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Las Tareas Matemáticas Inducen Fatiga Mental, Pero Tienen un Pequeño Efecto en una Habilidad Específica del Voleibol: Un Estudio Cruzado Aleatorizado con Jóvenes Jugadoras

Mathematics Induces Mental Fatigue but Has Small Effect on Specific Volleyball Skills: a Randomized Crossover Study in Young Female Players

Tarefas Matemáticas Induzem Fadiga Mental, Mas Têm Pequeno Efeito em uma Habilidade Específica do Voleibol: Um Estudo Cruzado Randomizado com Jovens Jogadoras

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RESUMEN

La fatiga mental se caracteriza por una sensación de cansancio después de realizar tareas cognitivas. Estudios anteriores han demostrado que las pruebas cognitivas prolongadas, el uso de redes sociales y los videojuegos pueden afectar el rendimiento deportivo. Sin embargo, el impacto de las tareas matemáticas en la percepción de la fatiga mental en jóvenes atletas, así como sus efectos en el rendimiento, sigue sin estar claro. Por lo tanto, los objetivos de este estudio fueron investigar si las tareas matemáticas provocan fatiga mental y afectan el rendimiento en una habilidad específica de voleibol en jóvenes jugadoras. Se utilizó un diseño experimental cruzado y aleatorizado. Las participantes fueron quince jóvenes jugadoras de voleibol que realizaron una habilidad específica de voleibol en dos condiciones experimentales (matemáticas y control) separadas por un período de lavado de 3 a 7 días. En este sentido, se midió el nivel de fatiga mental (antes y después) de la intervención y el rendimiento en la habilidad específica de voleibol (entre días). Se observó una diferencia estadística en el nivel de fatiga mental solo antes y después de la condición matemática. Además, aunque no se observó una diferencia estadística entre las condiciones en el rendimiento de la habilidad específica de voleibol, solo en la condición de control el promedio de tiempo para completar la tarea estuvo por debajo del umbral de "cambio ciertamente significativo". En conclusión, 30 minutos de una tarea matemática aumentan los niveles de fatiga mental en jóvenes jugadoras de voleibol. Además, parece haber una reducción en la habilidad específica de voleibol, aunque esto requiere una confirmación adicional. Número de Registro del Ensayo: Registro Brasileño de Ensayos Clínicos (RBR-8w7d8np). Registrado el 02 de enero de 2025 (registrado retrospectivamente).

Palabras clave: fatiga cognitiva; atletas de base; atletas escolares; carga académica.

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ABSTRACT

Mental fatigue is characterized by a sense of tiredness following cognitive tasks. Previous studies have shown prolonged cognitive testing, social media use, and video gaming can impair sports performance. However, the impact of mathematical tasks on the perception of mental fatigue in young athletes, as well as their effects on performance, remains unclear. Therefore, this study aimed to investigate whether mathematical tasks cause mental fatigue and affect the performance in a specific volleyball skill of young female players. A crossover and randomized experimental design was employed. The participants were fifteen young female volleyball players who performed a specific volleyball skill in two experimental conditions (mathematics and control) separated by 3 – 7 days of washout. In this sense, mental fatigue level (pre and post) intervention and the performance on specific volleyball skills (between days) were measured. A statistical difference was observed in mental fatigue level only pre-post the mathematics condition. Moreover, although no statistical difference was observed between the conditions in specific volleyball skill performance, only in the control condition was the time average for completing the task below the "certainly meaningful change" threshold. In conclusion, 30 minutes of a mathematical task increases the levels of mental fatigue in young female volleyball players. Furthermore, there seems to be a reduction in volleyball-specific skills, although this requires further confirmation. Trial Registration Number: Brazilian Clinical Trial Register (RBR-8w7d8np). Registered 02 January 2025 (Retrospectively registered).

Keywords: cognitive fatigue; cognitive effort; grassroots athletes; school athletes; academic load.

