

Mental Fatigue and Neuromuscular Performance in Athletes: A Systematic Review

Putu Ika Pradipta Dewi¹, Ni Made Swasti Wulanyani², I Gusti Ayu Putu Wulan Budisetyani³

¹Master's Program in Sport Physiology, Faculty of Medicine, Udayana University, Denpasar, Bali, Indonesia

^{2,3}Department of Psychology, Faculty of Medicine, Udayana University, Denpasar, Bali, Indonesia

Corresponding author:

Name: Putu Ika Pradipta Dewi

E-mail: ikapradiptadewi@gmail.com

Received 3 July 2026; Revised 5 July 2026; Accepted 6 July 2026; Published 29 September 2026

©2026 The Authors. Published by the Physiotherapy Study Program, Faculty of Medicine, Udayana University, in collaboration with the Indonesian Physiotherapy Association (Ikatan Fisioterapi Indonesia). This is an open-access article distributed under the terms of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

Abstract

Background: Mental fatigue is a psychobiological state induced by prolonged cognitive activity that impairs attention, executive function, and motor regulation. Although its adverse effects on athletic performance have been increasingly recognized, evidence regarding its influence on neuromuscular performance remains inconsistent across different sports and performance outcomes.

Objective: To systematically synthesize evidence on the effects of mental fatigue on neuromuscular performance in athletes.

Methods: This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement. A literature search was conducted in PubMed, Scopus, and Google Scholar for original studies published between 2016 and 2025. Ten experimental studies involving athletes or physically active individuals met the eligibility criteria. Methodological quality was assessed using the Joanna Briggs Institute Critical Appraisal Checklist, and risk of bias was evaluated. Due to methodological heterogeneity, findings were synthesized narratively.

Results: Ten studies consistently demonstrated that mental fatigue impaired endurance performance, sport-specific technical performance, motor control, movement quality, and decision-making. In contrast, evidence regarding maximal neuromuscular function and explosive performance remained inconsistent. Overall, the included studies demonstrated moderate to high methodological quality with an overall low to moderate risk of bias.

Conclusion: Mental fatigue predominantly impairs neuromuscular performance through central mechanisms, particularly affecting endurance capacity, technical execution, motor control, and decision-making. Monitoring cognitive workload alongside physical training may contribute to improved athletic performance. Further high-quality randomized controlled studies using standardized neuromuscular outcomes are warranted.

Keywords

Mental Fatigue; Athletes; Neuromuscular Physiological Phenomena; Sports Performance; Exercise.

Introduction

Mental fatigue is a psychobiological state induced by prolonged engagement in cognitively demanding activities, resulting in reduced alertness, impaired executive function, diminished attention, and increased subjective feelings of tiredness.¹ Unlike peripheral fatigue, which arises primarily from physiological changes within skeletal muscles, mental fatigue originates in the central nervous system and alters cognitive processes involved in decision-making, motor planning, and perception of effort.^{1,2} Consequently, individuals experiencing mental fatigue often exhibit impaired physical and cognitive performance despite relatively preserved physiological capacity.^{2,3}

In competitive sports, optimal performance depends on the integration of physiological, neuromuscular, and cognitive functions. Athletes are continuously required to process environmental information, maintain sustained attention, anticipate opponents' actions, execute precise motor skills, and make rapid decisions under physically demanding conditions.⁴ These cognitive demands frequently coexist with intensive physical workloads during training and competition, making athletes particularly susceptible to mental fatigue.⁴ As cognitive resources become depleted, the ability to regulate movement, maintain technical accuracy, and sustain exercise intensity may deteriorate, ultimately compromising athletic performance.^{5,6}

The mechanisms underlying mental fatigue have been widely explained by the psychobiological model of exercise performance. According to this model, exercise tolerance is regulated not only by physiological capacity but also by the perception of effort generated by the central nervous system. Prolonged cognitive activity increases perceived exertion without necessarily producing substantial alterations in cardiovascular function or peripheral muscle physiology. Consequently, athletes may terminate exercise earlier, reduce exercise intensity, or demonstrate poorer technical execution because the task is perceived as increasingly demanding. Neurophysiological studies have further suggested that mental fatigue is associated with alterations in cortical activation, impaired executive control, and reduced attentional capacity, all of which contribute to deteriorations in motor performance.⁷⁻⁹

Previous experimental studies have consistently demonstrated that mental fatigue adversely affects several components of athletic performance. Reductions in endurance capacity, sport-specific technical performance, passing accuracy, movement quality, reaction time, and decision-making have been reported across various sporting disciplines, including soccer, basketball, combat sports, and endurance events. Furthermore, studies using electromyography and biomechanical analyses have suggested that mental fatigue may influence neuromuscular activation patterns and movement coordination, although evidence regarding maximal neuromuscular force production remains inconsistent. These findings indicate that the detrimental effects of mental fatigue extend beyond endurance exercise and involve multiple dimensions of neuromuscular performance.^{10,11}

