination of sources are used to inform knowledge and practice about athletes' mental fatigue and mental recovery. A multimodal approach will be necessary when sharing any research outcomes with practitioners. The high reliance on 'other colleagues' to obtain information indicated that advancing practitioner knowledge through targeted education will have a two-fold impact, on the individual delivering the knowledge and practice in training and competition, and subsequently on the knowledge and practice of others through peer-support. 'Peer reviewed research' was ranked highly as a source of information, consistent with prior research.[43] The reported use of 'podcasts, websites, and blogs' demonstrated the need for researchers to actively engage with popular science communication tools to share their findings.[44] Furthermore, it should be highlighted that, consistent with prior research,[43] the modality of 'asking researchers' was limited and greater effort to develop meaningful, collaborative, and open relationships between researchers and practitioners is needed.

4.3.3 | Who is responsible?

Multiple practitioners were deemed to be largely or somewhat responsible for managing mental fatigue and mental recovery of athletes, highlighting shared accountability for knowledge and practice. Given the complexity of mental fatigue and mental recovery and subsequent need for

input from a variety of domains, such as coaching science, physical preparation, dietetics, and psychology, multidisciplinary management is recommended. Among the multiple contributing roles, coaches were identified as largely responsible for managing mental fatigue, followed by strength and conditioning staff, findings which support the notion of deliberately inducing mental fatigue in training. Psychologists were also perceived to be responsible for mental recovery. Given that for many sports, contact with the psychologist can be limited, sports may benefit from prioritizing the sport psychologists time to develop individualized mental recovery strategies for all athletes and train other sport science practitioners with frequent athlete interaction to assist in integrating mental recovery into daily practice. Interestingly, despite the strong evidence-base in support of nutritional strategies to mitigate the negative impacts of mental fatigue on performance,[3] dieticians and nutritionists were perceived by practitioners to have a low level of responsibility to manage mental recovery. Accordingly, large potential exists for dieticians to consider how to leverage existing evidence to mitigate mental fatigue and enhance mental recovery of the athletes they support.

4.4 | Future research

Practitioners reported a need for further evidence to inform; assessment methods, recovery protocols, improving tolerance to mental fatigue, the impact of sport-specific constraints, individual differences, and fatigue and recovery time-course responses. Furthermore, there is a need for the continued contribution of fundamental laboratory-based research investigating mental fatigue and mental recovery which is multi-disciplinary across cognitive science and sport science to contribute to knowledge, measurement, optimisation strategies, and ultimately best practice for applied practitioners working with coaches and athletes.

4.5 | Limitations

Whilst substantial value was gained from the findings, there is the need to acknowledge and consider the potential for a response-bias as almost a third of responding practitioners indicated prior research experience by completing a PhD or Honors.