RESUMO

A fadiga mental é caracterizada por uma sensação de cansaço após a realização de tarefas cognitivas. Estudos anteriores mostraram que testes cognitivos prolongados, o uso de redes sociais e os videogames podem prejudicar o desempenho esportivo. No entanto, o impacto das tarefas matemáticas na percepção da fadiga mental em jovens atletas, bem como seus efeitos no desempenho, ainda não estão claro. Portanto, os objetivos deste estudo foram investigar se tarefas matemáticas causam fadiga mental e afetam o desempenho em uma habilidade específica do voleibol em jovens jogadoras. Foi utilizado um desenho experimental cruzado e randomizado. As participantes foram quinze jovens jogadoras de voleibol que realizaram uma habilidade específica de voleibol em duas condições experimentais (matemática e controle) separadas por um período de washout de 3 a 7 dias. Nesse sentido, o nível de fadiga mental (antes e depois) da intervenção e o desempenho na habilidade específica do voleibol (entre os dias) foram medidos. Foi observada uma diferença significativa no nível de fadiga mental apenas antes e depois da condição “matemática”. Além disso, embora não tenha sido observada diferença estatística entre as condições no desempenho da habilidade específica do voleibol, apenas na condição de controle a média de tempo para completar a tarefa ficou abaixo do limiar de “mudança certamente significativa”. Em conclusão, 30 minutos de uma tarefa matemática aumentam os níveis de fadiga mental em jovens jogadoras de voleibol. Além disso, parece haver uma redução na habilidade específica do voleibol, embora isso exija uma confirmação adicional. Número de Registro do Ensaio: Registro Brasileiro de Ensaios Clínicos (RBR-8w7d8np). Registrado em 02 de janeiro de 2025 (registrado retrospectivamente).

Palavras chave: fadiga cognitiva; atletas de base; atletas escolares; carga acadêmica.

INTRODUCTION

Volleyball is a net sport played by two teams of six players each. The main objective of the game is to make the ball contact the opponent's court or prevent the opposing team from successfully returning it (Costa et al., 2017). To achieve this, players utilize six fundamental skills: serving, serve reception, setting, attacking, blocking, and digging (Palao et al., 2015). In particular, during serve reception and dig actions, players often use the forearm technique (bump) to control the ball and pass it to another player (Costa et al., 2018; Palao et al., 2009), as it is not allowed to retain the ball. Given this, executive functions, visual perceptual processing, and accurate motor responses (Castro et al., 2019; Hülsdünker et al., 2018; Montuori et al., 2019; Trecroci et al., 2021) were skills crucial to volleyball performance. Thus, brain areas such as the visual cortex, prefrontal cortex, anterior cingulate cortex, and pre- and supplementary motor cortex need to be fully functional. In this context, an impairment caused by mental fatigue in any of the aforementioned areas can have a detrimental impact on athletic performance.

Mental fatigue refers to a perception of tiredness or lack of energy, associated with a reduction in cognitive performance caused by a cognitive load (Lopes et al., 2023). In short, the magnitude of cognitive load is given by the relationship between complexity and duration of activity (Lopes et al., 2023). In other words, a cognitive activity that is simple but has a long duration can cause a similar mental fatigue level when compared to a complex cognitive task for a short time. In recent years, studies have shown that mental fatigue appears to impair sports performance. For instance, the passing and shooting skills of soccer players (Filipas et al., 2021; Smith et al., 2016), forehand stroke skills (speed and accuracy) of table tennis players (Le Mansec et al., 2018), and attacking technical-tactical performance in beach volleyball (Domingos-Gomes et al., 2024) were affected by mental fatigue.