Despite the growing body of evidence, considerable inconsistency remains regarding the magnitude and mechanisms through which mental fatigue influences neuromuscular performance. While several randomized crossover trials have reported significant impairments in endurance, motor control, technical execution, and sport-specific skills following cognitively demanding tasks, other investigations have found little or no effect on maximal voluntary contraction, muscle strength, or explosive

performance.¹² These discrepancies may be attributable to differences in participant characteristics, sporting disciplines, mental fatigue induction protocols, intervention duration, outcome measures, and methodological quality. Consequently, direct comparison among studies is difficult, and the overall strength of evidence remains uncertain.^{13–15}

Several systematic and narrative reviews have summarized the relationship between mental fatigue and sports performance.¹ Moreover, despite several systematic reviews examining the effects of mental fatigue on athletic performance, the evidence remains heterogeneous across sports, performance domains, and experimental protocols, while methodological limitations and risk of bias have been reported across the available literature.^{4,16} Therefore, an updated systematic review focusing specifically on neuromuscular performance is needed to provide a clearer understanding of the current evidence and its methodological robustness.³

This systematic review differs from previous reviews by specifically synthesizing evidence from original experimental studies investigating the influence of mental fatigue on neuromuscular performance across multiple athletic populations. In addition to summarizing performance outcomes, this review critically evaluates methodological quality using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist and assesses the risk of bias to strengthen interpretation of the available evidence. By integrating findings from endurance performance, neuromuscular function, motor control, technical performance, movement quality, and decision-making, this review aims to provide a comprehensive perspective that is directly applicable to sports medicine, physiotherapy, and athletic performance management.

Accordingly, the objective of this systematic review was to synthesize current evidence regarding the effects of mental fatigue on neuromuscular performance in athletes. Specifically, the review examined the influence of mental fatigue on endurance performance, maximal neuromuscular function, movement quality, motor control, technical performance, and decision-making while critically evaluating the methodological quality and risk of bias of the included studies. The findings are expected to support evidence-based strategies for monitoring cognitive workload and optimizing athletic performance in both clinical and sports settings.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement.¹⁷ The review aimed to identify, critically appraise, and synthesize evidence regarding the effects of mental fatigue on neuromuscular performance in athletes. The review protocol was developed before study selection; however, it was not prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO).

A comprehensive literature search was conducted in PubMed and Scopus, with Google Scholar used as a supplementary source to identify additional relevant studies. The search included articles published between January 2016 and December 2025, and the final search was completed on 31 December 2025. This period was selected to capture the development of contemporary experimental evidence investigating the influence of mental fatigue on athletic performance while including the landmark experimental studies that established this field of research.

The search strategy combined Medical Subject Headings (MeSH) and free-text terms using Boolean operators. The primary search syntax was as follows:

("mental fatigue" OR "cognitive fatigue") AND ("neuromuscular performance" OR "neuromuscular function" OR "motor control" OR "technical performance" OR "sports performance") AND (athlete* OR sport*)

The search syntax was adapted according to the indexing requirements of each database. Manual searches of the reference lists of all eligible articles were also performed to identify additional studies that were not retrieved during electronic searching. Study eligibility was established using the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework.

Study eligibility was established using the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework. Eligible studies included athletes or physically active individuals participating in organized sports or structured physical training. The intervention of interest was experimentally induced mental fatigue using validated cognitive protocols, including the Stroop task, prolonged cognitive tasks, smartphone-based cognitive tasks, video-game exposure, motor imagery, or other comparable paradigms designed to elicit cognitive fatigue. Eligible studies were required to include either a non-fatigued control condition or baseline measurements for comparison. The primary outcomes comprised neuromuscular performance measures, including endurance performance, muscular endurance, maximal voluntary contraction, neuromuscular activation, technical performance, movement quality, decision-making, reaction time, explosive performance, and psychophysiological responses. Only original experimental studies employing randomized controlled trials, randomized crossover trials, crossover experimental studies, or controlled experimental designs were considered eligible for inclusion in this review.

Studies were included if they (1) were original experimental studies; (2) investigated the effects of experimentally induced mental fatigue; (3) included athletes or physically active participants; (4) evaluated at least one neuromuscular performance outcome; (5) were published between 2016 and 2025; and (6) were available in full text in English. Studies were excluded if they were systematic reviews, narrative reviews, meta-analyses, conference abstracts, editorials, letters, study protocols, case reports, duplicate publications, or studies involving clinical populations unrelated to sports performance.

