Cuadernos de Psicología del Deporte, vol. 24, 2, 242-252
Recibido: 06/09/2023
Aceptado: 18/04/2024

Murcia (España) ISSN edición impresa:1578-8423
ISSNedicióneb(http://revistas.um.es/cpd):1989-5879

Cita: Domingos-Gomes, J., Costa, Y., Lima-Junior, D., Lanzoni, I. & Batista, G. (2024). The mental fatigue impaired beach volleyball attack technical-tactical performance: a crossover and randomized study. *Cuadernos de Psicología del Deporte, 24*(2), 242-252

The mental fatigue impaired beach volleyball attack technical-tactical performance: a crossover and randomized study

La fatiga mental perjudicó el desempeño técnico-táctico del ataque en voleibol de playa: estudio cruzado y aleatorizado

A Fadiga mental prejudicou desempenho tático-técnico do ataque no vôlei de praia: um estudo cruzado e randomizado

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ABSTRACT

The aim of this study was to investigate the effect of mental fatigue on the technical-tactical performance of beach volleyball players. Twelve males young beach volleyball players (16.1 ± 0.9 years old) were recruited to participate in this crossover and randomized study. The simulated match was performed under two conditions (control: 30 min without performing cognitive activities; mental fatigue: 30 min performing Stroop Task). The match is recorded and technical-tactical performance was calculated (coefficient of performance and/or efficiency of serve, serve reception, set, attack, block, and dig actions). The mental fatigue was "moderate" after Stroop Task, and statistically significant compared to the control condition [Mental fatigue: 62.5 mm ± 8.8 Vs. Control: 6.4 mm ± 4.1; p = .0001; ES: 0.9 (moderate effect)]. Moreover, attack coefficient of performance and efficiency was lower in mental fatigue condition that control condition (CP: Mental Fatigue= 1.5 ± 0.4 Vs. Control= 2.3 ± 0.2, p = .001; Eff: Mental Fatigue = 23.7 ± 7.0 Vs. Control = 36.0 ± 9.5; p = .004). In conclusion, mental fatigue impaired attack performance of beach volleyball players (one of the main key to win in this sport). Thus, is recommended avoid cognitive tasks or high cognitive effort before training and matches.

Keywords: cognitive fatigue; team sports; net sports; neuroscience; match analysis.

RESUMEN

Este estudio tuvo como objetivo investigar el efecto de la fatiga mental en el rendimiento técnico-táctico de los jugadores de voleibol de playa. Se reclutaron doce jugadores jóvenes de voleibol de playa masculino (16.1 ± 0.9 años) para participar en este estudio cruzado y aleatorizado. El partido simulado se llevó a cabo bajo dos condiciones (control: 30 minutos sin realizar actividades cognitivas; fatiga mental: 30 minutos realizando la Tarea de Stroop). El partido se registró y se calculó el rendimiento técnico-táctico (coeficiente de rendimiento y/o eficiencia de saque, recepción de saque, colocación, ataque, bloqueo y acciones de defensa). La fatiga mental fue

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"moderada" después de la Tarea de Stroop y estadísticamente significativa en comparación con la condición de control [Tarea de Stroop: 62,5 mm ± 8.8 frente a Control: 6.4 mm ± 4.1; p = .0001; ES: 0.9 (efecto moderado)]. Además, el coeficiente de rendimiento y la eficiencia del ataque fueron más bajos en la fatiga mental que en la condición de control (CR: Fatiga Mental = 1.5 ± 0.4 frente a Control = 2.3 ± 0.2, p = .001; Eficiencia: Fatiga Mental = 23.7 ± 7.0 frente a Control = 36.0 ± 9.5; p = .004). En conclusión, la fatiga mental afectó el rendimiento de ataque de los jugadores de voleibol de playa (uno de los principales elementos clave para ganar en el deporte). Por lo tanto, se recomienda evitar tareas cognitivas o un alto esfuerzo cognitivo antes de los entrenamientos y los partidos.

