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The Acute Effects Of Mental Fatigue On Cycling Performance And Psychophysiological Responses: A Systematic Review

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ABSTRACT

Purpose: Mental fatigue (MF) is known to negatively impact the performance of cyclists, but evidence regarding its effects on performance is limited. More comprehensive information is needed on this subject. In this context, the aim of this study is to systematically review publications in the literature that examine the effects of MF on cycling performance.
Method: Studies related to the keywords "mental fatigue", "cycling", "performance", and "acute effect" were searched in Google Scholar and PubMed databases. A total of 12 studies were examined using the PICO approach, in accordance with the PRISMA guidelines.
Results: According to the research findings, after prolonged MF applications of 30-90 minutes, time trial cycling performance at 80-100% of peak power for 8-10 minutes decreases in terms of exhaustion time and average power value. The rating of perceived exertion (RPE) level measured after the performance increases; this result indicates that the decrease in performance is related to the increase in RPE. Therefore, MF exposure reduces endurance performance. After MF application, there is no change on levels of physiological responses such as heart rate (HR), lactate (LA), and glucose (GLU); however, cognitive characteristics such as dexterity, motivation, EEG activity and perception are negatively affected. As the sports level of decreases, the negative effect of MF application on performance increases. In addition, MF negatively affects the performance of recreational or amateur athletes. In contrast, regardless of the duration of MF application has no effect on maximum intensity performance of 6 minutes and below, and 30 seconds of Wingate anaerobic performance.
Conclusion: In conclusion, prolonged MF of 30 minutes or more reduces cycling performance at over 80% intensity for at least 8 minutes and increases RPE; however, MF does not affect maximal, short-term performance for 6 minutes or less and physiological responses. Adding factors that mitigate or minimize the effects of MF, instead of factors that negatively impact performance, could eliminate the negative impact of MF on endurance performance. In this respect, incorporating practices that reduce the effects of MF in cyclists who are negatively affected cognitively could positively influence their performance graph.
Keywords: Acute effect, Cycling, Mental fatigue, Performance

ÖZET

Mental Yorgunluğun Bisiklet Performansı ve Psikofizyolojik Yanıtlar Üzerindeki Akut Etkileri: Sistematik Bir Derleme

Amaç: Mental yorgunluğun bisiklet performansı üzerindeki olumsuz etkileri bilinmesine rağmen, bu etkinin boyutu ve mekanizmaları hakkında literatürde sınırlı ve dağınık bulgular bulunmaktadır. Bu çalışmanın amacı, mental yorgunluğun bisiklet performansı üzerindeki akut etkilerini inceleyen çalışmaları sistematik olarak değerlendirmektir.

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Yöntem: Mental yorgunluk", "bisiklet", "performans" ve "akut etki" anahtar kelimeleri kullanılarak Google Scholar ve PubMed veri tabanlarında tarama yapılmıştır. PRISMA yönergelerine uygun olarak PICO yaklaşımı temelinde toplam 12 çalışma analize dahil edilmiştir.
Bulgular: Araştırma bulgularına göre, 30–90 dakika süren mental yorgunluk uygulamaları sonrasında, %80–100 şiddetinde gerçekleştirilen 8–10 dakikalık zamana karşı bisiklet performansında tükenme süresi ve ortalama güç değerlerinde azalma gözlenmiştir. Performans sonrasında ölçülen algılanan zorlanma düzeyinin (RPE) artması, performanstaki düşüşün RPE artışı ile ilişkili olduğunu göstermektedir. Bu doğrultuda mental yorgunluğun dayanıklılık performansını olumsuz etkilediği görülmektedir. Buna karşın, mental yorgunluk uygulamaları kalp atım hızı (HR), laktat (LA) ve glikoz (GLU) gibi fizyolojik parametrelerde anlamlı bir değişime neden olmamıştır. Ancak dikkat, motivasyon, EEG aktivitesi ve algı gibi bilişsel özelliklerin olumsuz etkilendiği belirlenmiştir. Sporcu seviyesi azaldıkça mental yorgunluğun performans üzerindeki olumsuz etkisinin arttığı, rekreatif ve amatör sporcuların bu durumdan daha fazla etkilendiği saptanmıştır. Buna karşılık, mental yorgunluğun süresinden bağımsız olarak 6 dakika ve altındaki maksimal performans ile 30 saniyelik Wingate anaerobik performansı üzerinde anlamlı bir etkisi bulunmamıştır.
Sonuç: Sonuç olarak, 30 dakika ve üzerindeki mental yorgunluk, en az 8 dakika süren ve %80'in üzerindeki şiddette gerçekleştirilen bisiklet performansını olumsuz etkilerken, kısa süreli maksimal performansı ve fizyolojik yanıtları etkilememektedir. Performansı olumsuz etkileyen faktörler yerine mental yorgunluğun etkilerini azaltmaya yönelik stratejilerin uygulanması, dayanıklılık performansı üzerindeki olumsuz etkileri azaltabilir. Bu bağlamda, bilişsel olarak etkilenen bisikletçilerde mental yorgunluğu azaltıcı uygulamaların performans üzerinde olumlu etkiler sağlayabileceği düşünülmektedir.
Anahtar Kelimeler: Akut etki, Bisiklet, Mental yorgunluk, Performans