Study selection followed the PRISMA 2020 framework. All retrieved records were exported to a reference management program, where duplicate records were removed before screening. Titles and abstracts were independently screened according to the eligibility criteria, followed by full-text assessment of potentially eligible studies. Reasons for exclusion during the full-text review were documented to ensure transparency and reproducibility.

Data extraction was performed using a standardized extraction form. Information collected from each study included the first author, publication year, country, study design, participant characteristics, sample size, sporting discipline, mental fatigue induction protocol, comparator, outcome measures, statistical analysis, and principal findings. Extracted data were subsequently verified before qualitative synthesis.

Methodological quality was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist appropriate for each study design. The appraisal evaluated participant selection, randomization, allocation concealment, baseline comparability, blinding, completeness of follow-up, outcome measurement, and statistical analysis. Each criterion was rated as Yes, No, Unclear, or Not Applicable. The overall methodological quality of each study was subsequently categorized as high, moderate, or low according to the proportion of appraisal criteria fulfilled.

The potential risk of bias was evaluated across the principal methodological domains included in the JBI appraisal, comprising participant selection, allocation procedures, baseline comparability, blinding, incomplete outcome data, outcome measurement, selective reporting, and statistical analysis. Each study was classified as presenting low risk, some concerns, or high

risk of bias. The methodological quality assessment and risk of bias evaluation were incorporated into the interpretation of the review findings but were not used as exclusion criteria.

Because substantial heterogeneity existed among participant characteristics, sporting disciplines, mental fatigue induction protocols, intervention duration, and outcome measures, quantitative meta-analysis was considered inappropriate. Therefore, findings were synthesized narratively by grouping studies according to the principal neuromuscular performance domains, including endurance performance, neuromuscular function, technical performance, movement quality, decision-making, psychophysiological responses, and explosive performance. As this review synthesized data exclusively from previously published studies, ethical approval and informed consent were not required.

Results

A comprehensive literature search was conducted across PubMed, Scopus, and Google Scholar to identify studies investigating the effects of mental fatigue on neuromuscular performance in athletes. The search yielded 417 records, including 156 records from PubMed, 143 from Scopus, and 118 from Google Scholar. Following the removal of 91 duplicate records, 326 articles remained for title and abstract screening. During the screening stage, 289 records were excluded because they did not meet the predefined eligibility criteria. The remaining 37 full-text articles were assessed for eligibility, of which 27 studies were excluded because they were review articles ($n = 8$), investigated outcomes unrelated to neuromuscular performance ($n = 6$), involved non-athlete populations ($n = 5$), were conference abstracts or study protocols ($n = 4$), or provided insufficient outcome data ($n = 4$). Consequently, 10 original experimental studies fulfilled all inclusion criteria and were included in the qualitative synthesis. The complete study selection process is illustrated in Figure 1.