Palabras clave: fatiga cognitiva; deportes en equipo; deportes de red; neurociencia; análisis de juego.

RESUMO

Este estudo teve como objetivo investigar o efeito da fadiga mental no desempenho técnico-tático de jogadores de voleibol de praia. Doze jogadores jovens do sexo masculino (16.1 ± 0.9 anos) foram recrutados para participar deste estudo cruzado e randomizado. A partida simulada foi realizada sob duas condições (controle: 30 minutos sem realizar atividades cognitivas; fadiga mental: 30 minutos realizando a Tarefa de Stroop). A partida foi registrada e o desempenho técnico-tático foi calculado (coeficiente de desempenho e/ou eficiência de saque, recepção de saque, levantamento, ataque, bloqueio e ações de defesa). A fadiga mental foi considerada "moderada" após a Tarefa de Stroop e estatisticamente significativa em comparação com a condição de controle [Tarefa de Stroop: 62.5 mm ± 8.8 vs. Controle: 6.4 mm ± 4.1; p = .0001; ES: 0.9 (efeito moderado)]. Além disso, o coeficiente de desempenho e a eficiência do ataque foram menores na fadiga mental do que na condição de controle (CD: Fadiga Mental = 1.5 ± 0.4 vs. Controle = 2.3 ± 0.2, p = .001; Eficiência: Fadiga Mental = 23.7 ± 7.0 vs. Controle = 36.0 ± 9.5; p = .004). Em conclusão, a fadiga mental prejudicou o desempenho de ataque dos jogadores de voleibol de praia (um dos principais elementos-chave para vencer no esporte). Portanto, é recomendado evitar tarefas cognitivas ou esforço cognitivo elevado antes dos treinos e das partidas.

Palavras-chave: fadiga cognitiva; esporte coletivo; esportes de rede; neurociência; análise de jogo.

INTRODUCTION

Beach volleyball is one of the Olympic net sports that is very popular all over the world. The main physical characteristics are intensity variation (i.e., intermittent sport) and use of jumps to perform the game actions (Costa et al., 2021; Magalhães et al., 2011). Moreover, the match analysis research helped in shedding some light on the keys to victory (performance indications). In this sense, George & Panagiotis (2008) indicated that error in attack with an important technical-tactical performance indicator. Using the others performance indicators, efficiency, and coefficient of performance [i.e., more complete indicators that allow analysing the relationship between positive and less effective actions (Coleman, 2002; Marcelino et al., 2010)], serve, serve reception, set, and attack were reported by Palao and Ortega (2015) as crucial to set victory. In same hand, Medeiros et al. (2017) found that the attack had a significant impact on distinguishing the winner in the U-19, U-21, and senior categories.

Briefly, most game actions of beach volleyball are classified as "open skills" (Chiu et al., 2017; Gallahue, 2002). In other words, the performance requires a quick perception of relevant stimuli, decision-making skills, and good movement execution to solve technical-tactical problems. For instance, athletes often use spike and shot techniques to hit the ball in attack actions (Medeiros et al., 2014). This variation is essential to confuse the opponent and succeed in scoring the point. However, perceptual-cognitive skills are fundamental to identifying the opponent's positioning, deciding, and executing the best action (Afonso et al., 2012; Hülsdünker et al., 2016). In summary, Beach volleyball players require strong perceptual-cognitive skills, which can be negatively impacted by cognitive impairments like mental fatigue.

In this sense, mental fatigue can be caused by tasks with high or long cognitive demand (Boksem & Tops, 2008; Lopes et al., 2023), and athletes associate it with “a difficulty in maintaining concentration”, “reduced motivation”, and “difficulty in reacting to mistakes” as reported by Thompson et al., (2020). Research typically employs cognitive tasks to induce mental fatigue, such as the Stroop Task or AX-CPT (Costa et al., 2022). Smith et al., (2018) suggested that performing these tasks leads to an increase in the concentration of adenosine in the anterior cingulate cortex, which impairs executive functions. Since executive functions are crucial for proper perceptual-cognitive skills, sports performance is negatively affected.