In this sense, Smith et al. (2018) suggest that when performing cognitive activities, there is an increase in adenosine levels, mainly in the anterior cingulate cortex. This neuromodulator competes with dopamine (i.e., excitatory neurotransmitter) and impairs executive functions (Smith et al., 2018). Moreover, mental fatigue can affect visual behavior (Fortes et al., 2022a; Fortes et al., 2022b) and field (Kunrath et al., 2020), which indicates that the visual brain areas are also negatively affected. Concerning the cognitive activities studied in this field, in general, no-ecological activities are used to induce mental fatigue [e.g., Stroop task (Costa et al., 2022)]. On another hand, ecological cognitive activities (i.e., activities that are reproduced in a real context) were also investigated, such as the use of social media and video games (Fortes et al., 2019; Fortes et al., 2020). However, the effect of academic activities (e.g., school lessons) on levels of mental fatigue is unclear.

In this context, it is not uncommon for young athletes to also have to balance academic activities at school with sports. Among the mandatory subjects, mathematics stands out as a discipline that, in addition to its demands, serves as the foundation for other subjects, such as physics and chemistry. Moreover, the cognitive workload is usually high in math lessons. For example, Yu et al. (2009) reported that typical mathematical operations, such as arithmetic calculations (e.g., 2 + 2), enhance sympathetic activity, suggesting greater cognitive effort. Furthermore, the brain areas involved in mathematical calculations are associated with the frontal and visual cortices, as well as the anterior cingulate cortex (Arsalidou et al., 2018), brain regions that are crucial for sports performance.

In summary, as young athletes usually train after school or do academic homework, it is possible that the cognitive load induced by mathematics tasks increases mental fatigue levels and therefore impairs sports performance. Previously, Filipas et al. (2018) found no effect of math-related activities on young prepubescent rowers. However, athletes involved in endurance sports seem to be more resistant to mental fatigue (Martin et al., 2016). Therefore, these results may not be replicated in athletes involved in sports with an emphasis on perceptual-cognitive skills as volleyball. Thus, this study aimed to investigate whether mathematical tasks cause mental fatigue and affect the performance in a specific volleyball skill of young female players. The hypothesis was that simple mathematical operations would increase the level of mental fatigue and consequently impair performance in a specific volleyball task using the forearm technique. The results of this research will be useful for coaches to understand the effect of mathematics on mental fatigue levels and better organize training sessions and competitions.

MATERIAL AND METHODS

The present study follows the CONSORT statement to randomized crossover trials (Dwan et al., 2019) to provide a detailed account of the methods employed. In addition, this study has been registered in the "Brazilian Registry of Clinical Trials (ReBEC)" and can be accessed: https://ensaiosclinicos.gov.br/rg/RBR-8w7d8np.