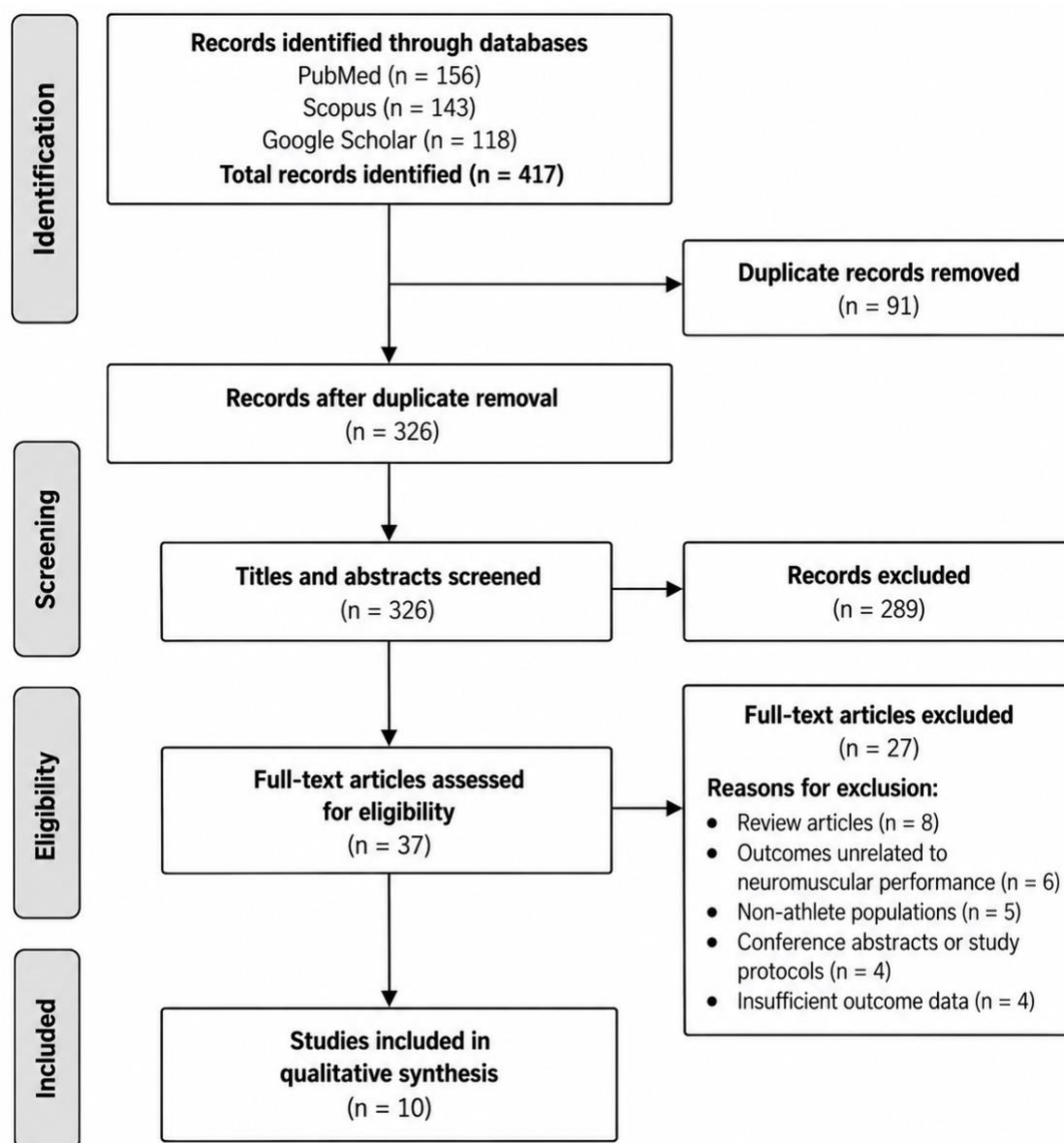


Figure 1. PRISMA Flow Diagram of the Study Selection Process

The characteristics of the included studies are presented in Table 1. The studies were published between 2016 and 2025 and primarily employed randomized crossover trials, randomized controlled trials, and controlled experimental designs. Collectively, the included studies enrolled athletes from multiple sporting disciplines, including soccer, basketball, boxing, badminton, and physically active adults. Mental fatigue was experimentally induced using validated cognitive paradigms such as the Stroop task, prolonged computerized cognitive tasks, smartphone-based cognitive activities, and video-game exposure. The evaluated outcomes encompassed endurance performance, neuromuscular function, technical performance, movement quality, decision-making, psychophysiological responses, neuromuscular activation, and sport-specific performance.

Table 1. Characteristics of the Included Studies

Author	Design	Participants	Mental Protocol	Fatigue	Outcome Measures	Main Findings
Smith et al., 2016	Randomized crossover	Soccer players	Stroop task		Physical and technical performance	Mental fatigue reduced running performance and technical accuracy
Smith et al., 2016	Randomized crossover	Soccer players	Cognitive task		Decision-making	Reduced decision-making accuracy following mental fatigue
Badin et al., 2016	Experimental	Soccer players	Stroop task		Technical performance	Decreased successful technical actions during small-sided games
Smith et al., 2017	Randomized crossover	Soccer players	Cognitive task		Passing and shooting performance	Reduced speed and accuracy of soccer-specific skills
Trecroci et al., 2020	Randomized crossover	Soccer players	Stroop task		Physical activity and decision-making	Lower physical performance and impaired decision-making
Filipas et al., 2021	Experimental	Youth soccer players	Computerized cognitive task		Soccer-specific performance	Decline in physical and technical performance
Fortes et al., 2022	Randomized trial	Basketball players	Stroop task		Decision-making and visual search	Reduced decision-making efficiency and visual search behavior
Fortes et al., 2023	Randomized crossover	Amateur boxers	Smartphone/video-game task		Decision-making	Mental fatigue impaired cognitive performance before exercise
Holgado et al., 2023	Randomized controlled trial	Physically active adults	Individualized cognitive task		Neuromuscular function and exercise performance	No significant impairment in maximal neuromuscular function
Soylu et al., 2025	Randomized crossover	Soccer players	Stroop task		Technical actions, kinematics, psychophysiological responses	Mental fatigue reduced movement quality and technical performance

Overall, the included studies demonstrated considerable methodological similarity in adopting experimental designs while differing in participant characteristics, cognitive fatigue protocols, and outcome measures. This heterogeneity prevented quantitative pooling of data and supported the use of narrative synthesis.

Methodological quality was evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, and the results are summarized in Table 2. Seven studies were classified as having high methodological quality, whereas three studies were rated as moderate quality. Overall, the included studies adequately described participant selection, intervention procedures, outcome assessment, and statistical analyses. The most common methodological limitation was the inability to blind participants because the cognitive interventions required active engagement and could not be concealed from participants.