INTRODUCTION

Athletic performance, especially in endurance sports, not only physiological processes but also central nervous system (CNS) processes and psychological factors play a significant role in performance outcomes (Marcora et al., 2009; Noakes, 2012). Mental fatigue (MF) is a psychobiological condition known to arise as a result of prolonged and strenuous cognitive activities; it is associated with an acute increase in subjective fatigue perception or an acute decrease in cognitive performance (Ackerman, 2011). This condition differs from acute fatigue associated with aging and certain diseases, or cognitive impairments. The decrease in performance due to MF is directly related to the duration and intensity of mental effort (Boksem & Tops, 2008). While the negative effects of MF on cognitive performance have long been known in the literature (Boksem et al., 2005; van der Linden et al., 2003), its effects on athletic performance have also been investigated recently. Literature findings indicate that MF negatively affects athletic performance, particularly in endurance-based sports, and that this may be related to central mechanisms rather than peripheral physiological limitations (Marcora et al., 2009; Pageaux & Lepers, 2013). Consequently, it is suggested that psychophysiological responses such as increased rating of perceived exertion (RPE), decreased motivation, and negative affect may contribute to the impact of MF on exercise performance (Van Cutsem et al., 2017a).

In cycling, in addition to psychological and environmental processes, athlete performance is closely related to the contribution of different energy systems. While cycling performance, where long-term endurance predominates, primarily depends on aerobic energy metabolism, short-term and high-intensity efforts rely more on anaerobic energy pathways such as the ATP-PCr and glycolytic systems (Noakes, 2012). Mental fatigue does not directly impair physiological parameters such as heart rate, lactate concentration, or oxygen consumption; however, it may indirectly affect performance by altering pacing strategies, perceived exertion, and central motor drive (Marcora et al., 2009; Van Cutsem et al., 2017). In prolonged exercise where aerobic metabolism predominates, increased perceived exertion may lead to a reduction in power output despite preserved physiological capacity (Marcora et al., 2009). In contrast, in short-term maximal efforts that rely on intramuscular energy stores, the effect of mental fatigue may be limited due to the short duration of the task and the predominant role of anaerobic energy systems (Rozand et al., 2014; Aras et al., 2020). Therefore, the relationship between mental fatigue and cycling performance can also be interpreted through its indirect effects on energy system utilization and exercise intensity regulation (Pageaux & Lepers, 2013).

Cycling exercise is a frequently used model for examining the acute effects of MF due to its ability to precisely control intensity and workload, and to provide repeatable and reliable performance measurements (Brownsberger et al., 2013; Pageaux et al., 2015). Constant load, time trial, and exhaustion-to-exercise protocols allow for detailed assessment of performance changes and accompanying psychophysiological responses following cognitive fatigue. However, studies do not show significant homogeneity in terms of measured variables, applied protocols, and exercise tests. Therefore, there is a need for a systematic evaluation of studies examining the acute effects of MF on cycling performance and psychophysiological responses. In this context, the aim of this research is to synthesize the existing literature by comprehensively analyzing studies examining the acute effects of MF on cycling performance and the accompanying psychophysiological responses and processes.

