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Effects of mental fatigue on Olympic ball sports performance: a systematic review

Xiaoyang Pan [a,1], Kim Geok Soh [a,*,1], Wan Marzuki Wan Jaafar [b,1], Kim Lam Soh [c,2], Mingtian Li [a,2], Huange Liu [a,2], Cong Liu [a,2]

[a] Department of Sport Studies, Faculty of Education Studies, Universiti Putra Malaysia, Selangor, Malaysia
[b] Department of Counsellor Education and Counselling Psychology, Faculty of Educational Studies, Universiti Putra Malaysia, Selangor, Malaysia
[c] Department of Nursing, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Selangor, Malaysia

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ABSTRACT

Ball sports differ from Olympic events such as athletics, gymnastics, and diving due to their dynamic and unpredictable environments, real-time changing tasks, and complex object manipulation. Mental fatigue due to cognitive load is almost inevitable. This review searched PubMed, Web of Science, SPORTDiscus, and Scopus, including 23 articles and analyzing 10 Olympic ball sports. Results indicate that mental fatigue negatively impacts various aspects of ball sport athletes' performance, including psychological, cognitive, decision-making, physical, and specific skill performance. Among the studied sports, soccer and basketball have the highest number of studies. However, research on other globally popular sports, such as rugby and golf, remains limited, and many Olympic ball sports still lack relevant studies, highlighting gaps in the research. In certain ball sports, physical performance, specific skill performance, and decision-making time did not significantly decline under mental fatigue. This could be attributed to differences in athletes' cognitive resource reserves, cognitive load tolerance, recovery ability, and psychological resilience. Due to differences in competition environments and task demands across ball sports (such as basketball vs. golf), the patterns of mental fatigue may vary, posing challenges in formulating a universal intervention strategy for mental fatigue recovery. Furthermore, most existing studies induce mental fatigue using laboratory tasks, which may not adequately simulate real competition scenarios. Future research should consider field data collection or using actual competitions as an intervention to induce mental fatigue.

Systematic Review Registration: [https://inplasy.com/][INPLASY202410112].

1. Introduction

Ball sports hold a significant position on the international stage, accounting for 29.58 % of all Olympic events (International Olympic Committee, 2022). 90 % of the top 50 highest-paid athletes globally come from ball sports, with only Formula 1 racing and boxing representing non-ball sports (Forbes, 2024). This highlights ball sports' global attention and substantial influence (Abdulsalam et al., 2022; O'Brien & Finch, 2014; Pan et al., 2024).

Due to their unique competitive modes, ball sports are often considered a distinct field of review (Ter Stege et al., 2014; O'Brien & Finch, 2014; Fortington et al., 2017; Doeven et al., 2018; Farley et al., 2020; Faure et al., 2020; Costa et al., 2022; Sarmento et al., 2022; Chia, De Oliveira Silva, et al., 2022; Chia, Silva, et al., 2022; Lindsay et al., 2022; Pan et al., 2024; Whitty et al., 2024). Specifically, ball sports occur in dynamic and unpredictable environments, requiring athletes to constantly perceive opponents' actions, monitor spatial situations, frequently adapt to game scenarios, make quick decisions, and switch between offensive and defensive strategies (Gallahue, 2008; Remmert & Chau, 2019; Montuori et al., 2019; Sun et al., 2021; Costa et al., 2022; Sun, Soh, Mohammadi, et al., 2022; Cao et al., 2022; Foteinakis et al., 2023; Foteinakis et al., 2024; Ding et al., 2024; Pan et al., 2024). This acute and frequent decision-making process significantly increases ball players' cognitive load and mental fatigue risk (Pan et al., 2024; Sun

* Corresponding author.
E-mail address: kims@upm.edu.my (K.G. Soh).
[1] These authors contributed equally to this work.
[2] These authors also contributed equally to this work.

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et al., 2021; Sun, Soh, Roslan, et al., 2022).

Another distinguishing feature of ball sports is manipulating the ball through equipment such as clubs, bats, or rackets or via direct physical interaction (Ding et al., 2024; Lees, 2003). Manipulating objects with the hands is one of the primary characteristics distinguishing humans from other animals (De Freitas et al., 2008). Successful manipulation requires predicting motor commands needed for grasping, lifting, transporting, interacting with, and releasing objects, as well as the sensory events resulting from these commands (Flanagan et al., 2006; Nowak et al., 2013; O'Shea & Redmond, 2021). Contact between the hands and the object's surface and the initiation and termination of movements are discrete and distinct motor events (Nowak et al., 2013; Rosenbaum et al., 2012). Even simple tasks such as grasping and lifting objects involve complex interactions between multiple sensorimotor systems (Flanagan et al., 2006; Nowak et al., 2013; Wolpert & Flanagan, 2001). Studies have shown that performing object manipulation tasks while memorizing words impairs cognitive performance related to memory (Weigelt et al., 2009). This suggests that the motor control required for object manipulation occupies cognitive resources (Weigelt et al., 2009).

Early research by Mosso (1904) found that prolonged high-intensity cognitive activity increases cognitive load and reduces cognitive performance and attention, leading to a psychobiological state described by the psychological/mental model of fatigue. This state then affects the skeletal muscles by impacting the central nervous system, impairing sports performance (Jaberzadeh & Zoghi, 2022; Mosso, 1904). Consequently, for athletes who must continuously strive for excellence (Aquilina, 2016), mental fatigue undoubtedly limits the performance of ball sport athletes (Filipas, 2020; Pan et al., 2024; Sun et al., 2021; Yuan et al., 2023).

Regarding the scientific definition of “mental fatigue” ambiguity and controversy still persist. At the core of this issue lies the fact that the term encompasses multiple interrelated and conceptually overlapping constructs and phenomena (Hassan et al., 2024), including self-regulation, ego depletion, cognitive fatigue, psychological fatigue, and mental fatigue (Goodman et al., 2025; Pattyn et al., 2018). The boundaries between these terms remain unclear, and scholars continue to debate whether they represent a common or separate phenomena (Baumeister, 2020; Forestier & Chalabaev, 2020; Habay et al., 2021). In terms of conceptual construction, Sun, Soh, and Xu (2022), by integrating the psychobiological model of exercise performance with the strength model of self-regulation, lean toward viewing these terms as different expressions of the same psychological mechanism. Pattyn et al. (2018) also described these differing interpretations of mental fatigue as being “mainly semantic differences”. In this review, we adopt the term “mental fatigue” to encompass related concepts such as self-regulation, ego depletion, cognitive fatigue, psychological fatigue, and mental fatigue. This integrative terminology strategy has been widely adopted in several recent systematic reviews (Cao et al., 2022; Costa et al., 2022; Jaberzadeh & Zoghi, 2022; Pan et al., 2024; Pan et al., 2025; Sun et al., 2021; Sun et al., 2024; Sun, Soh, Mohammadi, et al., 2022), reflecting a broadly shared understanding and methodological consensus on the concept of mental fatigue in current research.