Previous studies show detrimental effects of mental fatigue on perceptual-cognitive skills. For example, badminton players were slower in a visuomotor task (Van Cutsem et al., 2019), soccer players reduced the visual field and decision quality (Gantois et al., 2020; Kunrath et al., 2020), table tennis and soccer players' accuracy were impaired in specific tests for the respective sports (Le Mansec et al., 2018; Smith et al., 2015, 2016), and tactical behavior was affected (Coutinho et al., 2017). Moreover, regarding the technical-tactical performance, some authors investigated using small-sided games. Moreira et al. (2018) and Badin et al., (2016) showed a negative effect on basketball and soccer athletes, respectively.

Although there are literary body suggesting a potential link between mental fatigue and decreased performance, it’s important to consider the unique characteristics of beach volleyball. For instance, teams are format only two players, there are no substitutions, and ball retention is not permitted. Rationally, it is possible that mental fatigue impairs the technical-tactical performance of beach volleyball players as on other sports, but this is not yet clear. Furthermore, research following official rules is scarce in the literature. Therefore, the aim of this study was to investigate the effect of mental fatigue on the technical-tactical performance of beach volleyball players. Based on previous research, it was hypothesized that mental fatigue would negatively affect attack technical-tactical performance during a simulated match with official rules. In addition, the data from this study will be important practical application for coaches and beach volleyball players to decide the best strategies and behaviors before an official match.

METHODS

Experimental design

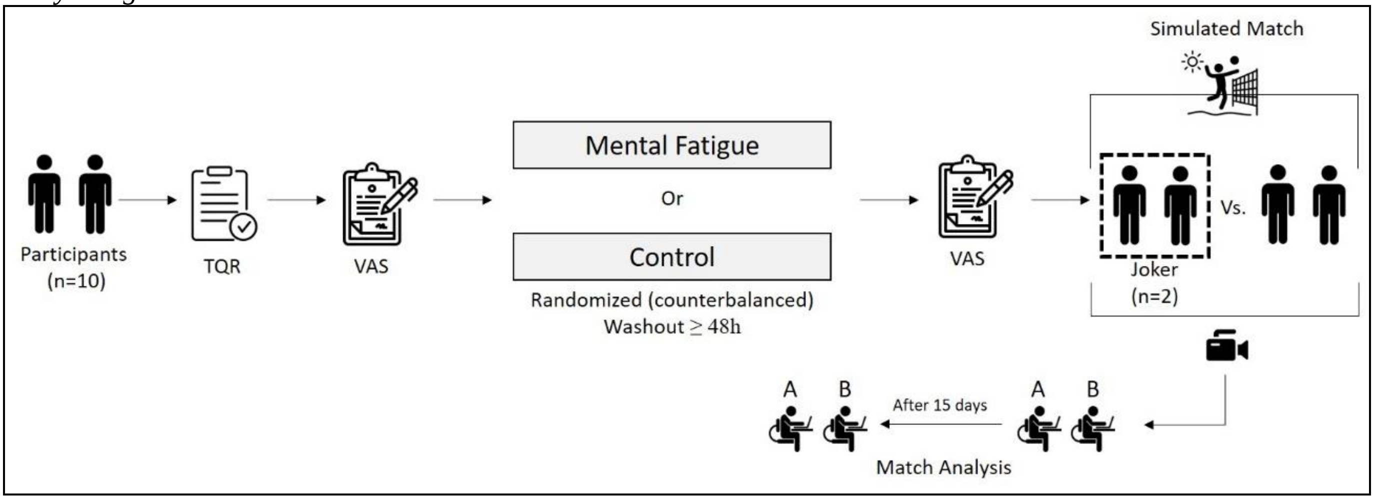
This study is characterized as experimental with an acute effect, randomized, and crossover design (Ato et al., 2013). The procedures were approved by the local ethics committee under protocol (CAAE: 85367818.4.0000.5188) write in accordance with the Declaration of Helsinki (World Medical Association, 2013). Initially, the “joker team” was drawn (i.e., opposing team of all other teams participating in the research). These athletes did not participate in the control and mental fatigue conditions (n= 2). The benefit of this approach is that the athletes who participated in the experimental conditions (n= 10) faced the same level of technical-tactical challenge. The experimental design adopted is crossover and randomized within-subject counterbalanced (Figure 1).