METHODS

Research Design and Protocol

The research included studies involving MF interventions conducted on cyclists.

Inclusion criteria were:

1) Studies published as full-text articles

2) Studies conducted with healthy adult cyclists without gender or level restrictions

3) Studies in which "Mental Fatigue" intervention was applied before performance measurement in the experimental group

4) Studies with control groups that completed the procedures

5) Studies with outcome measures that; body composition, muscle endurance, muscle strength, cardiovascular endurance, power, rating of perceive exertion, heart rate, glucose level etc variables;

Exclusion criteria were:

1) Reviews;

2) Studies that did not include MF as an intervention

3) Studies without a control group

4) Unpublished studies were not included in the research.

In addition, Studies that included MF interventions for lasting 30 minutes or more, such as Stroop, AX-CPT, RVIP, concentration box, and were from the last fifteen years were examined.

Information Sources and Research Strategy

The aim of this research is to examine the acute effects of MF on cycling performance and psycho-physiological responses during performance, through a systematic review of studies in the literature from 2009 onwards. Studies were reviewed using Google Scholar and PubMed databases. Studies were searched using the keywords “mental fatigue”, “cycling”, “performance”, “acute effect” and combinations thereof, starting from “January 1, 2009”. Current articles published in the last 15 years that met the inclusion criteria were evaluated. The literature was searched according to the PRISMA guidelines used for Systematic Reviews and Meta-analyses (Moher et al., 2015). The selection criteria for the studies were; the application of MF and the inclusion of a cycling performance test, and the results of 12 studies that met these criteria were included in the study using the PICO (Population, Intervention, Comparison, Outcome) approach (Huang et al., 2006). The initial review of the accessed databases focused on article titles, results, and abstracts; a more comprehensive search was conducted for data not available in the abstracts.