Table 2. Methodological Quality Assessment Using the JBI Critical Appraisal Checklist

Study	Randomization	Allocation Concealment	Baseline Similarity	Blinding	Follow-up	Outcome Measurement	Statistical Analysis	Overall Quality
Smith et al., 2016	✓	✓	✓	X	✓	✓	✓	High
Smith et al., 2016	✓	✓	✓	X	✓	✓	✓	High
Badin et al., 2016	✓	?	✓	X	✓	✓	✓	Moderate
Smith et al., 2017	✓	✓	✓	X	✓	✓	✓	High
Trecroci et al., 2020	✓	✓	✓	X	✓	✓	✓	High
Filipas et al., 2021	✓	?	✓	X	✓	✓	✓	Moderate
Fortes et al., 2022	✓	✓	✓	X	✓	✓	✓	High
Fortes et al., 2023	✓	✓	✓	X	✓	✓	✓	High
Holgado et al., 2023	✓	✓	✓	X	✓	✓	✓	High
Soylu et al., 2025	✓	?	✓	X	✓	✓	✓	Moderate

Abbreviations: ✓ = Yes; X = No; ? = Unclear.

To complement the methodological appraisal, the overall risk of bias of the included studies was assessed and summarized in Table 3. Most studies presented a low overall risk of bias, particularly regarding participant selection, outcome measurement,

completeness of follow-up, and statistical analysis. The principal source of potential bias was participant blinding, which was considered unavoidable because participants were aware of the cognitive tasks used to induce mental fatigue. No study demonstrated a high overall risk of bias.

Table 3. Summary of Risk of Bias Across the Included Studies

Risk of Bias Domain	Low Risk	Some Concerns	High Risk
Randomization process	9	1	0
Allocation concealment	7	3	0
Baseline comparability	10	0	0
Participant blinding	0	10	0
Outcome assessor blinding	8	2	0
Incomplete outcome data	10	0	0
Selective reporting	10	0	0
Statistical analysis	10	0	0
Overall risk of bias	7	3	0

Narrative synthesis of the included studies revealed a consistent pattern indicating that mental fatigue predominantly impaired sport-specific technical performance, decision-making, and endurance-related performance. Six studies reported significant reductions in technical execution, including passing accuracy, shooting accuracy, successful technical actions, or movement quality during sport-specific tasks. Five studies also demonstrated impaired decision-making performance characterized by slower responses, reduced decision accuracy, and less efficient visual search behavior following cognitively demanding tasks.

Four studies consistently reported reductions in endurance-related outcomes, including decreased exercise tolerance, lower running performance, and reduced physical activity during sport-specific exercise. In contrast, evidence regarding maximal neuromuscular function was less consistent.¹⁸ Holgado et al. observed no significant reduction in maximal neuromuscular function despite successful induction of mental fatigue, suggesting that cognitive fatigue primarily influences exercise performance through central mechanisms rather than direct impairment of peripheral muscle contractile capacity.¹⁸

Overall, the qualitative synthesis indicates that mental fatigue exerts its greatest influence on performance domains requiring sustained attention, executive function, motor coordination, and complex technical execution. Current evidence suggests that experimentally induced mental fatigue can adversely affect endurance performance, decision-making, and sport-specific technical performance, although the magnitude and consistency of these effects vary substantially across performance domains. In contrast, maximal neuromuscular function appears relatively preserved under some experimentally induced mental fatigue conditions.¹⁸ These findings provide a comprehensive overview of the current evidence and establish the basis for interpreting the underlying mechanisms and clinical implications discussed in the subsequent section.

Discussion

This systematic review synthesized evidence from ten original experimental studies published between 2016 and 2025 to evaluate the effects of mental fatigue on neuromuscular performance in athletes. Overall, the findings consistently demonstrated that mental fatigue adversely affected endurance performance, sport-specific technical performance, movement quality, motor control, and decision-making. Conversely, evidence regarding maximal neuromuscular function remained inconsistent, suggesting that the detrimental effects of mental fatigue are more closely associated with central nervous system regulation than with peripheral muscular impairment.^{18,19} These findings support the growing consensus that cognitive fatigue represents an important determinant of athletic performance and should be considered alongside traditional physiological factors during training and competition.¹

One of the most consistent findings identified across the included studies was the decline in sport-specific technical performance following mental fatigue induction. Soccer-based studies conducted by Smith et al., Badin et al., Trecroci et al., and Soylu et al. consistently reported reductions in passing accuracy, technical execution, movement quality, and successful technical actions during sport-specific tasks.²⁰ Similarly, studies involving basketball players and amateur boxers demonstrated impaired decision-making accuracy and less efficient visual search behavior after exposure to cognitively demanding tasks.^{13,15} Collectively, these findings suggest that technical performance is highly dependent on intact executive function, sustained attention, and rapid information processing, all of which are negatively affected by mental fatigue.^{5,16} Because technical execution in competitive sports frequently requires simultaneous cognitive processing and motor coordination, even subtle reductions in cognitive efficiency may substantially impair performance under competitive conditions.²¹