Regarding ball sports, there is currently no dedicated systematic review that specifically focuses on the effects of mental fatigue on ball sport performance. Existing systematic review strategies often limit keyword searches to terms like “mental fatigue”, “sports”, “exercise”, or “performance” (such as Nédélec et al., 2012; Van Cutsem et al., 2017; Sun et al., 2021; Cao et al., 2022; Grgic et al., 2022; Sun et al., 2024). For example, the meta-analysis by Sun et al. (2024) is an excellent piece of work. Still, due to its different research focus, the search for sports studies primarily relied on combinations such as “Athletes”, “Player”, or “Sport*”, which limited the ability to retrieve studies specific systematically and comprehensively to ball sports. Indeed, among the 13 articles included in their review, only six focus on ball sports, comprising four on basketball, one on soccer, and one on tennis. Different ball sports may exhibit significant differences in rules, tactics, physical demands, and cognitive load (such as basketball and golf). Therefore, a more comprehensive search strategy is essential. To address this shortcoming, this systematic review aims to integrate research findings from the past decade, focusing on all Olympic ball sports. The aim is to uncover the general effects of mental fatigue on ball sports while exploring specific impact patterns for different sports, thus enriching academic research. Moreover, the findings of this review will explicitly identify ball sports that remain under-researched, providing clear directions for future studies.

2. Methods

This article adhered to the PRISMA (2020) guidelines (Page et al., 2021). This title has already been registered on the International Platform of Registered Systematic Review and Meta-analysis Protocols, and the registration number is INPLASY202410112.

This study used electronic databases such as PubMed, Web of Science, SPORTDiscus, and Scopus were utilized to search for relevant articles. The literature search was completed on January 1, 2024, and included articles from the last ten years. Multiple terms were employed for each key concept to maximize retrieval of pertinent articles: mental fatigue, sports performance, and ball sports. For mental fatigue, the search terms included: “mental fatigue” OR “cognitive fatigue” OR “mental effort” OR “cognitive effort” OR “mental exertion” OR “ego depletion” For sports performance, the terms were: “performance” OR “decision making” OR “skill” OR “technique” For ball sports, we searched for all Olympic ball sports (including those in the Summer Olympics, Winter Olympics, and Youth Olympics) based on the latest list of Olympic sports published on the official website of the International Olympic Committee. The keywords used were based on the terms provided on the official International Olympic Committee website: “3 × 3 Basketball” OR “Badminton” OR “Baseball” OR “Softball” OR “Basketball” OR “Beach Handball” OR “Beach Volleyball” OR “Cricket” OR “Flag Football” OR “Football” OR “Futsal” OR “Golf” OR “Handball” OR “Hockey” OR “Ice Hockey” OR “Lacrosse” OR “Rugby Sevens” OR “Squash” OR “Table Tennis” OR “Tennis” OR “Volleyball” OR “Water Polo”. The terms for these keywords were combined using OR, while terms between different topics were combined using AND. The exact search string was applied across all four databases.

The Population, Intervention, Comparison, Outcome, and Study Design (PICOS) criteria were used as inclusion criteria, as stated in Table 1. Studies were needed to meet the following requirements: (1) The sample population consisted of ball athletes, with no restrictions on gender, age, or skill level; (2) Tasks had to induce mental fatigue, with the comparison group experiencing either no induced mental fatigue or less induced mental fatigue than the intervention group; (3) The tasks had to be skill-related and relevant to ball sports; (4) Outcomes had to include any form of sports performance; (5) The study design included only randomized controlled trials (RCTs).

No automated tools were used in the literature collection and screening process and two reviewers screened all records and search reports. If there was a dispute about whether a study met the criteria for inclusion in the review, a third reviewer was consulted to adjudicate. The data collection process based on PRISMA is shown in Fig. 1.

The methodology quality was assessed using “QualSyst” (Kmet,

Table 1
PICO criteria for inclusion criteria.

Items	Detailed inclusion criteria
Population	Players
Intervention	Mental fatigue
Comparison	Without mental fatigue
Outcome	Any form of performance
Study design	RCTs

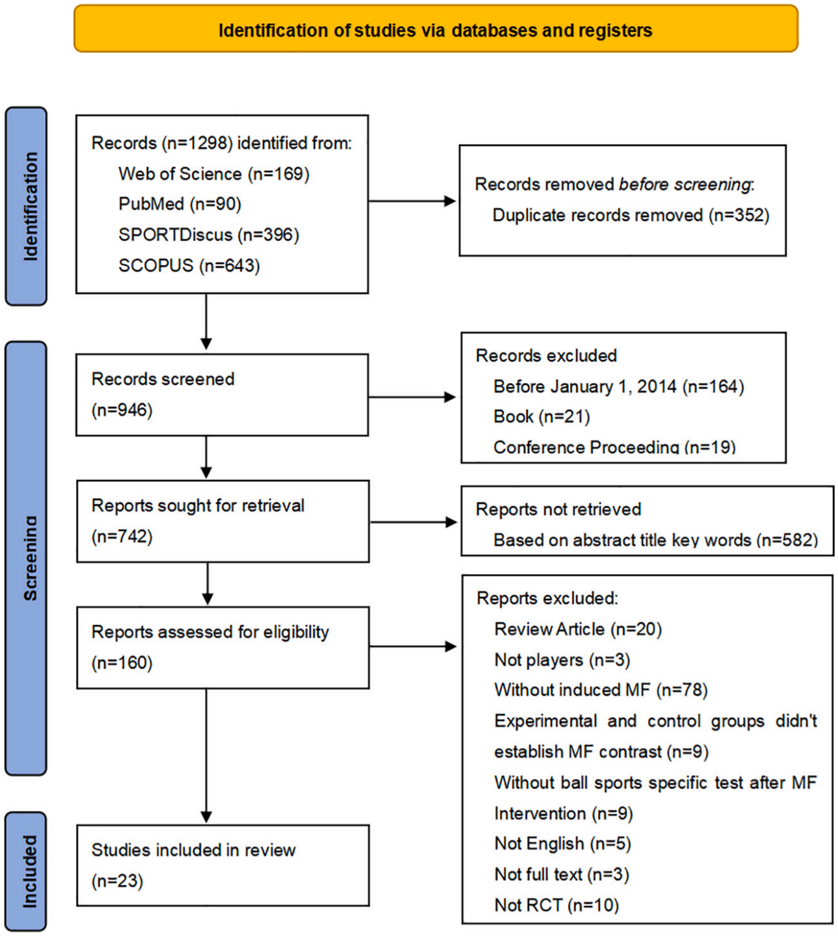

Fig. 1. PRISMA flow-process diagram. Note: MF, mental fatigue.