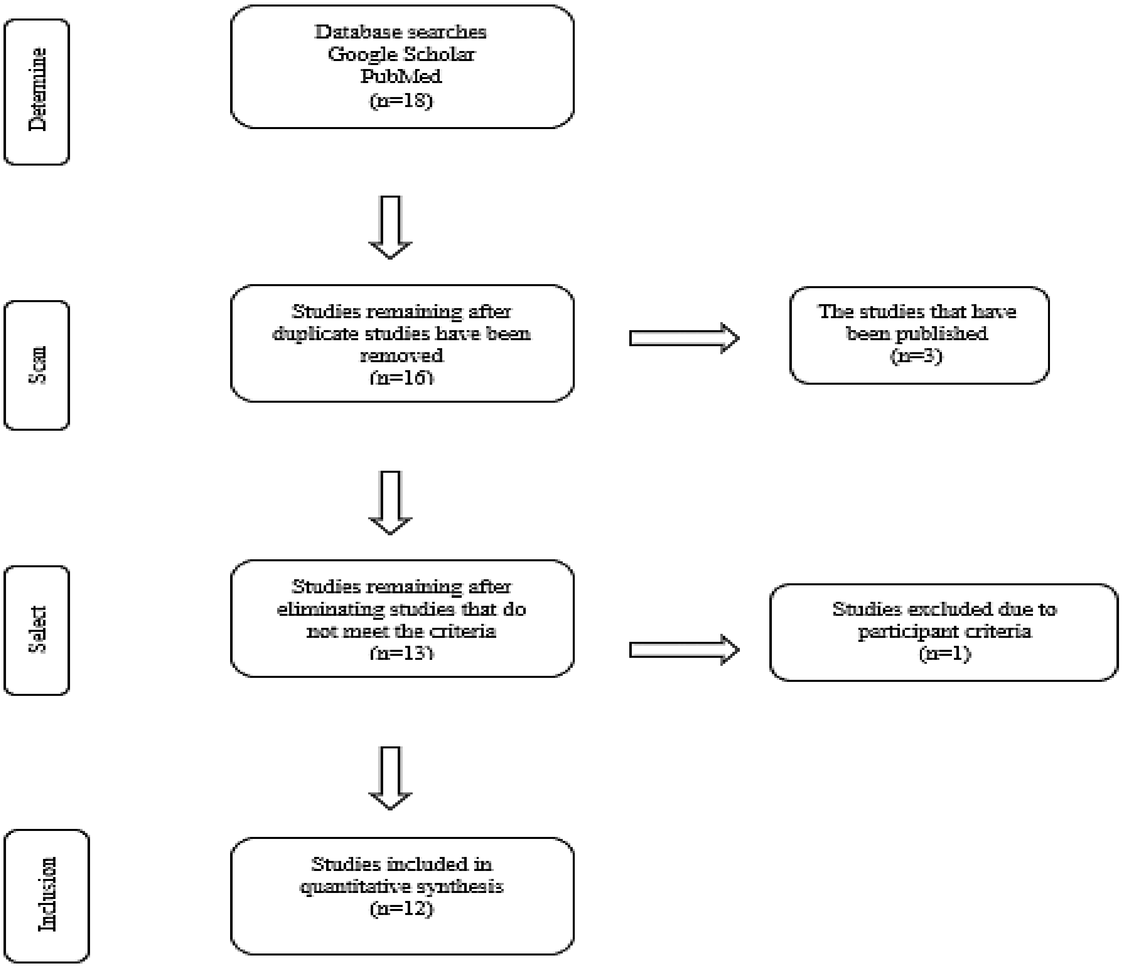

Figure 1. Systematic review procedure

RESULTS

A review of the literature reveals that studies in healthy adult individuals have shown that 90 minutes of cognitive activity reduces the exhaustion time of a 10-minute free performance test and the average power value of a time trial; it increases the perceived difficulty level; however, it does not alter physiological responses such as HR and GLU levels (Brownsberger et al., 2013; Marcora et al., 2009). Similarly, in male road cyclists, a 30-minute Stroop test followed by a 20-minute cycling test resulted in decreased power and distance covered, while HR and LA levels remained unchanged (Martin et al., 2016). In line with these findings, cognitive activities lasting 30 minutes or more negatively impact long-term cycling performance but do not affect physiological responses. Some studies have observed that elite athletes can maintain their power output even under cognitive load, and given that elite-level or well-trained athletes are more resistant to cognitive fatigue than recreational athletes (Martin et al., 2016), study results may vary depending on the participants' level. Furthermore, when an elite-level athlete realizes they are mentally fatigued, they may exert more effort to compensate for it; they may completely mask the negative impact of fatigue with motivation.

Although MF negatively impacts long-term cycling performance, it does not affect short-term performance. In this regard, it has been reported that 90 minutes of MF in physically active individuals did not affect 3-minute maximal cycling and CMJ performance, but it reduce motivation (Martin et al., 2016). Similarly, 40 minutes of MF in physically active individuals did not alter four sets of Wingate performance or HR (Duncan et al., 2015). Silva-Cavalcante et al. reported that 30 minutes of Stroop in physically active male did not affect maximal performance or HR immediately following 6 minutes of time trial cycling at 80% peak power; however, it increase RPE level (Silva-Cavalcante et al., 2018). Likewise, it was reported that 90 minutes of MF did not affect 4-minute time trial performance (Silva-Cavalcante et al., 2018).

Literature findings indicate that 30-90 minutes of MF increase the RPE level in both short- and long-term performance in physically active or recreational cyclists (Marcora et al., 2009; Brownsberger et al., 2013; Duncan et al., 2015; Huang et al., 2006; Pires et al., 2018). In contrast, Van Cutsem et al. (2017b) found that in trained male cyclists, 45 minutes of Stroop test did not alter the RPE level in 15 minutes of cycling at 80% peak power immediately following 45 minutes of submaximal test at 60% peak power. Similarly, Silva-Cavalcante et al. (2018) reported that 90 minutes of MF did not affect 4km time trial performance or RPE level in recreational cyclists. Apart from all these parameters, MF exposure does not cause significant changes in physiological responses such as cadance (pedalling rate per minute), LA, and GLU in cyclists (Marcora et al., 2009; Van Cutsem et al., 2017b; Salam et al., 2018). However, it negatively affects cognitively-based performance such as motivation (Huang et al., 2006), perception, and dexterity (Duncan et al., 2015).