The observed decline in endurance-related performance further supports the psychobiological model of exercise regulation proposed by Marcora and colleagues, which suggests that exercise tolerance is influenced not only by physiological capacity but also by the perception of effort generated within the central nervous system. Across several included studies, mentally fatigued participants demonstrated reduced exercise tolerance, shorter running distances, and lower physical activity despite the absence of substantial physiological changes indicating peripheral muscle fatigue. These findings indicate that prolonged cognitive activity increases perceived exertion, thereby limiting voluntary exercise performance before physiological exhaustion is reached. Consequently, the reduction in endurance capacity observed in mentally fatigued athletes appears to reflect altered central regulation rather than impaired muscular energy production or contractile function.^{2,3}

In contrast, evidence regarding maximal neuromuscular function was considerably less consistent. Holgado et al. reported that individualized mental fatigue protocols did not significantly reduce maximal neuromuscular function or maximal exercise performance despite successful induction of cognitive fatigue.¹⁸ Similar observations have been reported in previous experimental studies indicating that maximal voluntary contraction, peak force production, and peripheral neuromuscular activation may remain relatively unaffected following acute mental fatigue.^{18,19} This discrepancy may be explained by the different physiological mechanisms underlying maximal strength and prolonged exercise performance. Whereas endurance activities require continuous cognitive regulation of effort, pacing strategies, and attentional control, maximal force production depends predominantly on short-duration neuromuscular recruitment that appears less susceptible to transient cognitive fatigue. Therefore, mental fatigue may exert a greater influence on complex motor performance than on isolated maximal muscular strength.^{18,19}

Another important observation emerging from this review is the substantial methodological heterogeneity among the included studies. Considerable variation existed in participant characteristics, sporting disciplines, mental fatigue induction protocols, intervention duration, and outcome measures. Most studies employed prolonged Stroop tasks as the primary cognitive fatigue protocol, whereas others used smartphone-based activities, video-game exposure, or individualized cognitive tasks. Similarly,

neuromuscular performance was evaluated using diverse outcome measures, including endurance capacity, sport-specific technical performance, movement quality, decision-making accuracy, psychophysiological responses, and maximal neuromuscular function. Such methodological diversity limited direct comparison across studies and precluded quantitative synthesis through meta-analysis. Nevertheless, the consistency of findings across multiple sporting disciplines strengthens confidence in the overall conclusion that mental fatigue adversely affects several dimensions of athletic performance.

The methodological quality of the included studies was generally satisfactory. Most investigations employed randomized crossover or controlled experimental designs, standardized cognitive fatigue protocols, validated performance assessments, and appropriate statistical analyses. The overall risk of bias was considered low to moderate, supporting the reliability of the synthesized evidence. The principal methodological limitation identified across studies was the inability to blind participants to the mental fatigue intervention. Because participants were necessarily aware of the cognitively demanding tasks performed before exercise testing, complete blinding was practically impossible. Although this limitation is reported in experimental studies investigating cognitive fatigue, future investigations should consider additional strategies to minimize expectation bias, including assessor blinding and standardized intervention procedures.^{16,22}

The findings of this review have important implications for sports medicine, physiotherapy, and athletic performance management. Monitoring cognitive workload before training and competition may help identify athletes at increased risk of performance deterioration. Coaches and sports scientists should recognize that mentally demanding academic activities, prolonged tactical meetings, excessive smartphone use, and cognitively intensive tasks performed immediately before competition may negatively influence technical execution and decision-making despite preserved physical readiness.¹³ Consequently, strategies aimed at minimizing unnecessary cognitive load or optimizing recovery before competition may improve athletic performance and reduce the likelihood of performance decrements associated with mental fatigue.²³

Several limitations of this review should be acknowledged. First, the included studies represented a limited number of sporting disciplines, with soccer accounting for the majority of available evidence, thereby restricting the generalizability of the findings to other sports. Second, considerable heterogeneity in mental fatigue induction protocols and outcome measures limited direct comparison across studies and precluded quantitative meta-analysis. Third, most studies evaluated only the acute effects of experimentally induced mental fatigue, whereas the long-term consequences of repeated cognitive fatigue remain largely unknown. Finally, although the methodological quality of the included studies was generally acceptable, several investigations lacked complete reporting of allocation concealment and assessor blinding, potentially introducing methodological bias.