Table 2
QualSyst assessing the quality of studies.

Items	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII	XIII	XIV	Rating
Englert & Bertrams, 2015	2	2	2	2	2	0	0	2	2	2	2	1	2	2	Strong
Englert et al., 2015	2	2	2	2	2	0	0	2	2	2	2	1	2	2	Strong
Smith, Coutts, et al., 2016	2	2	2	1	2	1	0	2	1	2	2	1	2	2	Strong
Smith, Zeuwts, et al., 2016	2	2	2	2	2	0	1	2	1	2	2	1	2	2	Strong
Badin et al., 2016	2	2	2	1	2	0	0	2	1	2	2	1	1	2	Moderate
Coutinho et al., 2017	2	2	2	1	2	0	0	2	1	2	2	1	2	2	Moderate
Veness et al., 2017	2	2	2	2	2	0	0	2	1	2	2	1	2	2	Strong
Vogt et al., 2018	2	2	2	2	2	0	0	2	2	2	2	1	2	2	Strong
Shin et al., 2019	2	2	1	2	2	0	0	2	2	2	2	1	2	2	Strong
Van Cutsem et al., 2019	2	2	2	2	2	0	1	2	2	2	2	1	2	2	Strong
Kosack et al., 2020	2	2	2	1	2	0	0	2	2	2	2	1	2	2	Strong
Boat et al., 2021	2	2	2	2	2	0	2	2	1	2	2	1	2	2	Strong
Fortes et al., 2021	2	2	2	2	2	0	1	2	2	2	2	1	2	2	Strong
Habay et al., 2021	2	2	2	2	2	0	2	2	1	2	2	1	2	2	Strong
Fortes, Lima-Junior, et al., 2022	2	2	2	2	2	0	0	2	1	2	2	1	2	2	Strong
Angius et al., 2022	2	2	2	2	2	0	1	2	1	2	2	1	2	2	Strong
Ciocca et al., 2022	2	2	2	1	2	0	0	2	1	2	2	1	2	2	Strong
Fortes, Berriel, et al., 2022	2	2	2	2	2	0	1	2	1	2	2	1	2	2	Strong
Bian et al., 2022	2	2	2	2	2	0	1	2	1	2	2	1	2	2	Strong
Davidow et al., 2023	2	2	2	2	2	0	0	2	2	2	2	1	2	2	Strong
Daub et al., 2023	2	2	2	2	2	0	1	2	1	2	2	1	2	2	Strong
Faro et al., 2023	2	2	2	2	2	0	0	2	1	2	2	1	2	2	Strong
Filipas et al., 2024	2	2	2	2	2	0	0	2	1	2	2	1	2	2	Strong

Note: I, question describe; II, appropriate study design; III, appropriate subject selection; IV, characteristics describe; V, random allocation; VI, researcher blinded; VII, subjects blinded; VIII, outcomes measure well defined and robust to bias; IX, sample size appropriate; X, analytic methods well described; XI, estimate of variance reported; XII, controlled for confounding; XIII, results reported in detail; XIV, conclusion supported by results. N/A, not applicable; 2, for yes; 1, for partial; 0, for no.

2004), which includes 14 items (Table 3). Each item was scored based on the degree to which specific criteria were met: yes = 2, partial = 1, no = 0. Items that did not apply to the study design were marked as "N/A" and excluded from the total score calculation. A score of ≥75 % indicated strong quality, 55–75 % indicated moderate quality, and a ≤ 55 % indicated weak quality. The detailed ratings are shown in Table 2.

3. Results

23 articles were ultimately included in the review. Fig. 1 flowchart depicting the study selection process from search to inclusion in the review. Studies that met the inclusion criteria but were excluded are labelled in the flow. The quality evaluation results showed that 21 studies were of strong quality, 2 studies were of moderate quality (Badin et al., 2016; Coutinho et al., 2017), and none were of weak quality (Table 3). 91 % are rated as strong, indicating robust experimental designs and reliable outcome measures. The fact that only RCTs studies were included in this review may be the reason for the generally high-quality assessment, and it also proves that RCTs are an excellent method for conducting intervention research (Kmet, 2004).

3.1. General study characteristics

A total of 474 participants were included in the 23 studies. The smallest sample size was 10 participants (Veness et al., 2017), while the largest sample size was 57 participants (Englert & Bertrams, 2015). Six studies did not report the gender of the participants (Badin et al., 2016; Ciocca et al., 2022; Coutinho et al., 2017; Kosack et al., 2020; Smith, Coutts, et al., 2016). Most of the studies included only male participants, but 3 studies included both genders (Englert & Bertrams, 2015; Habay et al., 2021; Van Cutsem et al., 2019), and only 1 study focused solely on female participants (Shin et al., 2019). Females accounted for 24.03 % of the participants, while males accounted for 75.97 %. Most studies focused on professional or semi-professional players, with only one study targeting beginners (Shin et al., 2019).

According to the International Olympic Committee (2022), there are 24 Olympic ball sports that span the Summer Olympic Games, Winter Olympic Games, and Youth Olympic Games. However, our literature review revealed that only 10 of these sports have been the subject of RCTs investigating the impact of mental fatigue on sports performance. Among these sports, soccer has been the most extensively studied, with 9 identified studies (Angius et al., 2022; Badin et al., 2016; Bian et al., 2022; Ciocca et al., 2022; Coutinho et al., 2017; Smith, Coutts, et al., 2016; Smith, Zeuwts, et al., 2016; Vogt et al., 2018). Basketball follows with 4 studies (Daub et al., 2023; Englert et al., 2015; Faro et al., 2023; Fortes, Lima-Junior, et al., 2022), followed by volleyball (Fortes et al., 2021; Fortes, Berriel, et al., 2022), tennis (Englert & Bertrams, 2015; Filipas et al., 2024), and badminton (Kosack et al., 2020; Van Cutsem et al., 2019), each with 2 studies. Golf, rugby, cricket, hockey, and table tennis each have 1 study available study (Boat et al., 2021; Davidow et al., 2023; Habay et al., 2021; Shin et al., 2019; Veness et al., 2017).