DISCUSSION

The Effect of Cognitive Fatigue on Short-Term Performance

Literature results show that regardless of the duration of MF, single-set or multiple sets do not affect maximal and short-term cycling performance and physiological responses

(Martin et al., 2016; Duncan et al., 2015). In maximal short-term efforts, performance is limited because the muscle uses its own energy stores (ATP-PCr), and since the athlete focuses on maximum effort, the brain may not restrict motor unit involvement and muscle firing (Rozand et al., 2014). In short-term and high-intensity activities, MF has a limited effect on physiological changes such as the contractile properties of active muscles and the CNS's ability to activate them. Based on this, it can be said that MF does not affect anaerobic work, maximal strength, and explosive power and the fatigue here is of physical origin (Aras et al., 2020). When high-intensity exercise, such as sprinting begins, the release of adrenaline and noradrenaline along with high physiological arousal, can mask the "drowsiness" or "loss of motivation" effects and the negative signals generated by cognitive load.

The Effect of Mental Fatigue on Endurance Performance

The findings of the current systematic review show that MF has a consistent negative effect on endurance performance in cyclists (Brownsberger et al., 2013; Huang et al., 2006; Otani et al., 2017; Barzegarpoor et al., 2020). This decline is generally manifested as a decrease in time trial performance, a longer time to complete a given distance, or a significant shortening of time to failure (Pageaux et al., 2015; Van Cutsem et al., 2017b). In their study, Barzegarpoor et al. (2020) reported that cognitively fatigued cyclists experienced a significant decrease in time to fatigue compared to the control group. The studies reviewed in this compilation reported a decrease in average power (Brownsberger et al., 2013; Martin et al., 2016; Otani et al., 2017; Pires et al., 2018), distance (Martin et al., 2016), and time to exhaustion (Marcora et al., 2009; Salam et al., 2018) in long-duration maximal performance tests exceeding 6 minutes. It is noteworthy that power decreases after MF are observed in individuals who is recreationally and physically active. In contrast, studies on elite cyclists, showed a negative impact on power values after MF (Salam et al., 2018), and mostly they remained unchanged (Martin et al., 2016; Van Cutsem et al., 2017b; Clark et al., 2019). These results demonstrate that MF negatively impacts long duration cycling performance in amateur athletes. Therefore, they highlight the importance of avoiding cognitively demanding activities, both before training and competition.

The Role of Increased Rating of Perceived Exertion (RPE)

The primary mechanism of MF on endurance performance is considered to be an increase in RPE without significant changes in physiological variables (Marcora et al., 2009; Van Cutsem et al., 2017b). A review of studies in the literature shows that MF has the most negative impact on the RPE, regardless of the type or duration of application, participant characteristics, age, or sport. According to the model popularized by Samuele Marcora regarding the effect of MF on RPE level, the reason for abandoning exercise is that RPE reaches the threshold of maximum effort willing to expend (Marcora et al., 2009). Exposure to MF leads to starting exercise with a high RPE level; even though the physical load is the same, this load is perceived as greater. Studies have shown that cyclists, even when cognitively fatigued and pedaling at the same external load (Watt), perceive the exercise as more challenging and therefore report higher RPE values (Duncan et al., 2015; Salam et al., 2018). The increased RPE is attributed to changes in neural activity in brain regions such as anterior cingulate cortex, which reduces the athlete's ability to delay fatigue or inhibit the urge to stop (Pires et al., 2018).

MF does not affect maximal and short-term cycling performance and physiological responses; however, it increase RPE level. In the study by Van Cutsem et al. (2017b), it was shown that 45 minutes of Stroop intervention did not change RPE level in cycling performance at 80% peak power, immediately followed by 15 minutes of cycling at 60% peak power. In this study, it is thought that RPE level did not change because the participants were well-trained. Athletes with good training levels can be in good physical and psychological condition; therefore, they can overcome the negative effects of MF because they have the ability to overcome all physical and cognitive obstacles. This argument is also supported by Clark et al. (2019), they showed that after 30 minutes of MF application, followed by a 6-minute high-intensity and then 6-minute time trial cycling test, HR of recreational cyclists increased, while HR of trained cyclists remained unchanged. Indeed, it appears that MF application does not affect the short-term power values of either elite or recreational cyclists; however, its effect on physiological responses may vary. From this perspective, it can be said that the physiological responses to a load during MF may vary depending on sports level. In short, the negative effect of MF applications on duration, average power or time to exhaustion in maintaining performance may be related to central mechanisms that limit the athlete's willingness or endurance to maintain effort. High RPE can lead to an early performance termination by reducing the cyclist's motivation or desire to maintain performance (Van Cutsem et al., 2017b). This mechanism supports the idea that MF acts as a psychobiological state, affecting central regulation rather than peripheral muscle fatigue. A comprehensive summary of MF protocols, performance tests, and outcomes is shown in Table 1.