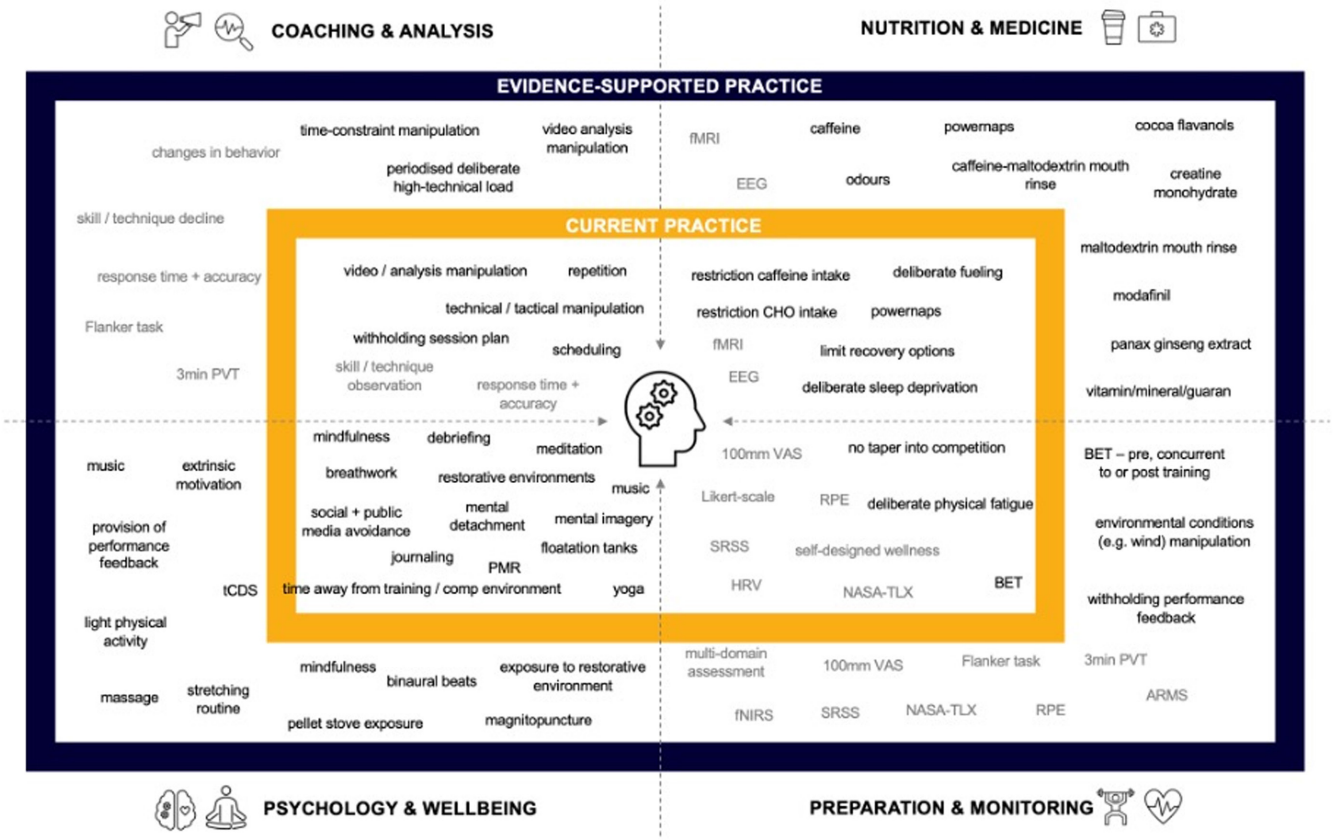

FIGURE 5 Current practice with scientific evidence for the assessment (gray text) and management (black text) of mental fatigue and mental recovery of athletes used in high-performance sport.

5 | CONCLUSIONS

The current research provided novel information about the current state of knowledge regarding the assessment and management of mental fatigue and mental recovery in high-performance sport. Practitioners reported that mental fatigue and mental recovery impact both training and competition performance of their athletes. However, only one-third of practitioners indicated intentional assessment or management, using a combination of techniques, both with and without supporting evidence. The findings highlight the need to share information about the temporal nature of mental fatigue and mental recovery of athletes with practitioners and co-design of research to answer practitioner driven questions. Both researchers and practitioners can collaborate meaningfully to share knowledge and evidence-based practice. Figure 5 provides a summary of current practices shared by respondents and relevant available evidence for practitioners. Lastly, coaches and practitioners can adopt a multi-disciplinary approach to the consistent assessment and management of mental fatigue and mental recovery of their athletes in a periodized manner to support outcomes in training and performance in competition.

6 | PERSPECTIVE

A multi-disciplinary sample of global high-performance sports practitioners reported that they perceive mental fatigue and mental recovery to impact athletes' training and competition performances. At present, however, there is limited intentional assessment or management of mental fatigue and mental recovery in high-performance sport. Practitioners shared their lack of self-reported knowledge and confidence in application of knowledge as a barrier. Coaches and practitioners can use several evidence-based measures and strategies which may aid in the management of mental fatigue and mental recovery to support training and competition performance (Figure 5). Research is required to further validate assessment and management strategies that have utility in the field as best-practice.

AUTHOR CONTRIBUTIONS

All listed authors contributed to the conceptualization and methodology. SR was primarily responsible for the investigation and project administration. SR and RD contributed to data curation, formal analysis and visualization. RS, SH, SR and were responsible for funding support. SR and RJ were responsible for software used to support execution of the project. Initial draft of the manuscript was written by SR. SR, RJ, SH, and RS were responsible for manuscript review and editing. All listed authors read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

None of the listed authors have a conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The datasets generated during and analyzed in this study are not publicly available due to ethical and GDPR guidelines, and risk of potential re-identification of participants, non-identifying data is available from the corresponding author on reasonable request.