3.2. Effectiveness and application of intervention strategies

In the included studies, researchers employed various cognitive tasks to artificially induce mental fatigue. Among these, the Stroop task was the most frequently used method, covering a wide range of sports, including soccer (Angius et al., 2022; Badin et al., 2016; Bian et al., 2022; Smith, Coutts, et al., 2016; Smith, Zeuwts, et al., 2016; Vogt et al., 2018), basketball (Davidow et al., 2023), tennis (Filipas et al., 2024), badminton (Kosack et al., 2020; Van Cutsem et al., 2019), rugby (Davidow et al., 2023), cricket (Veness et al., 2017), hockey (Boat et al., 2021), and table tennis (Habay et al., 2021). The Stroop task requires individuals to inhibit automatic responses. When the meaning of a color word (such as "red," "blue") does not match its displayed color, participants must suppress the automated reading response and focus on naming the color. During this process, executive functions of the brain are continuously engaged to maintain attention, resolve cognitive conflicts, and control errors. As the task duration increases, cognitive control resources are gradually depleted, leading to mental fatigue. Among the 15 studies utilizing the Stroop task, 9 studies adopted a 30-min intervention duration (Angius et al., 2022; Badin et al., 2016; Daub et al., 2023; Davidow et al., 2023; Filipas et al., 2024; Smith, Coutts, et al., 2016; Smith, Zeuwts, et al., 2016; Veness et al., 2017), making this duration a commonly used experimental standard.

In addition to the Stroop task, other methods were used to induce mental fatigue, often involving working memory engagement, sustained attention, information filtering, and cognitive processing:

Text transcription task: Participants were required to omit specific letters, such as "e" or "n," while transcribing a text. This task demands sustained attention, working memory maintenance, and cognitive control to follow the rules and minimize errors. Prolonged cognitive exertion leads to mental fatigue. Sports involved included basketball (Englert et al., 2015), tennis (Englert & Bertrams, 2015), and golf (Shin et al., 2019). The duration of this task was relatively short, typically lasting 6 to 10 min.

Video or tactical tasks: Mental fatigue was induced by having participants watch tactical videos or match footage to simulate game-related decision-making processes. This method was applied in soccer (Ciocca et al., 2022) and basketball (Daub et al., 2023), with a task duration of 30 min.

Social media use: Prolonged browsing of social media platforms (such as Facebook, Instagram) was used to induce mental fatigue. This method was applied in volleyball (Fortes et al., 2021; Fortes, Berriel, et al., 2022), with a task duration of 30 min.

Sports-related video games: Engaging in prolonged sports simulation video games was used to increase cognitive load. This method was applied in basketball (Faro et al., 2023; Fortes, Lima-Junior, et al., 2022), with a task duration of 60 min.

Overall, the Stroop task dominates mental fatigue induction research due to its high level of standardization and ease of experimental control. Other methods are relatively less common and are typically used to meet specific research needs, such as simulating game decision-making or studying the psychological effects of social media on athletes.

3.3. Impact of mental fatigue on sports performance

Mental fatigue has a detrimental impact on athletes' sports performance abilities, primarily affecting psychological, cognitive, decision-making, sport-specific skills performance, and physical performance. The influence of mental fatigue on tactical decision-making is particularly significant, especially in sports such as basketball, soccer, and volleyball. Studies by Smith, Zeuwts, et al. (2016), Fortes et al. (2021), Fortes, Lima-Junior, et al., 2022, and Boat et al. (2021) have shown that mental fatigue reduces decision-making accuracy while increasing the time required for decisions. In field hockey (Boat et al., 2021), prolonged decision-making time and increased error rates indicate that mental fatigue may impair athletes' tactical adaptability during competition.

In tennis, Englert and Bertrams (2015) and Filipas et al. (2024) found that serving performance declines under mental fatigue, with a significant reduction in serve accuracy. Similarly, in golf, Shin et al. (2019) reported that mental fatigue not only impairs athletes' self-regulation (ego depletion effect) but also significantly reduces putting accuracy. Comparable effects have been observed in basketball (Daub et al., 2023; Englert et al., 2015; Faro et al., 2023), soccer (Badin et al., 2016; Bian et al., 2022; Ciocca et al., 2022; Smith, Coutts, et al., 2016), rugby (Davidow et al., 2023), and field hockey (Boat et al., 2021), where mental fatigue was found to impair key technical performances such as passing accuracy, shooting precision, and error control. However, it is noteworthy that not all technical performances are affected by mental fatigue. For instance, in badminton, Van Cutsem et al. (2019) and Kosack et al. (2020) found that despite increased mental fatigue,

Table 3
Characteristics of the studies.