In two laboratory visits, the participants were recommended to sleep 8-h, not consume any stimulant substance (e.g., caffeine, soda), and/or perform cognitively demanding tasks 4-h before collections. A checklist was used to check if the athletes followed this recommendation. Moreover, to ensure that participants were in a similar state of readiness, the creatine kinase and lactate dehydrogenase was cheeked one day before of collection day, adopting reference values of 50 - 180 U/l and 100 - 190 U/l, respectively. In addition, immediately prior to starting the collection procedures, players' recovery was verified through the Total Quality Recovery Scale (TQR), so it was necessary to report TQR $\geq$ 16 to continue research procedures.

The teams performed two matches following the official rules of the International Volleyball Federation after control or experimental treatment. A referee with experience in national competitions was responsible for controlling the match, and three balls (i.e., Mikasa VLS300) were used. Then the athletes warmed up for 10 minutes with ball and started the match. The match ended after two sets, regardless of a set score draw, the benefit of this approach is that external load was equalized. Moreover, all matches were recorded. In addition, a manipulation check was performed before and after each experimental condition (i.e., control and mental fatigue) using the visual analog scale [VAS - (Smith et al., 2019)]. The washout between conditions lasted at least 48 hours to ensure that athletes had the same physical conditions between days.

Figure 1

Study design.



Note: TQR = Total Quality Recovery Scale; VAS = visual analogic scale.

Participants

The sample size calculation was previously performed using the G*power software (Faul et al., 2007), to power 0.80, $\alpha = 0.05$, and effect size 1.00 (Fortes et al., 2020). Thus, twelve young brazillian beach volleyball players (Males; Age: 16.1 ± 0.9 years; Body Mass: 74.5 ± 8.8 kg; Height: 183.1 ± 2.8 cm; Body fat: 12.6 ± 4.5 kg; Muscle mass: 41.4 ± 15. 9 kg) were recruited by convenience in two beach volleyball training centers. In addition, the height was measured using a stadiometer (W200A, Welmy, Brazil), and body weight, fat mass and body mass measurements were obtained using bioimpedance scale (InBody 720 MF-BIA, South Korea). The players had 2.7 ± 0.6 of experience in the Beach Volleyball National Tour, and training and performance caliber was "Trained/Developmental" (McKay et al., 2022).

All athletes were volunteers and provide written consent. Moreover, their legal guardians provided written consent too. This research was approved by the Ethics Committee in Research with Human Beings, following the guidelines of the Declaration of Helsinki. The inclusion criteria adopted were a) to have competed on the national circuit in the last 12 months; b) do not use psychoactive substances; and c) do not have any visual impairment that may affect data collection. The exclusion criteria adopted were a) injured during the beach volleyball matches; and b) participants who withdrew from the study. It was not necessary to apply the exclusion criteria.

Materials/Instruments

Variables measurements

Technical-tactical performance indicators

The matches were recorded using a camcorder (Sony DSC-SX21. Manaus, Brazil, 2011) positioned at the back of the court. The notational analysis was performed by two researchers with large experience in beach volleyball. The inter- and intra-operator reliability were tested by Kappa Coefficient. Thus, the "A" and "B" operator analyzed all video recorded, and after 15 days, the same processes were preformatted (see Figure 1). All notations were performed using Lince 1.3 software, and at least k= 0.80 (Interpretation of Kappa = strong) was observed for all variables inter- and intra-operator inter- and intra-operator (McHugh, 2012).