Future research should prioritize multicenter randomized controlled trials involving athletes from diverse sporting disciplines and competitive levels. Standardization of mental fatigue induction protocols and neuromuscular outcome measures would improve comparability across studies and facilitate future meta-analyses. Additionally, further investigation is required to clarify the neurophysiological mechanisms linking cognitive fatigue to neuromuscular performance, including the role of cortical activation, motor unit recruitment, and central motor drive. Such evidence would strengthen the development of evidence-based interventions aimed at minimizing the detrimental effects of mental fatigue on athletic performance.

Overall, the present review demonstrates that mental fatigue predominantly impairs athletic performance through central cognitive mechanisms affecting endurance capacity, technical execution, movement quality, and decision-making rather than direct reductions in maximal neuromuscular function. These findings reinforce the importance of integrating cognitive workload management into athlete monitoring programs and provide a comprehensive evidence base for clinicians, physiotherapists, coaches, and sports scientists seeking to optimize performance and recovery in competitive athletes.

Conclusion

This systematic review synthesized evidence from ten original experimental studies published between 2016 and 2025 to evaluate the effects of mental fatigue on neuromuscular performance in athletes. Overall, the available evidence indicates that mental fatigue negatively affects multiple components of athletic performance, particularly endurance capacity, sport-specific technical performance, movement quality, motor control, and decision-making. In contrast, current evidence regarding maximal neuromuscular function remains inconsistent, suggesting that the detrimental effects of mental fatigue are primarily mediated through central cognitive mechanisms rather than direct impairment of peripheral muscle function.^{18,19}

These findings emphasize the importance of considering cognitive workload as an integral component of athlete monitoring and performance optimization. Incorporating strategies to minimize mental fatigue before training and competition may contribute to improved technical execution, decision-making, and overall athletic performance.²⁴ The present review also highlights the need for coaches, physiotherapists, sports scientists, and clinicians to recognize mental fatigue as a potentially modifiable factor that may influence sport-specific performance.²⁵

Future research should focus on well-designed multicenter randomized controlled trials involving athletes from diverse sporting disciplines, using standardized mental fatigue induction protocols and validated neuromuscular outcome measures. Greater methodological consistency will facilitate comparisons across studies, strengthen the evidence base, and support the development of effective interventions aimed at mitigating the adverse effects of mental fatigue on athletic performance.

Clinical Implications

The findings of this review suggest that monitoring cognitive workload should complement conventional physical training and recovery strategies in athletes. Coaches and sports medicine professionals should consider scheduling cognitively demanding activities separately from training sessions and implementing appropriate recovery strategies to reduce the potential impact of mental fatigue on technical performance, motor control, and decision-making during competition.²⁴

Limitations

This review has several limitations. Most included studies involved soccer players, limiting the generalizability of the findings to other sporting disciplines. Considerable heterogeneity in mental fatigue induction protocols, outcome measures, and participant characteristics precluded quantitative meta-analysis. Additionally, most studies investigated only the acute effects of mental fatigue, while evidence regarding chronic cognitive fatigue and long-term athletic performance remains limited.

Author Contribution

Putu Ika Pradipta Dewi: Conceptualization, Methodology, Literature Search, Data Curation, Formal Analysis, Investigation, Writing Original Draft, Visualization.

Ni Made Swasti Wulanyani: Conceptualization, Methodology, Validation, Interpretation of Findings, Writing Review and Editing, Supervision.

I Gusti Ayu Putu Wulan Budisetyani: Validation, Interpretation of Findings, Writing Review and Editing, Supervision.

All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Acknowledgments

The authors would like to express their sincere appreciation to the Faculty of Medicine, Udayana University, for supporting the completion of this systematic review. The authors also acknowledge all researchers whose published studies contributed to the evidence synthesized in this review.

Conflict of Interest Statement

The authors declare that they have no competing interests or conflicts of interest related to this study.

Funding Sources

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics Statement

This study is a systematic review of previously published literature and did not involve direct interaction with human participants or the collection of identifiable personal data. Therefore, ethical approval and informed consent were not required. Ethical approval and informed consent were not applicable to the present systematic review because the study analyzed previously published literature and did not involve direct recruitment or interaction with human participants.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. All data analyzed in this review were obtained from previously published studies.

AI Statement

The authors declare that artificial intelligence assisted in improving the language and readability of the manuscript. All scientific content, interpretation, critical appraisal, and final approval of the manuscript remain the sole responsibility of the authors.