Authors (year)	Ball sports	Population	Characteristics	Intervention	Duration	Comparison	Study designs	Outcome
Englert and Bertrams (2015)	Tennis	29 M ; 28FM	Semi-professional ; [Age = 24.67, ±4.48]	Transcribing aneutral text (omit all letters “e” and “n”)	6 min	Transcribing a neutral text without any instructions	RCTs	MF ↑ in I vs. C; Tennis serve performance ↓ in I vs. C
Englert et al. (2015)	Basketball	31 M	Professional ; [Age = 29.26, ±4.90]	Transcribing aneutral text (omit all letters “e” and “n”)	6 min	Transcribing a neutral text without any instructions	RCTs	Ego depletion ↑ in I vs. C; Attention ↓ in I vs. C; Free throw percentage ↓ in I vs. C
Smith, Coutts, et al. (2016) Exp. 1	Soccer	12	Well trained ; [Age = 24.0, ±0.4]	Stroop color-word task	30 min	Leisure reading magazines	RCTs, Crossover	MF ↑ in I vs. C; Running distance ↓ in I vs. C;
Smith, Coutts, et al. (2016) Exp. 2	Soccer	14	Professional ; [Age = 19.6, ±3.5]	Stroop color-word task	30 min	Leisure reading magazines	RCTs, Crossover	MF ↑ in I vs. C; Passing accuracy ↓ in I vs. C; Shots speed ↓ in I vs. C; Shots accuracy ↓ in I vs. C
Smith, Zeuwts, et al. (2016)	Soccer	12 M	Semi-professional ; [Age = 19.3, ± 1.5]	Stroop color-word task	30 min	Leisure reading magazine	RCTs, Crossover	MF ↑ in I vs. C; Decision-making accuracy ↓ in I vs. C; Decision-making time ↑ in I vs. C
Badin et al. (2016)	Soccer	20	Professional ; [Age = 17.8, ±1.0]	Stroop color-word task	30 min	Watch the documentary	RCTs, Crossover	MF ↑ in I vs. C; Passing accuracy ↓ in I vs. C; Running distance → in I vs. C; Running speed → in I vs. C
Coutinho et al. (2017)	Soccer	12	Trained ; [Age = 15.9, ±0.8]	Motor coordination task	20 min	Control task	RCTs, Crossover	MF ↑ in I vs. C; Laterally synchronized time ↓ in I vs. C; Contraction speed ↓ in I vs. C
Veness et al. (2017)	Cricket	10 M	Professional ; [Age = 21, ±8]	Stroop color-word task	30 min	Leisure reading magazine	RCTs, Crossover	MF ↑ in I vs. C; Cricket run-two ↓ in I vs. C; Running distance ↓ in I vs. C
Vogt et al. (2018)	Soccer	33 M	Semi-professional ; [Age = 13.5, ±1.0]	Stroop color-word task	10 min	Watch the soccer game	RCTs	MF ↑ in I vs. C; Speed of action → in I vs. C; Ball control → in I vs. C
Shin et al. (2019)	Golf	51FM	Beginner ; [Age = 22.25, ±1.78]	Neutral Transcription (3 min) + transcription with the omission of “e” and “t” (7 min)	10 min	Neutral Transcription (3 min) + browsing shopping magazines (7 min)	RCTs	Ego depletion ↑ in I vs. C; MF ↑ in I vs. C; Putting performance ↓ in I vs. C
Van Cutsem et al. (2019)	Badminton	10 M ; 10FM	11 Beginner [Age = 25, ±4] 9 Professional ; [Age = 23, ±3]	Stroop color-word task	90 min	Watch the documentary	RCTs, Crossover	MF ↑ in I vs. C; Visuomotor accuracy → in I vs. C; Visuomotor response time ↑ in I vs. C
Kosack et al. (2020)	Badminton	19	Professional ; [Age = 20, ±2.8]	Stroop color-word task	60 min	Watch the documentary	RCTs, Crossover	MF ↑ in I vs. C; Badminton-Specific Test → in I vs. C
Boat et al. (2021)	Hockey	13 M	Professional ; [Age = 20, ±1]	Stroop color-word task	4 min	Congruent Stroop task	RCTs, Crossover	MF ↑ in I vs. C; Attention ↓ in I vs. C; Decision-making time → in I vs. C; Errors in skills tests ↑ in I vs. C
Fortes et al. (2021)	Volleyball	24 M	Semi-professional ; [Age = 15.7, ±0.6]	Used social media apps (Facebook, Instagram, and Whatsapp)	30 min	Documentaries about Olympic Games	RCTs	MF ↑ in I vs. C; Decision-making ↓ in I vs. C; Running distance → in I vs. C; Countermovement Jump → in I vs. C
Habay et al. (2021)	Table tennis	7 M ; 4FM	Semi-professional ; [Age = 24, ±2]	Stroop color-word task	60 min	Watch the documentary	RCTs, Crossover	MF ↑ in I vs. C; Visuomotion response time ↓ in I vs. C
Fortes, Lima-Junior, et al. (2022)	Basketball	16 M	Professional ; [Age = 24.3, ±4.1]	Play sports-based videogames for prolonged periods	60 min	Watch sports magazines and Olympic documentaries	RCTs, Crossover	MF ↑ in I vs. C; Decision-making accuracy ↓ in I vs. C;

(continued on next page)

Table 3 (*continued*)

Authors (year)	Ball sports	Population	Characteristics	Intervention	Duration	Comparison	Study designs	Outcome
Angius et al. (2022)	Soccer	17 M	Professional ; [Age = 26, ±2]	Stroop color-word task	30 min	Watch the documentary	RCTs, Crossover	Decision-making time ↑ in I vs. C MF ↑ in I vs. C; Repeated sprint ability → in I vs. C; Psychomotor vigilance → in I vs. C
Ciocca et al. (2022)	Soccer	10	Semi-professional ; [Age = 17.2, ±0.9]	Video-based tactical task	30 min	Watch the documentary	RCTs, Crossover	MF → in I vs. C; Running distance → in I vs. C; Missed passes → in I vs. C; Missed tackles → in I vs. C; Missed shots → in I vs. C
Fortes, Berriel, et al. (2022)	Volleyball	18 M	Semi-professional ; [Age = 17.33, ±0.22]	Used social media (Instagram) on a smartphone	30 min	Watch Olympic documentaries	RCTs, Crossover	MF → in I vs. C; Visuomotor response time ↓ in I vs. C
Bian et al. (2022)	Soccer	15 M	Trained ; [Age = 22, ±2.5]	Repeated interval Loughborough Soccer Passing Test OR Stroop task	20 min	Without MF intervention	RCTs, Crossover	MF ↑ in I vs. C; Technical ability ↓ in I vs. C; Passing accuracy ↓ in I vs. C
Davidow et al. (2023)	Rugby	20 M	Semi-professional ; [Age = 21.4, ±2.6]	Stroop color-word task	30 min	Leisure reading magazine	RCTs, Crossover	MF ↑ in I vs. C; Overall tackling proficiency ↓ in I vs. C
Daub et al. (2023)	Basketball	15 M	Professional ; [Age = 20.2, ±1.2]	Stroop color-word task OR Watch basketball video	30 min	Watch the documentary	RCTs, Crossover	MF ↑ in I vs. C; Number of shots ↓ in I vs. C; Missed shots ↑ in I vs. C
Faro et al. (2023)	Basketball	14 M	Professional ; [Age = 24.3, ±4.1]	Play sport-based video game	60 min	Watch Olympic documentaries	RCTs, Crossover	MF ↑ in I vs. C; Visuomotor accuracy ↓ in I vs. C; Visuomotor response time ↓ in I vs. C
Filipas et al. (2024)	Tennis	10 M	Semi-professional ; [Age = 18, ±4]	Stroop color-word task	30 min	Easy cognitive task (10 min) + Sit quietly (20 min)	RCTs, Crossover	MF ↑ in I vs. C; Tennis serve speed → in I vs. C; Serve accuracy ↓ in I vs. C

Note: M, male; F, female; I, intervention; C, control; RCTs, randomized controlled trials; MF, mental fatigue; ↑,Increase; ↓, Decrease; →, Unchanged.

visuomotor accuracy and performance in specific badminton skill tests remained unchanged. Similarly, Vogt et al. (2018) observed in soccer that while players experienced mental fatigue, their movement speed and ball control remained unaffected.