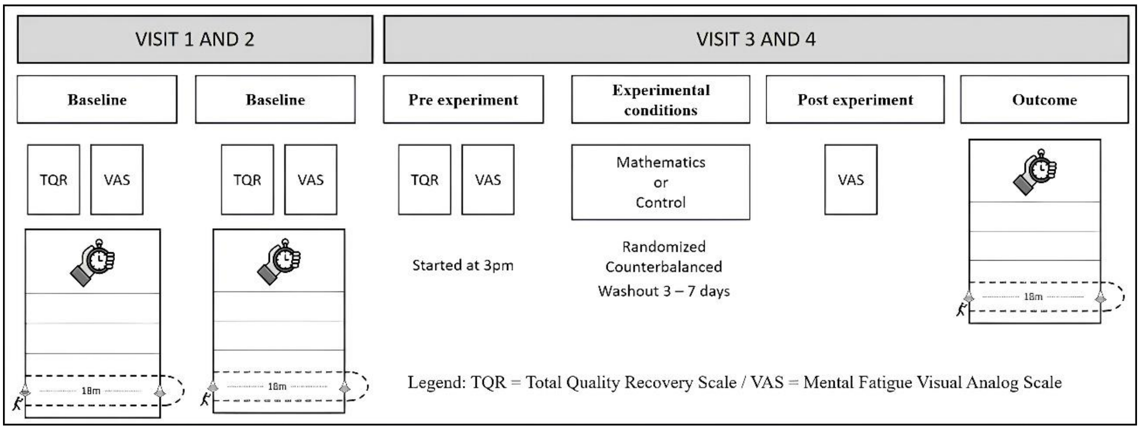
Design

The current study employed an experimental design with crossover and randomized methods, conducted over four visits, to investigate the acute mental fatigue effect. Figure 1 summarizes the study protocol. At each visit, participants were instructed to sleep for a minimum of eight hours, avoid consuming stimulant nutrients (e.g., coffee, soft drinks, energy drinks, etc.), and refrain from engaging in demanding cognitive tasks (e.g., study, social media, etc.) for a minimum two hours before the collection procedures. If a participant failed to adhere to the recommendations, a new visit was scheduled.

The visit 1 and 2 were used for familiarization with the Total Quality Recovery Scale (TQR) and Mental Fatigue Visual Analog Scale (VAS). In addition, the participants were introduced to the definition of mental fatigue and were requested to recall mentally fatiguing activities. Then, the Volleyball Specific Skill - Ball Control Volleyball Task (BCVT) for baseline was performed. During subsequent visits, participants were subjected to two experimental conditions (i.e., mathematics or control). In the pre-experiment, the athlete's quality of recovery and subjective perception of mental fatigue were checked using the TQR and VAS, respectively. After treatment, the subjective perception of mental fatigue was measured again, and immediately after the BCVT was performed. In addition, a washout of 3 – 7 days between experimental conditions was adopted (Franco-Alvarenga et al., 2019).

Figure 1

Study Design.



Participants

Fifteen female young volleyball players [Age^{mean}= 15.8 ±0.53 years; Body mass^{mean}= 65.44 ± 8.7Kg; Height^{mean}= 1.68 ±0.07m; maturity offset^{mean} = 3.0 ±0.47 (using Mirwald et al., 2002's equation)], was recruited by convenience to participate of this study. They were in the final 4 years of school (equivalent to High School - freshman year to senior year), trained volleyball at a club (4 ±0.27 days per week), and had experience with regional and national tournaments. Moreover, the training and performance caliber were classified as "trained/development", respectively, following McKay et al. (2022) criteria.

The inclusion criteria adopted were: a) to be aged between 12 and 17 years old; b) to have been training volleyball for at least 2 years with competition objectives; c) to be training regularly; d) not to have been diagnosed with any neurological problems. The exclusion criterion adopted was a) giving up, or b) getting injured during the research period. This research followed the Helsinki Declaration and standardized ethical principles for sports science (Harriss et al., 2022). Thus, the methods were perversely approved by the local ethics committee for research with human beings (Approval Opinion No. 6.330.636 - Health Sciences Center of the Federal University of Paraíba - CCS/UFPB). All participants were volunteers, written consent was obtained from the subjects, and permission for adolescents to participate was obtained from their legal guardians.

Procedures

Settings and location

Data were collected at two places. The participants were taken to a classroom with a temperature between 20 - 22ºC, where they completed the pre-experiment procedures and experimental conditions were performed. Moreover, an official volleyball court was used. The distance between the classroom and the court was ≤ 50m, all data was collected in October.

Experimental conditions

The participants were exposed to two experimental conditions. In the "mathematical" condition, the participant received a list of 600 mathematics questions generated randomly in Microsoft Excel 2013. The questions involved mathematical operations of sum and multiplication with four-digit numbers ranging from 1 to 9 (E.g., 4 + 5 + 7 + 9 = ? or 5 * 3 * 9 * 1 = ?). All answers were provided using a pencil, with participants sitting in a classroom. In the control condition, a pure control was adopted (Pires et al., 2018). Thus, the participants remained in the room without carrying out an activity with a high cognitive load. In both experimental conditions, a duration of 30 minutes was employed (Gantois et al., 2019). In addition, two researchers supervise to ensure participants' commitment.