The game actions were classified according to effectiveness. Serve, attack, and block actions were classified using criteria a) 0 – errors, b) 1 - maximum attack options for the opponent, c) 2 - limited attack options for the opponent, c) 3 - no attack options for the opponent, and d) 4 - point. Serve reception, set, and dig actions were classified as a) 0 - error; 1 - no attack options, 2 - limited attack options, and c) maximum attack options (see more details Palao et al., 2015). The coefficient of performance (sum of all actions per category multiplied by the value of the category and divided by the total attempts) and efficiency [E= (points or perfect actions – errors) / (total actions) *100] was used as technical-tactical performance indicators (Coleman, 2002). This way is adopted because these indicators report a global vision of performance in the match and are keys to victory in beach volleyball (Marcelino et al., 2010; Medeiros et al., 2017).

Procedures

Randomization

An order of conditions (mental fatigue and control) was generated using the Random.org Platform (https://www.random.org/lists/). Then, according to the order of conditions generated on the platform, the block of participants (2 players - 1 team) was assigned. In addition, counterbalancing was applied so that if team 1 started with the mental fatigue condition, team 2 would start with the control condition.

Treatments

In rooms with controlled temperature (23 °C), the participants performed the research conditions. In the control condition (CC), participants remained seated without performing any cognitive activity for 30 minutes (Pires et al., 2018). In experimental condition, mental fatigue was induced using computerized Stroop Task. The participants were instructed to ignore the word and provide verbal respond only to its color in this task. Four colors were used (yellow, red, green, and red), and all stimuli were incongruent with a time of 1000ms, followed by a white screen of 1000ms, totaling 900 attempts in 30 minutes (Badin et al., 2016). Two researchers individually checked the answers and provided feedback when the participant responded to them wrong.

Manipulation Check

The visual analogic scale (VAS) measures subjective mental fatigue (Smith et al., 2019). Therefore, the participants were instructed to indicate the level of mental fatigue by marking a point on a 10_{cm} line anchored in 0 (no mental fatigue at all) and 10 (maximal mental fatigue). The distance in millimeters from the beginning of the line to the athlete's marking was considered the level of mental fatigue. Moreover, the mental fatigue level was interpreted as mild fatigue ($0 – 40_{mm}$), moderate fatigue ($50 – 70_{mm}$), and high fatigue ($8 – 10_{mm}$), adapted from Abbasi et al. (2018). A metacognition process was adopted (Thompson et al., 2019), giving examples of activities experienced by athletes that cause mental fatigue (e.g., studying) and symptoms (e.g., lethargy).

Statistical analysis

The data showed normal distribution and homogeneity tested by Shapiro-Wil and Levene, respectively. Thus, all data are presented as mean and standard deviation (±). The manipulation check is compared using Anova two-way repeated measurement (time: pre and post; condition: control and mental fatigue). Moreover, the Bonferroni post hoc was used when there was a significant difference. Paired t-tests were performed to compare technical-tactical performance indicators. Furthermore, Cohen's "d" (Cohen, 1988) was calculated as effect size, and Hopkins magnitudes is adopted (Hopkins et al., 2009): <0.2 (trivial); 0.2 to 0.6 (small effect); >0.6 to 1.2 (moderate effect); >1.2 to 2.0 (large effect); >2.0 (very large effect). The IBM SPSS Statistics (Version 20.0 for Windows, Armonk, NY: IBM Corp.) was used for all statistical analyses, and the level of significance was 5% ($p < .05$).