Although the impact of mental fatigue on decision-making and sport-specific skills is relatively clear, its effect on physical performance remains inconsistent. Some studies suggest that mental fatigue may lead to physical decline. For example, Veness et al. (2017) reported that in cricket matches, mental fatigue resulted in reduced running distance. Likewise, in soccer, Smith, Coutts, et al. (2016) and Bian et al. (2022) found that running distance and sprinting ability decreased under mental fatigue conditions. However, other studies indicate that certain physical performance indicators remain stable despite mental fatigue. For example, Badin et al. (2016) and Angius et al. (2022) found that in soccer matches, players' running speed and repeated sprint ability were not significantly affected. Additionally, in volleyball, Fortes et al. (2021) reported that approach jump performance remained unchanged under mental fatigue conditions.

From a practical application perspective, developing effective mental fatigue management strategies is crucial for enhancing athletes' training and competition performance. The findings from Englert and Bertrams (2015) and Shin et al. (2019) suggest that athletes can reduce the cognitive load or take appropriate rest and recovery measures to mitigate the impact of mental fatigue before high-intensity competitions or training. For instance, psychological adjustment training (such as meditation and deep breathing exercises) may help improve athletes' cognitive abilities and mental resilience, thereby reducing the negative impact of mental fatigue on their performance. Additionally, personalized psychological preparation measures might be effective strategies. For example, in their study on soccer players, Smith, Zeuwts, et al. (2016) showed that appropriate psychological adjustment and rest could significantly enhance athletes' decision-making and technical execution abilities. Similarly, Fortes et al. (2021) found that reducing social media use and increasing psychological recovery time significantly improved volleyball players' decision-making speed and endurance performance.

4. Discussion

4.1. *Impact of mental fatigue on sports performance*

4.1.1. *Screening of Olympic ball sports*

To comprehensively and systematically obtain research on the impact of mental fatigue on ball sports performance, we referred to the latest list of Olympic sports published on the official website of the International Olympic Committee. Based on this, we identified all officially established ball sports categories in the Summer Olympics, Winter Olympics, and Youth Olympics. This review ultimately included key variables across multiple ball sports, covering psychological, cognitive, decision-making, physical performance, and sport-specific skills performance. However, the available data for these variables were limited and unevenly distributed. Apart from "Mental fatigue" as the core variable, only five of the 32 primary outcome variables included in this review appeared more than three times: "Visuomotor response time" (4 times), "Decision-making accuracy" (3 times), "Decision-making time" (3 times), "Running distance" (5 times), and "Passing accuracy" (soccer) (3 times). Due to the insufficient number of data points, this review is unable to quantify the effect size of mental fatigue on different ball sports performance through meta-analysis. Additionally, it is not feasible to conduct a meta-analysis to explore potential moderating factors, such as how differences in sports types, skill categories, or experimental tasks influence the effects of mental fatigue (Turner et al., 2013). Forcing data synthesis with a very limited number of studies may lead to poor parameter estimation, thereby reducing the credibility of the meta-analysis and potentially resulting in erroneous assessments of intervention effects (Impellizzeri & Bizzini, 2012; Valentine et al., 2010; Wetterslev et al., 2017). Therefore, a meta-analysis is not a suitable approach for this review. This also highlights the limited research on mental fatigue in ball sport athletes, indicating that this field has not yet reached a saturation point and requires further investigation. Under such circumstances, a systematic review remains the most appropriate method for identifying studies and analyzing data at the current stage (Valentine et al., 2010). A systematic review not only summarizes the general impact of mental fatigue on sports performance, categorizes trends by variable type, and analyzes inconsistencies between studies but also explores potential mechanisms. More importantly, it identifies research gaps to guide future studies.

This review covers 10 of the 24 Olympic ball sports, including soccer (9 studies), basketball (4 studies), volleyball (2 studies), tennis (2 studies), badminton (2 studies), rugby (1 study), field hockey (1 study), cricket (1 study), table tennis (1 study), and golf (1 study). The findings indicate that mental fatigue negatively affects the psychological, cognitive, decision-making, physical, and sport-specific skills performance of athletes in various ball sports. Soccer and basketball had the highest number of studies, reflecting their status as two of the most popular and highly competitive sports worldwide, which have received considerable attention in sports science research. Additionally, sports such as volleyball, tennis, and badminton had a moderate number of related studies, whereas rugby, field hockey, cricket, table tennis, and golf had relatively fewer studies. Notably, rugby and golf, like soccer and basketball, have some of the largest sports competition markets worldwide (Forbes, 2024). However, research on mental fatigue in these sports remains limited, indicating a need for further studies in these areas. Meanwhile, many Olympic ball sports were not included in this review, primarily due to the lack of relevant studies in the existing literature. The absence of research on these sports highlights gaps in the field. Future studies should aim to address these gaps through broader experimental research to uncover the specific effects of mental fatigue across different sports. Such research could provide scientific guidance for training and competition strategies in various ball sports, helping athletes and coaches manage fatigue more effectively and optimize performance.

4.1.2. *Conflicting evidence*

The evidence provided in this review is consistent with existing research on mental fatigue, showing that it can impair various aspects of athletes' physical, psychological, cognitive, tactical, and technical performance (Cao et al., 2022; Kunrath et al., 2018; Kunrath et al., 2020; Pan et al., 2024; Sun et al., 2021). However, this systematic review also reveals some contradictory evidence. Specifically, endurance performance in volleyball (Fortes et al., 2021), physical performance in soccer (Angius et al., 2022; Badin et al., 2016), movement speed (Vogt et al., 2018), ball control (Vogt et al., 2018), sport-specific skills performance in badminton (Kosack et al., 2020), and decision time in field hockey (Boat et al., 2021) showed no significant decline under mental fatigue. The contradictory evidence pertains to physical, cognitive, and technical performance, and most of the conflicting findings come from team sports like soccer (Angius et al., 2022; Badin et al., 2016; Vogt et al., 2018), volleyball (Fortes et al., 2021), and field hockey (Boat et al., 2021), while individual sports only include badminton (Kosack et al., 2020).

Since these studies were conducted under conditions where mental fatigue was effectively induced, the contradiction may arise from the fact that the performance tasks used were not sensitive enough to detect the effects of mental fatigue. For high-level athletes, these skills may have become automated responses, reducing reliance on cognitive resources (Vogt et al., 2018), as professional and semi-professional athletes with higher technical skills and competitive levels often possess more excellent fatigue resistance (Reilly et al., 2000). The results of this review support this view, as all the cases that were not significantly affected occurred in studies of professional or semi-professional athletes (Angius et al., 2022; Badin et al., 2016; Fortes et al., 2021; Kosack et al., 2020; Vogt et al., 2018).