Measurement

State of readiness. To ensure that the participants were in the same physical condition across all experimental conditions, the athletes' perception of recovery was assessed. Thus, the athletes were instructed to respond to the question "How do you feel about your recovery?" using a 6-20 points Total Quality Recovery Scale (TQR) anchored between "very-very poor recovery" and "very-very good recovery". This approach was previously validated in the Brazilian context (Osiecki et al., 2015). The higher the score, the better the athlete's recovery.

Manipulation Check. A visual analogic scale (VAS) was used to measure subjective perception of mental fatigue (Filipas et al., 2021). The participants were instructed to mark a point on a 100mm line corresponding to the subjective perception of mental fatigue at the moment. The scale was anchored between "not at all mentally fatigued" and "mentally fatigued". Mental fatigue score was correspondent to distance in millimeters measured with school ruler. In addition, the definition of mental fatigue and examples of mentally fatiguing tasks were provided to the participants to improve metacognition skills as recommended by Thompson et al. (2019).

Quantity and accuracy in the mathematical task. The number of questions the participants were able to answer in 30 minutes and the accuracy [i.e. the number of correct questions as a percentage [accuracy = (correct answers * 100)/total attempts)] were checked. A researcher checked the answers compared to answers provided by Microsoft Excel 2013.

Volleyball Specific Skill - Ball Control Volleyball Task (BCVT). The participants were instructed to cover the 18-meter distance (the distance to go back and forth from one sideline to the other on an official volleyball court – see Figure 1) as quickly as possible while controlling the official ball (Mikasa, V200W) using the forearm technique. If they dropped the ball or crossed the centerline, the participant had to return to the start of the task. Two attempts were performed, and the shorter time was used as a performance indicator. In addition, the reproducibility test-retest showed good reproducibility (ICC = 0.755) and coefficient of variation = 7% (±4.47). Moreover, the time was marked using a hand-held stopwatch (Multideia, MI-1024, China), and the evaluator's objectivity was excellent (ICC = 0.995). In general terms, this task involved the use of the forearm technique that is heavily used in volleyball, short-distance movement, changing direction, and keeping the ball in the air, which are all skills required in the volleyball game.

Sample size

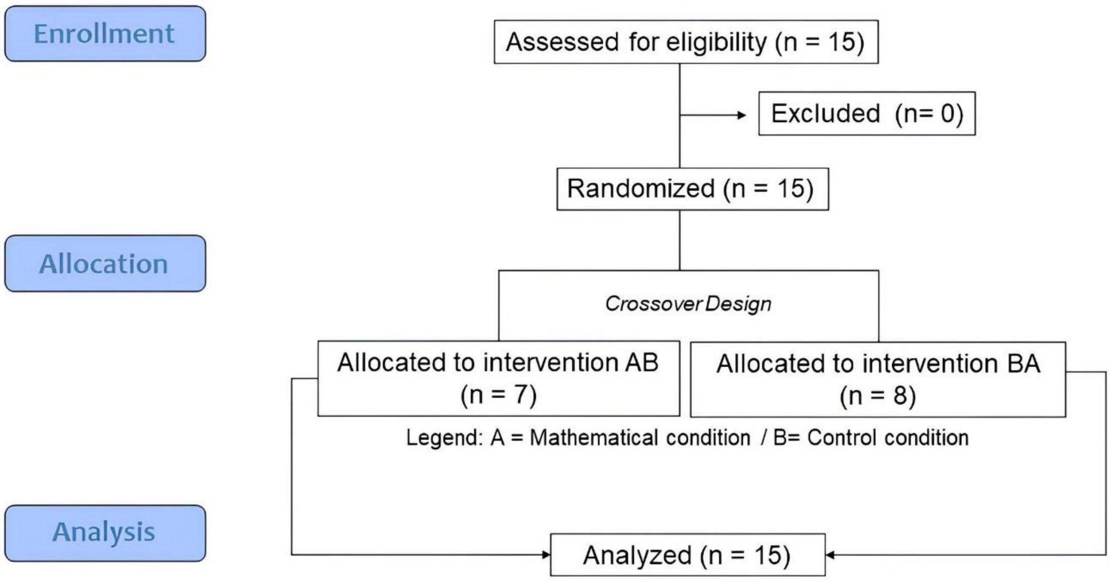
The minimum number of participants required for the dependent Student t-test was eight, according to the sample size calculated a priori with power (1 - ß) = 0.80, alpha (α) = 0.05, and effect size (Cohen's d) = 0.98 (G*Power, version 3.1.9.4), based on a preview study with athletes and mental fatigue induced by ecological activity (Fortes et al., 2019).