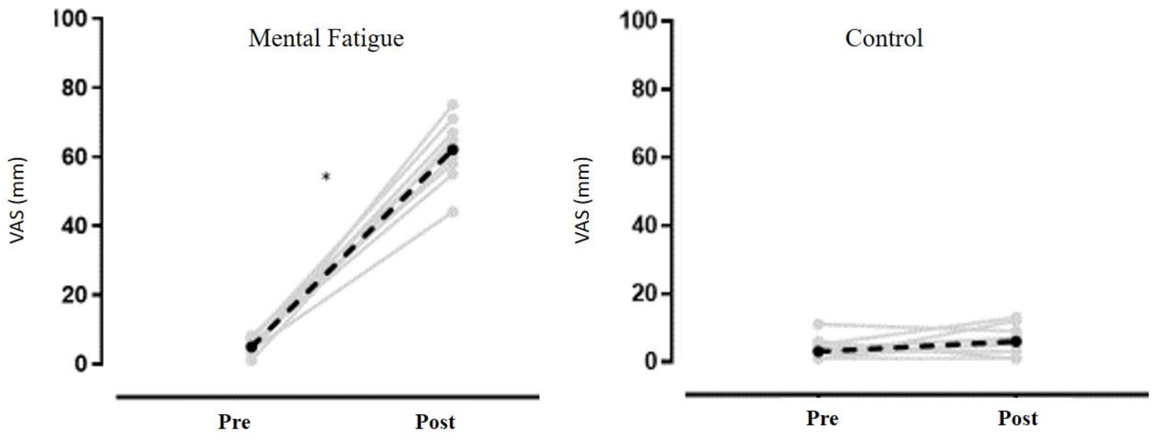
RESULTS

Manipulation Check

The Figure 2 reports individual subjective mental fatigue level. There was a significant conditions x time interactions ($F(1,9) = 313.322$; $p = .001$). After the Stroop task, the perception of mental fatigue was greater than the control condition [Stroop Task: 62.5 mm ± 8.8 Vs. Control: 6.4mm ± 4.1; $p = .0001$; ES: 0.9 (moderate effect)].

Figure 2

Comparison of the perception of mental fatigue pre/post treatment.



Note: Gray lines represent individual responses; Dotted black lines represent the mean. *$p \leq .05$

Technical-tactical performance indicators

The attack coefficient of performance and efficiency revealed a significant difference between conditions [p = .001, ES: 2.5 (very large); p = .004, ES: 1.4 (very large), respectively]. Thus, the performance in the attack was better in the control condition than in mental fatigue (Table 1).

Table 1

Mean and standard deviation (±) of the Technical-tactical performance in control and mental fatigue conditions (n= 10).

	MF	Control	*t*	*p*	EF
CP					
Serve	1.3 ± 0.2	1.3 ± 0.2	-0.72	0.47	0.0 (trivial)
Serve reception	2.0 ± 0.3	2.1 ± 0.2	-0.33	0.74	0.3 (small)
Set	2.2 ± 0.2	2.2 ± 0.2	-0.02	0.97	0.0 (trivial)
Attack	1.5 ± 0.4	2.3 ± 0.2	-4.82	0.001*	2.5 (very large)
Block	0.8 ± 0.9	0.9 ± 1.2	-0.21	0.83	0.0 (trivial)
Dig	2.0 ± 0.2	2.0 ± 0.2	-0.56	0.57	0.0 (trivial)
Efficiency					
Serve	2.9 ± 3.5	4.5 ± 4.9	-0.79	0.43	0.3 (small)
Serve reception	34.3 ± 15.1	33.8 ± 11.5	0.08	0.93	0.0 (trivial)
Set	37.2 ± 12.9	42.1 ± 13.2	-0.84	0.41	0.3 (small)
Attack	23.7 ± 7.0	36.0 ± 9.5	-3.28	0.004*	1.4 (large)
Block	12.6 ± 19.3	12.7 ± 17.8	-0.00	0.93	0.0 (trivial)
Dig	38.5 ± 9.6	39.5 ± 10.5	-0.22	0.82	0.0 (trivial)

Note: MF = mental fatigue condition; CP = coefficient of performance; EF= effect size.