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REFERENCES

1. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med (Auckland, NZ)*. 2014;44(2):139-147.
2. Lorist MM, Boksem MA, Ridderinkhof KR. Impaired cognitive control and reduced cingulate activity during mental fatigue. *Cogn Brain Res*. 2005;24(2):199-205.
3. Proost M, Habay J, De Wachter J, et al. How to tackle mental fatigue: a systematic review of potential countermeasures and their underlying mechanisms. *Sports Med*. 2022;1-30:2129-2158.
4. Qi P, Ru H, Gao L, et al. Neural mechanisms of mental fatigue revisited: new insights from the brain connectome. *Engineering*. 2019;5(2):276-286.

5. Boksem M, Tops M. Mental fatigue: costs and benefits. *Brain Res Rev*. 2008;59(1):125-139.
6. Chaudhuri A, Behan PO. Fatigue in neurological disorders. *Lancet*. 2004;363(9413):978-988.
7. Russell S, Jenkins D, Rynne S, Halson S, Kelly V. What is mental fatigue in elite sport? Perceptions from athletes and staff. *Eur J Sport Sci*. 2019;19(10):1367-1376.
8. Kellmann M, Bertollo M, Bosquet L, et al. Recovery and performance in sport: consensus statement. *Int J Sports Physiol Perform*. 2018;13(2):240-245.
9. Van Cutsem J, Marcora S, De Pauw K, Bailey S, Meeusen R, Roelands B. The effects of mental fatigue on physical performance: a systematic review. *Sports Med (Auckland, NZ)*. 2017;47(8):1569-1588.
10. Russell S, Jenkins D, Smith M, Halson S, Kelly V. The application of mental fatigue research to elite team sport performance: new perspectives. *J Sci Med Sport*. 2019;22(6):723-728.
11. Russell S, Jenkins D, Halson S, Kelly V. Mental fatigue increases across a 16-week pre-season in elite female athletes. *J Sci Med Sport*. 2021;25:356-361.
12. Russell S, Jenkins D, Halson S, Juliff L, Connick M, Kelly V. Mental fatigue over 2 elite netball seasons: a case for mental fatigue to be included in athlete self-report measures. *Int J Sports Physiol Perform*. 2021;17:1-10.
13. Abbott W, Brownlee T, Naughton R, Clifford T, Page R, Harper L. Changes in perceptions of mental fatigue during a season in professional under-23 English premier league soccer players. *Res Sports Med*. 2020;28(4):529-539.
14. Russell S, Jenkins D, Halson S, Kelly V. Changes in subjective mental and physical fatigue during netball games in elite development athletes. *J Sci Med Sport*. 2019;23(6):615-620.
15. Díaz-García J, Filipas L, La Torre A, Gómez-Rivera J, Rubio-Morales A, García-Calvo T. Mental fatigue changes from regular season to play-offs in semiprofessional soccer: a comparison by training days. *Scand J Med Sci Sports*. 2023;33(5):712-724.
16. Díaz-García J, González-Ponce I, López-Gajardo MÁ, Van Cutsem J, Roelands B, García-Calvo T. How mentally fatiguing are consecutive world Padel tour matches? *Int J Environ Res Public Health*. 2021;18(17):9059.
17. Russell S, Jenkins D, Halson S, Juliff L, Kelly V. How do elite female team sport athletes experience mental fatigue? Comparison between international competition, training and preparation camps. *Eur J Sport Sci*. 2021;1-11:877-887.
18. Roelands B, Kelly V, Russell S, Habay J. The physiological nature of mental fatigue: current knowledge and future avenues for sport science. *Int J Sports Physiol Perform*. 2021;17:1-2.
19. Albertella L, Kirkham R, Adler A, et al. Building a Transdisciplinary Expert Consensus on the Cognitive Drivers of Performance under Pressure: an International Multi-Panel Delphi Study. 2022.
20. Perrey S. Training monitoring in sports: it is time to embrace cognitive demand. *Sports*. 2022;10(4):56.
21. Harper LD, McCunn R. "Hand in glove": using qualitative methods to connect research and practice. *Int J Sports Physiol Perform*. 2017;12(7):990-993.
22. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006;3(2):77-101.
23. Dallaway N, Lucas SJE, Ring C. Concurrent brain endurance training improves endurance exercise performance. *J Sci Med Sport*. 2021;24(4):405-411.
24. Habay J, Van Cutsem J, Verschueren J, et al. Mental fatigue and sport-specific psychomotor performance: a systematic review. *Sports Med*. 2021;51(7):1527-1548.