Unfortunately, most of the studies in this review had small sample sizes, and some studies did not report gender (Badin et al., 2016; Ciocca et al., 2022; Coutinho et al., 2017; Kosack et al., 2020; Smith, Coutts, et al., 2016), making it impossible to determine whether there are any moderating or mediating variables related to individual differences in the effects of mental fatigue. The cognitive resource reserves, cognitive load tolerance, recovery ability, and psychological resilience of different athletes may influence the speed of mental fatigue accumulation and the extent of its impact on performance. Therefore, future studies should compare the performance differences of athletes at different competitive levels (amateur, semi-professional, and professional) under mental fatigue, and broaden the measurement of individual difference variables such as stress response-ability, self-control resources, and cognitive resilience. Identifying the characteristics of athletes who are more susceptible to mental fatigue or possess stronger resistance to fatigue will help develop more targeted training programs and interventions to enhance athletes' performance under high-load conditions.

4.1.3. *Dynamic changes in mental fatigue*

This systematic review reveals significant differences in the duration of tasks used to induce mental fatigue across studies. For example, in the case of the English transcription task, Englert and Bertrams (2015) conducted a 6-min transcription task where participants were asked to avoid writing certain specific letters deliberately. This cognitive task that violated writing habits increased mental fatigue and negatively affected tennis players' serving performance. Similarly, Englert et al. (2015) showed that a 6-min transcription task increased mental fatigue and impaired basketball players' free throw performance. Shin et al. (2019) used a 10-min transcription task, which also increased mental fatigue and negatively impacted the putting performance of golf beginners. Likewise, the Stroop color-word task, widely used in this review, also exhibited significant variability in duration, ranging from the shortest of 4 min (Boat et al., 2021) to 10 min (Vogt et al., 2018), 20 min (Bian et al., 2022), 30 min (Angius et al., 2022; Badin et al., 2016; Daub et al., 2023; Davidow et al., 2023; Filipas et al., 2024; Smith, Coutts, et al., 2016; Smith, Zeuwts, et al., 2016; Veness et al., 2017), 60 min (Kosack et al., 2020), and up to 90 min (Van Cutsem et al., 2019). These studies successfully induced mental fatigue regardless of the duration of the Stroop color-word task.

Although significant differences exist in the duration of tasks used to induce mental fatigue across studies, the negative impact on performance does not increase linearly with time. Hülsheger (2016), based on recovery theory, studied the changes in mental fatigue throughout the day and found that mental fatigue varies nonlinearly during the workday. The continuous consumption and replenishment of cognitive resources determine the trajectory of mental fatigue dynamics (Hülsheger, 2016). This phenomenon highlights the importance of cognitive resource depletion rather than task duration. In other words, even short, high-intensity cognitive tasks, such as the 6-min transcription task (Englert et al., 2015; Englert & Bertrams, 2015) or the 4-min Stroop color-word task (Boat et al., 2021), can be sufficient to induce mental fatigue and impair performance, if they can sufficiently deplete the cognitive resources of participants. This aligns closely with the core concept of the Psychological/Mental Model of Fatigue. Mental fatigue results from the continuous consumption of cognitive resources rather than being determined solely by the absolute duration of the task (Jaberzadeh & Zoghi, 2022; Mosso, 1904). The consumption of cognitive resources is a dynamic process involving various factors such as cognitive demand, task complexity, and individual fatigue tolerance. Therefore, the differences in competitive styles across different ball sports may affect the rate at which mental fatigue accumulates and how it impacts performance.

4.2. Mental fatigue patterns in different ball sports

The rules and competitive nature of different ball sports determine variations in tactical collaboration and strategy adjustments, and these differences in cognitive demands may directly influence the development and manifestation of mental fatigue. To explain this, we can refer to Newell's (1986) Constraints Model (Fig. 2), which identifies three categories of constraints that influence sports performance: organismic, environmental, and task. Organismic constraints refer to limitations imposed within the boundaries of an individual's system, which broadly encompass physical, psychological, physiological, or morphological constraints (Newell & McGinnis, 1985). Environmental constraints are those external to the movement system, involving the spatial and temporal arrangement of the surrounding world or external forces acting continuously on the movement system (Glazier, 2017; Newell, 1986). In sports, this includes environmental factors like light, temperature, altitude, gravity, and the ground or equipment that exerts reactive forces on the body (Glazier, 2017). Task constraints are related to the goals and rules of the specific sport being performed (Newell, 1986), such as scoring a basket in basketball, scoring a goal in soccer, or getting the ball in the golf hole (Glazier, 2017). The final coordination and control patterns are shaped by the combined effects of organismic, environmental, and task constraints (Newell, 1986), and athletes' sports psychology, physiology, motor development, strength, and conditioning are constantly challenged by the sports environment and the task demands (Glazier, 2017), which includes mental fatigue.

In confrontation team sports, multiple athletes interact in real-time, and teamwork and opposition form the core elements of the competition. Team sports athletes face more task constraints than individual sports like athletics, swimming, gymnastics, and diving. Basketball, soccer, rugby, volleyball, field hockey, and cricket involve high decision-making pressure, multi-tasking demands, and dynamic game situations (Ashford et al., 2021), requiring athletes to evaluate the opponents' tactics and adjust strategies accordingly quickly (Ashford et al., 2021; Cao et al., 2022; Sun et al., 2021). The combination of teamwork and opposition in these sports forces athletes to handle individual tasks and maintain coordination with teammates, further increasing cognitive resource consumption, which can lead to mental fatigue.

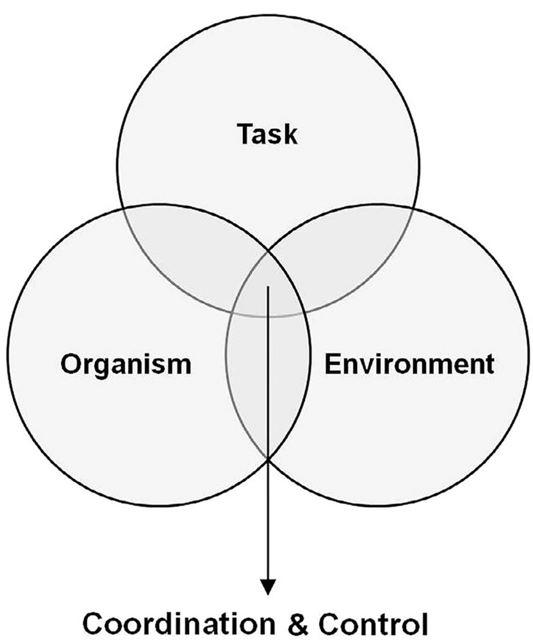

Fig. 2. Constraints Model (Newell, 1986). Note: The model was initially depicted as a triangle, with each corner representing a category of constraints. Glazier (2017) illustrated the model as three overlapping circles, as this format better demonstrates how behavior (patterns of coordination and control) emerges from the confluence of interacting constraints, represented by the intersecting or overlapping dark gray area. Furthermore, since the relative positions and degrees of overlap of the three circles dynamically change depending on the specific task characteristics, this representation effectively captures the dynamic nature of the constraints and their respective contributions to motor performance at any given time (Glazier, 2017).