DISCUSSION

The aim of this study was to investigate the effect of mental fatigue on the technical-tactical performance of beach volleyball players. The beach volleyball players reported a moderate level of mental fatigue after 30 minutes of Stroop task. Furthermore, mental fatigue impaired the technical-tactical performance of the attack. These results were consistent with initial hypotheses. To the best of our knowledge, this is the first study to investigate this variable in beach

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volleyball. Therefore, research with other similar sports is used to discuss the data.

In beach volleyball, attack performance is the key to winning the set (Medeiros et al., 2017; Palao et al., 2018). Our data revealed that the performance of moderately mentally fatigued athletes was ~50% lower compared to control. Regarding studies where participants performed open skill tasks (i.e., small-sided game), mental fatigue also showed negative effects on performance. For example, the number of turnovers increased when basketball players were mentally fatigued (Moreira et al., 2018), and soccer players presented worse performance executing defensive actions, passing, and controlling the ball (Badin et al., 2016). Then, our study shows that mental fatigue impairs the considered key to winning (i.e., attack) with a large effect size, which means cognitive load should be monitored to avoid reduced performance in beach volleyball players.

The possible explanation for this reduction in performance involves a series of perceptual-cognitive skill impairments. In this sense, mental fatigue reduces the peripheral field of vision of soccer athletes (Kunrath et al., 2020), decision-making skills during soccer matches (Fortes et al., 2020; Gantois et al., 2020), and accuracy of table tennis athletes (Le Mansec et al., 2018). Therefore, it is likely that beach volleyball athletes, when mentally fatigued, competed with a considerable deterioration in perceptual functions, decision-making skills, and accuracy of motor actions (i.e., motor programming). Furthermore, opponents were not mentally fatigued, and it is not common for this sport to develop high endurance ability, leaving athletes more susceptible to mental fatigue (Martin et al., 2016).

The mechanism that attempts to explain the effect of mental fatigue on perceptual-cognitive skills and hence on technical-tactical performance suggests an increase in adenosine (i.e., inhibitory neurotransmitter) and a reduction in dopamine (i.e., excitatory neurotransmitter) in the anterior cingulate cortex (Smith et al., 2018) because this region is associated attention, inhibition control, and conflict resolution (Ruff et al., 2001). Moreover, some studies also showed changes in visual behavior (Fortes et al., 2022; Kunrath et al., 2020) and worse performance in motor skills (Filipas et al., 2021; Rozand et al., 2015; Smith et al., 2016). Perhaps the visual cortex, premotor cortex and supplementary motor cortex are potentially affected, considering the importance of transforming visual stimuli into motor responses (Hülsdünker et al., 2018). In summary, changes in cognitive function and visual behavior may be responsible for the poorer performance in the mental fatigue state of beach volleyball athletes.

The practical application suggests that athletes should avoid cognitively demanding activities before matches and training sessions. In addition, sports psychologists and the technical staff (e.g., coach) must provide this advice (Costa et al., 2024). Some limitations are important to consider. First, it is almost impossible for athletes to do the Stroop task before official competitions, although this approach helps to subject the participants to the same cognitive load. Therefore, in future studies, more ecological activities should be investigated [e.g., using social networks, (more details in Fortes et al., 2020). Second, the manipulation check was done only by a subjective means, and perhaps mental fatigue was overestimated (Thompson et al., 2019). However, we tried to improve the metacognitive capacity of the participants to minimize this limitation. Finally, only male athletes were included in the sample, and we focus on technical-tactical performance indicators. Therefore, future research should consider more ecological tasks, use more objective manipulation check (e.g., neurophysiological and behavioral), and include female players. Moreover, other variables important to the performance of beach volleyball athletes can also be investigated (i.e., serve speed and accuracy, attack zones, etc.).

CONCLUSION

In conclusion, moderate levels of mental fatigue impair the attack technical-tactical performance of beach volleyball players. Therefore, it is recommended that activities with high cognitive demand should be avoided before official matches and training sessions.

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