References

1. 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.* 2017;47(8):1569-1588.
2. Marcora SM, Staiano W, Manning V. Mental fatigue impairs physical performance in humans. *J Appl Physiol* (1985). 2009;106(3):857-864.
3. 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.* 2017;47(8):1569-1588.
4. Yuan R, Sun H, Soh KG, Mohammadi A, Toumi Z, Zhang Z. The effects of mental fatigue on sport-specific motor performance among team sport athletes: a systematic scoping review. *Front Psychol.* 2023;14:1143618.
5. Sun H, Soh KG, Roslan S, Wazir MRWN, Soh KL. Does mental fatigue affect skilled performance in athletes? A systematic review. *PLoS One.* 2021;16(10):e0258307.
6. Aitken B, MacMahon C. Shared demands between cognitive and physical tasks may drive negative effects of fatigue: a focused review. *Front Sports Act Living.* 2019;1:45.
7. Badin OO, Smith MR, Conte D, Coutts AJ. Mental fatigue: impairment of technical performance in small-sided soccer games. *Int J Sports Physiol Perform.* 2016;11(8):1100-1105.
8. Smith MR, Franssen J, Deprez D, Lenoir M, Coutts AJ. Impact of mental fatigue on speed and accuracy components of soccer-specific skills. *Sci Med Footb.* 2017;1(1):48-52.
9. Alix-Fages C, Jiménez-Martínez P, de Oliveira DS, Möck S, Balsalobre-Fernández C, Del Vecchio A. Mental fatigue impairs physical performance but not the neural drive to the muscle: a preliminary analysis. *Eur J Appl Physiol.* 2023;123(8):1671-1684.
10. Trecroci A, Boccolini G, Duca M, Formenti D, Alberti G. Mental fatigue impairs physical activity, technical and decision-making performance during small-sided games. *PLoS One.* 2020;15(9):e0238461.
11. Filipas L, Borghi S, La Torre A, Smith MR. Effects of mental fatigue on soccer-specific performance in young players. *Sci Med Footb.* 2021;5(2):150-157.
12. Habay J, Uyenbroeck R, Van Droogenbroeck R, De Wachter J, Proost M, Tassignon B, et al. Interindividual variability in mental fatigue-related impairments in endurance performance: a systematic review and multiple meta-regression. *Sports Med Open.* 2023;9(1):14.
13. Fortes LS, Lima-Junior D, Barbosa BT, Faro HKC, Ferreira MEC, Almeida SS. Effect of mental fatigue on decision-making skill and visual search behaviour in basketball players: an experimental and randomised study. *Int J Sport Exerc Psychol.* 2025;23(5):40-59.
14. Fortes LS, Gantois P, de Lima-Junior D, Barbosa BT, Ferreira MEC, Nakamura FY, 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.
15. Fortes LS, Gantois P, de Lima-Junior D, Barbosa BT, Ferreira MEC, Nakamura FY, 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.
16. Habay J, Van Cutsem J, Verschueren J, De Bock S, Proost M, De Wachter J, et al. Mental fatigue and sport-specific psychomotor performance: a systematic review. *Sports Med.* 2021;51(7):1527-1548.

17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71.
18. Holgado D, Jolidon L, Borragán G, Sanabria D, Place N. Individualized mental fatigue does not impact neuromuscular function and exercise performance. *Med Sci Sports Exerc*. 2023;55(10):1823-1834.
19. Yang HS, Atkins LT, James CR. Effects of mental fatigue on isometric mid-thigh pull performance and muscle activities. *PLoS One*. 2025;20(3):e0318238.
20. Soyulu Y, Arslan E, Akçay N, Akgul MS, Kilit B, Lopes TR, et al. Effects of mental fatigue on psychophysiological responses, kinematic variables and technical actions in small-sided soccer games: a time course analysis. *Front Psychol*. 2025;16:1654701.
21. Lu Q, Liu D, Chen X, Wang J, Song Y, Chai Y. Effects of mental fatigue on sport-related reaction-time, technical, and decision-making performance: a systematic review and meta-analysis. *BMC Psychol*. 2026;14(1):1118.
22. Bian C, Russell S, Mali A, Lathouwers E, De Pauw K, Habay J, et al. Methodological considerations and effectiveness for ecologically valid mental fatigue inducement in sports: a systematic review. *Sports Med Open*. 2025;11(1):82.
23. da Costa YP, Freitas-Junior C, de Lima-Junior D, Soares-Silva EL, Batista GR, Hayes L, et al. Mental fatigue and ball sports: a narrative review focused on physical, technical, and tactical performance. *Motriz Rev Educ Fis*. 2022;28:e102200041.
24. Sun H, Soh KG, Mohammadi A, Toumi Z, Zhang L, Ding C, et al. Counteracting mental fatigue for athletes: a systematic review of the interventions. *BMC Psychol*. 2024;12(1):67.
25. Sun H, Soh KG, Mohammadi A, Toumi Z. The counteractive effects of interventions addressing mental fatigue on sport-specific performance among athletes: a systematic review with a meta-analysis. *J Sports Sci*. 2024;42(24):2279-2291.