In confrontation individual sports, cognitive load primarily stems from the direct opposition between athletes. While no teamwork is involved, sports like tennis, badminton, and table tennis require athletes to rapidly detect changes in their opponents' movements and adjust competitive strategies (Ding et al., 2024), placing high demands on cognitive resources. The intense confrontation and fast-paced changes in the game increase cognitive depletion and are likely to lead to mental fatigue (Ding et al., 2024; Mizuno et al., 2011).

In indirect confrontation sports (such as golf), there is no direct interaction between athletes, and the competition relies more on individual skills and performance. Although golf does not involve confrontation, the environmental constraints in golf are much more complex than in other sports with standardized field sizes (Farrally et al., 2003). Golfers must continuously assess the complex field conditions, climate factors, and devise strategies for the next shot based on the ball's position (Farrally et al., 2003). In a typical 5-h round of golf without a halftime break (Broman et al., 2004; Gosheger et al., 2003; Riccio, 2012), environmental constraints constantly adjust the task constraints (such as offensive strategies, club selection, and shot techniques), requiring golfers to continually adapt their technical and strategic approaches to the complex environment. This high level of cognitive demand can also induce mental fatigue.

Although Newell's (1986) constraints model has broad applicability, it helps reveal the pathways through which mental fatigue affects different ball sports, providing a systematic framework for analyzing the ways in which mental fatigue manifests and functions in various sports. Individual constraints (such as an athlete's cognitive ability and experience level) influence their adaptability in tactical decision-making and their resistance to mental fatigue. Environmental constraints (such as competition pressure and audience interference) may exacerbate the effects of mental fatigue, further impacting an athlete's focus and execution. Task constraints (such as the rules and tactical requirements of different ball sports) determine the cognitive load involved in decision-making and execution, thereby influencing the development and manifestation of mental fatigue. The dynamic interaction of these three types of constraints shapes the state and performance of ball sport athletes in competition—a complexity that is not present in sports such as athletics, gymnastics, and diving.

Different types of ball sports vary significantly in competition formats, task demands, and environmental factors (such as basketball versus golf), which may result in different accumulation rates of mental fatigue and varying patterns of its impact on performance. However, many existing studies on mental fatigue use laboratory-based tasks to induce fatigue and examine its effects on sports performance. This approach may fail to accurately simulate the real-world competition context of mental fatigue, potentially causing a disconnect between experimental results and actual competitive scenarios. Laboratory tasks typically last 30 to 60 min (such as the Stroop task), whereas real competitions can extend for several hours. As a result, laboratory-induced mental fatigue may underestimate the actual fatigue experienced in competition. Additionally, laboratory studies struggle to replicate the dynamic changes in real competition environments, such as weather conditions, competitive pressure, audience influence, and team atmosphere, which can affect ecological validity. Furthermore, experimental tasks often involve isolated cognitive tasks, whereas during competition, athletes must continuously switch between movement and decision-making, making the actual cognitive load significantly more complex. Therefore, future research should focus on the dynamic characteristics of mental fatigue in real competitions and the unique demands of mental fatigue in different ball sports to further reveal its profound impact on sports performance. For example, future research can be conducted in real competitions or simulated competition settings to reconstruct the environmental and task constraints present in actual matches, designing experiments with higher ecological validity. During the experiment, real competition elements such as competitive pressure, audience noise, and time constraints can be introduced to more accurately simulate the psychological state of athletes during competition. Meanwhile, real or simulated competitions themselves can also serve as interventions to induce mental fatigue, allowing researchers to explore the mechanisms by which mental fatigue affects sports performance across different sports.

5. Conclusions

The results indicate that mental fatigue has a detrimental effect on the psychological, cognitive, decision-making, physical performance, and sport-specific skills of athletes across various ball sports. Among them, soccer and basketball have the highest number of studies; however, research on rugby and golf—both of which are also globally popular—remains relatively scarce. Additionally, many Olympic ball sports lack relevant studies, highlighting the need for further research in these areas. The review also reveals some contradictory evidence. The reason for this may be related to the skill automation and fatigue resistance of high-level athletes. The consumption and recovery of cognitive resources is a dynamic process (Hülsheger, 2016) that involves various factors such as cognitive demand, task complexity, and an individual's fatigue tolerance. Differences in cognitive resource reserves, cognitive load tolerance, recovery ability, and psychological stress resistance may influence the accumulation rate of mental fatigue and its impact on performance.

Different ball games have distinct sporting environments and tasks, and the relative contribution of task and environmental constraints to performance depends on the specific performance context and task requirements, which are dynamically changing (Glazier, 2017; Newell, 1986). When athletes have similar personal characteristics (such as sports psychology, physiology, motor development, strength and conditioning), the rules and competitive nature of different sports will lead to varying contributions of these constraints to mental fatigue. With different constraints, the sources of mental fatigue vary, making it challenging to develop a unified intervention strategy for different sports. For example, an intervention designed to restore focus in golf may not be effective in basketball or other direct-contact sports. Future studies should adopt methods with higher ecological validity to better simulate the mental fatigue conditions encountered in real competition environments and explore its impact on ball sport performance.

6. Limitations

This review aims to comprehensively and systematically retrieve studies on the effects of mental fatigue on ball sports performance. While the search strategy covering all Olympic ball sports is representative, some ball sports with fewer studies may have been overlooked due to their lower global popularity, relatively limited competitive level, or insufficient research resources (as non-Olympic sports). Additionally, language limitations in this review may have led to the exclusion of studies on culturally specific ball sports, potentially affecting the comprehensiveness of the research.

CRediT authorship contribution statement

Xiaoyang Pan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization, Visualization. **Kim Geok Soh:** Writing – review & editing, Methodology, Conceptualization. **Wan Marzuki Wan Jaafar:** Methodology, Supervision, Conceptualization. **Kim Lam Soh:** Writing – review & editing, Validation. **Mingtian Li:** Investigation, Validation. **Huange Liu:** Investigation, Validation. **Cong Liu:** Investigation, Validation.

Declaration of competing interest

All authors have declared no conflicts of interest relevant to the content of this article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.105109.

Data availability

Data will be made available on request.

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