Randomization

Figure 2 shows a CONSORT flow diagram with a crossover design. The athletes were allocated to the AB or BA sequence using a simple randomization technique with counterbalancing. Thus, the athletes were assigned by drawing lots using the Random.org platform (https://www.random.org/lists). Counterbalancing was done according to their performance in the volleyball task during the baseline phase, if the athlete with the best performance started with the AB sequence, the athlete with the most similar performance started with the BA sequence.

Figure 2

The CONSORT Flow Diagram for Crossover Design.



Blinding

The researcher who performed the timing measurements during the ball control volleyball task was blind to the participants' experimental condition. Similarly, the data were coded so that the researcher responsible for the statistical analysis could not identify the participants' experimental condition.

Statistical methods

The data was presented in mean and standard deviation because showed a normal distribution and homogeny cheeked by Shapiro-Wilk and Levene tests, respectively. The state of readiness and ball control volleyball task were compared using the Student T test. The subjective perception of mental fatigue was compared using two-way repeated measures ANOVA (time, condition, and interaction). Furthermore, Bonferroni's post hoc test was employed for paired comparisons, eta partial squared utilized as an effect size to ANOVA, and interpreted as small: 0.01; moderate: 0.09; large: 0.25 similar to adopted in previous mental fatigue study (Costa et al., 2024). In paired comparisons, Cohen's d was used as effect size interpreted as recommended by Hopkins et al. (2009): ≤ 0.2 (trivial); ≥ 0.2 – 0.6 (small); ≥ 0.6 – 1.2 (moderate); ≥ 1.2 – 2.0 (large); ≥ 2.0 – 4.0 (very large); ≥ 4.0 (nearly perfect).

Additionally, the performance real change in BCVT was checked using the "smallest worthwhile change" approach (Hopkins, 2004). In this sense, "certainly meaningful change" was considerate when the time measured in experimental conditions was below of 2 * coefficient of variation in accordance to baseline data. The SPSS 20.0 software (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) was used to all statistics procedures with $\alpha = 0.05$ (5%).

RESULTS

State of readiness

The state of readiness verified by the total quality recovery scale was similar between mathematics and control conditions [TQR: mathematics = 15.57 (±1.98) Vs. control = 14.71 (±2,86); p= 0.396; d= 0.350 (small)].

Quantity and accuracy in the mathematical task

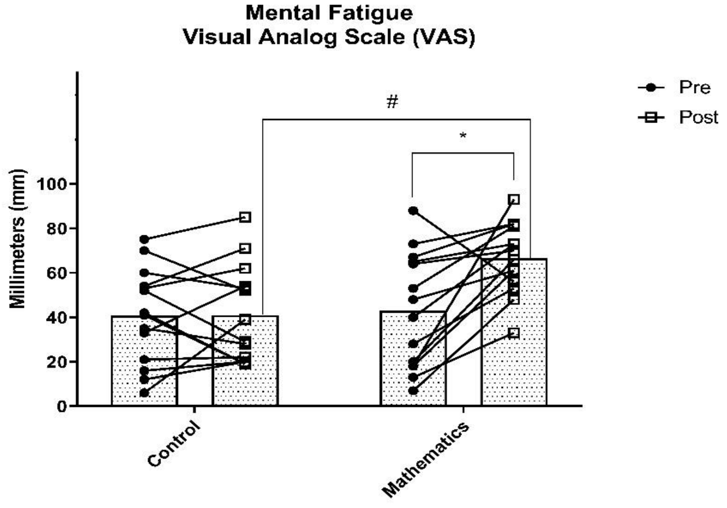
The participants answer 59.64 (± 35.24) questions with an accuracy of 85.71% (± 12.74%).