Table 1. Physiological and psycho-physiological responses of cycling performance in conjunction with Mental Fatigue Intervention

Reference	Participants	MF intervention	Performance test	Psycho-physiological parameter	Effect
Marcora et al., 2009	Physically active 16 adult individual (10 ♂, 6 ♀)	90 min AX-CPT 90 min video	%80 PP CTE	HR RPE GLU	Exhaustion time ↓ RPE ↑ HR-GLU ↔
Brownsberger et al., 2013	12 healthy adult (8 ♂ , 4 ♀)	90 min Stroop 90 min video	2 consecutive 10 min free (RPE 11-RPE15) CTE	VAS RPE GLU EEG	EEG Beta activation↑ RPE ↑ W ↓ (RPE 11- RPE 15)
Martin et al., 2016	12 healthy, physically active adult (7 ♂, 5 ♀)	90 min AX-CPT 90 min video	CMJ İzometric leg extention 3 min maximal cycling	RPE Motivation HR LA	RPE ↑ Motivation ↓
Pageaux et al., 2015	Physically active adult 12 ♂	30 min Stroop	İzokinetic strength EMG %80 ZG 6 dk TTB + maks kuvvet	NASA BRUNEL RPE HR	Vastus lateralis-EMG RMS ↑ RPE ↑
Duncan et al., 2015	Physically active adult (7 ♂, 1 ♀)	40 min Concentration box 40 min control	4*30' Wingate Minesota hand skill Simultaneous sensing		Wingate ↔ Minnesota hand skill ↓ Simultaneous sensing ↓
Martin et al., 2016	20 ♂ road cyclists (11 pro - 9 recreative)	30 min Stroop	20 min incremental cycling test	LA HR RPE	(recreative road cyclists) distance ↓ W ↓
Otani et al., 2017	Physically active adult 8 ♂	90 min Stroop + 30 min WI (40 C)	%80 Vo^{2}max CTE	RPE HR SBP-DBP	MF % 0,8 ↓ WI % 26,6 ↓ MF+WI % 46,3 ↓
Van Cutsem et al., 2017a	Well trained 10 ♂ triathlon/cycling athlete	45 min Stroop 45 min control video (30 C - %30 humidity)	45 min %60 Wmax + 15 min CTE %80 Wmax	HR LA RPE	W ↔ RPE ↔ LA ↔ HR ↔
Pires et al., 2018	Recreational cyclist 8 ♂	30 min RVIP	20 dk TTCT	RPE EEG	RPE ↑ W %2,7 ↓
Clark et al., 2019	20 ♂ cyclists (10 well trained - 10 recreational)	30 min Stroop+ N-back	6 dk HICT + 6 dk TTCT	LA GLU HR	(Rekreasyonel bisikletçiler) HR ↑ (both group) W ↔
Salam et al., 2018	Well trained-elite 11 ♂ cyclist	30 min Stroop	CTE four group (%40-60-80-100 Vo^{2}max)	RPE HR LA GLU	RPE ↑ HR ↔ W'↓ Before&after exercise LA ↓
Silva-Cavalcante et al., 2018	Recreative road cyclist 8 ♂	90 min AX-CPT	3*5'' MVC (30'' recovery) EMG 4 km TTCT	VAS RPE	RPE ↔