25. Ponce-Bordón JC, García-Calvo T, López-Gajardo MA, Díaz J, González-Ponce I. How does the manipulation of time pressure during soccer tasks influence physical load and mental fatigue? *Psychol Sport Exerc*. 2022;63:102253.
26. Loch F, Ferrauti A, Meyer T, Pfeiffer M, Kellmann M. Resting the mind–a novel topic with scarce insights. Considering potential mental recovery strategies for short rest periods in sports. *Perform Enhance Health*. 2019;6(3–4):148-155.
27. Eisenmann J. Translational gap between laboratory and playing field: new era to solve old problems in sports science. *Transl J Am Coll Sports Med*. 2017;2(8):37-43.
28. Smith MR, Chai R, Nguyen HT, Marcora SM, Coutts AJ. Comparing the effects of three cognitive tasks on indicators of mental fatigue. *J Psychol*. 2019;153(8):759-783.
29. Gattoni C, O'Neill BV, Tarperi C, Schena F, Marcora SM. The effect of mental fatigue on half-marathon performance: a pragmatic trial. *Sport Sci Health*. 2021;17(3):807-816.
30. Kölling S, Schaffran P, Bibbey A, et al. Validation of the acute recovery and stress scale (ARSS) and the short recovery and stress scale (SRSS) in three English-speaking regions. *J Sports Sci*. 2020;38(2):130-139.
31. Martin K, Meeusen R, Thompson KG, Keegan R, Rattray B. Mental fatigue impairs endurance performance: a physiological explanation. *Sports Med (Auckland, NZ)*. 2018;48(9):2041-2051.
32. Luis-del Campo V, Morenas Martín J, León Llamas JL, Ortega Morán JF, Díaz-García J, García-Calvo T. Influence of the time-task constraint on ocular metrics of semi-elite soccer players. *Scie Med Footb*. 2023;1-8. doi:10.1080/24733938.2023.2172203
33. Grant DA, Honn KA, Layton ME, Riedy SM, Van Dongen HPA. 3-minute smartphone-based and tablet-based psychomotor vigilance tests for the assessment of reduced alertness due to sleep deprivation. *Behav Res Methods*. 2017;49(3):1020-1029.
34. Englert C, Taylor IM. *Motivation and Self-Regulation in Sport and Exercise*. Routledge/Taylor & Francis Group; 2021. doi:10.4324/9781003176695
35. Fortes LS, Gantois P, de Lima-Júnior D, et al. Playing videogames or using social media applications on smartphones causes mental fatigue and impairs decision-making performance in amateur boxers. *Appl Neuropsychol Adult*. 2023;30(2):227-238.
36. Staiano W, Merlini M, Gattoni C, Marcora S. Impact of 4-week Brain Endurance Training (BET) on Cognitive and Physical Performance in Professional Football Players. Paper presented at: Medicine and Science in Sports and Exercise. 2019.
37. Staiano W, Merlini M, Romagnoli M, Kirk U, Ring C, Marcora S. Brain endurance training improves physical, cognitive, and multitasking performance in professional football players. *Int J Sports Physiol Perform*. 2022;17(12):1732-1740.
38. Axelsen JL, Kirk U, Staiano W. On-the-spot binaural beats and mindfulness reduces the effect of mental fatigue. *J Cogn Enhanc*. 2020;4:31-39.
39. Mo X, Qin Q, Wu F, et al. Effects of breathing meditation training on sustained attention level, mindfulness attention awareness level, and mental state of operating room nurses. *Am J Health Behav*. 2021;45(6):993-1001.

40. Fortes LS, Fonseca FS, Nakamura FY, et al. Effects of mental fatigue induced by social media use on volleyball decision-making, endurance, and countermovement jump performance. *Percept Mot Skills*. 2021;128:2745-2766.
41. Halson SL, Martin DT. Lying to win—placebos and sport science. *Int J Sports Physiol Perform*. 2013;8(6):597-599.
42. Fullagar HHK, McCall A, Impellizzeri FM, Favero T, Coutts AJ. The translation of sport science research to the field: a current opinion and overview on the perceptions of practitioners, Researchers and Coaches. *Sports Med*. 2019;49(12):1817-1824.
43. Fullagar HHK, Harper LD, Govus A, McCunn R, Eisenmann J, McCall A. Practitioner perceptions of evidence-based practice in elite sport in The United States of America. *J Strength Cond Res*. 2019;33(11):2897-2904.
44. Sperlich B, Wicker P. Knowledge transfer into sport practice: an empirical user analysis of a sport science website. *Eur J Sport Sci*. 2021;21(5):753-761.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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