Preservation of Physiological Responses

While cognitive fatigue negatively affects long-term performance parameters in cyclists, it interestingly does not affect physiological responses (Marcora et al., 2009; Van Cutsem et al., 2017a; Salam et al., 2018). Studies have reported no significant changes in parameters such as cortisol, prolactin, HR, psychomotor alertness, and maximum voluntary contraction following cognitive fatigue protocols (Barzegarpoor et al., 2020; Marcora et al., 2009). Another systematic review reported that MF negatively affects endurance performance; furthermore, in 86% of studies, MF caused a decrease in endurance performance, while there was no significant change in HR and LA levels, but RPE level increased. These findings highlight the importance of avoiding activities with high cognitive load before training or competition (Mera-González et al., 2025); and also reveal a critical point supporting the idea that the mechanisms leading to MF and performance decline are related to CNS rather than peripheral metabolic limitations. It is suggested that MF does not directly affect intramuscular metabolic changes leading to physical fatigue, but rather alters how the brain processes the effort signal (Van Cutsem et al., 2017b). This physiological stability reinforces the importance of focusing on perceptual and motivational factors in understanding the impact of cognitive fatigue on sports performance. Therefore, future research should focus more on the relationship between neurophysiological changes and increased RPE.

Differences Between Elite and Sub-Elite Athletes

Different results in the literature suggest that sports level may play a significant role in resistance to MF (Martin et al., 2016; Filipas et al., 2019). Martin et al. (2016) suggested that MF negatively impacts time trial performance in recreational cyclists, but this effect is not observed in Professional cyclists (Martin et al., 2016). The current study supports this and the hypothesis that elite cyclists may possess superior resistance to MF or have a more developed ability to inhibit the sensation of fatigue. On the other hand, in sub-elite cyclists, such as under 23, MF has been found to lead to decreased performance and affect autonomous HR regulation (Filipas et al., 2019). These differences in level mean that training and high-level competitive experience can enhance athletes' ability to sustain effort despite perceived high exertion. Therefore, in studies examining the effects of MF, is important to classify athletes more precisely and compare the underlying cognitive control mechanisms.

Reducing the Negative Effects of Cognitive Fatigue

Incorporating performance-positive practices alongside MF can positively influence the impact of MF on athletic performance. One study reported that MF significantly reduced endurance performance, but this negative effect could be prevented when visual performance feedback was provided (Dallaway et al., 2022). A meta-analysis reported that practices such as transcranial current stimulation, mindfulness exercises, GLU and caffeine mouth-rinsing reduced the negative effects of MF on sport-specific performance (Sun et al., 2024). André et al. (2025) defined MF as a psychobiological condition resulting from prolonged mental exertion that negatively affects perceptual, performance and physiological responses. In another study, it was reported that in elite male cyclists, the consumption of 400 mg of caffeine along with cognitive fatigue significantly increased maximum effort for 20 minutes called functional threshold power (FTP), normalized power (NP), relative power and LA level during performance (Akgönül, 2023). A systematic review indicated that among physiological practices aimed at reducing cognitive fatigue, the use of scents during and caffeine intake before MF are effective methods that eliminate the negative effects of MF (Proost et al., 2022). In this regard, Guo et al. (2015) also reported that less MF occurred in the group that performed the activity with relaxing music; the reaction time increased in the group that did not listen to music.

CONCLUSION

The study concludes that cycling durations of 30 minutes or more significantly negatively impact cycling performance, particularly in endurance-based, medium-to-long-distance exercises, especially in amateur athletes. Furthermore, the performance-reducing effect of cycling was found to be mostly associated with an increase in RPE. This effect can occur without significant changes in traditional physiological parameters such as heart rate, lactate, and glucose. These results support the idea that the effects of cycling on performance occur through central nervous system and psychobiological processes rather than peripheral mechanisms.

The review also shows that athlete performance levels are a significant factor influencing MF; recreational and sub-elite cyclists are more affected, while elite athletes may be more resistant to these effects. It was concluded that short-duration and maximal cycling performances (≤6 min, Wingate, etc.) are not affected by MF. Furthermore, the literature suggests that the negative effects of cognitive impairment can be reduced through physiological, behavioral, and psychological strategies such as caffeine consumption, scent applications, music listening, external motivation, mental awareness, and brain endurance training. However, these applications should be implemented after carefully examining the optimal doses, timing, and underlying neurophysiological mechanisms. In conclusion, avoiding activities that create high cognitive load before training and races, and implementing strategies to reduce MF in a planned manner, are important for performance in cyclists. Future studies are recommended to examine the neurophysiological basis of MF and the effectiveness of methods to reduce its negative effects in more detail, taking into account differences in gender, age groups, and sports level.

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