Manipulation check

The subjective perception of mental fatigue showed an interaction effect [$F_{(1.00\ 13.00)} = 8.769$; p = 0.011; $\eta_p^2 = 0.403$ (large) – Figure 3]. A significant difference was observed pre-post in mathematics condition [43.00 (±25.96) Vs. 66.57 (±15.95); p = 0.004; d = 1.094 (moderate)], but not in control condition [40.71 (±21.45) Vs. 40.93 (±21.91); p = 0.964; d = 0.010 (trivial)]. Moreover, subjective perception of mental fatigue was similar pre-experiment between conditions [pre-experiment: mathematics = 43.00 (±25.96) Vs. Control = 40.71 (±21.45); p = 0.711; d = 0.096 (trivial)], but post-experiment the subjective perception of mental fatigue was higher in the mathematics condition [post-experiment: mathematics = 66.57 (±15.95) Vs. control = 40.93 (±21.91); p = 0.002; d = 1.338 (large)].

Figure 3

Effect of Experimental Conditions on Subjective Perception of Mental Fatigue.



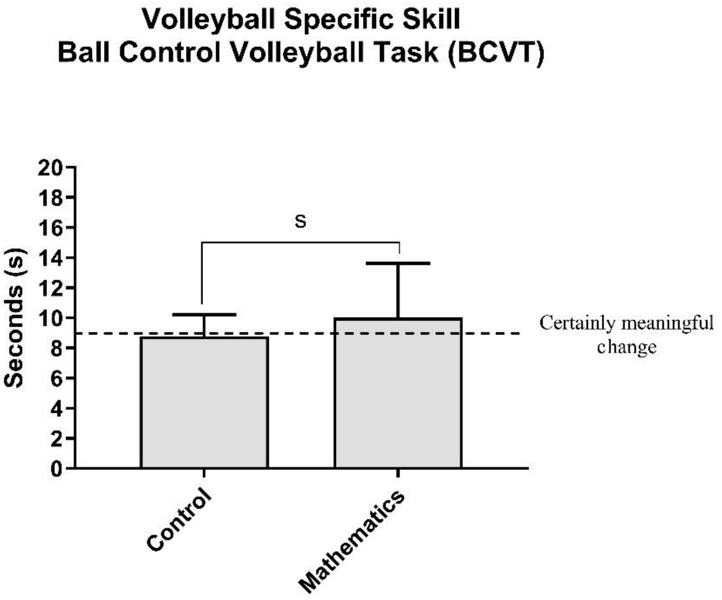
Note. *Significant difference pre-post (p ≤ .05); #Significant difference between conditions (p ≤ .05).

Volleyball Specific Skill - Ball Control Volleyball Task (BCVT)

A significant difference was not observed in the comparison of performance in the ball control volleyball task [BCVT: mathematics = 10.02 (±3.60) Vs. control = 8.78 (±1.42); p= 0.235; d= 0.453 (small); power (1 – ß err prob) = 0.484 – Figure 4]. However, the average time in the control condition was below of "certainly meaningful change" threshold (see Figure 4), and the mean difference between the conditions was 1.24 (±3.73 sec.).

Figure 4

Mean and standard deviation of volleyball-specific skill - ball control volleyball task (BCVT) performance.



Note. Backward line (- - -) = certainly meaningful change threshold; S = small effect size.

DISCUSSION

This study aimed to investigate whether mathematical tasks cause mental fatigue and affect the performance of a specific volleyball skill of young female players. The participants seemed to be in the same state of readiness, avoiding confusion when interpreting the subsequent data. Thus, 30 minutes of mathematics task increased subjective perception of mental fatigue in accordance with initial hypotheses. Moreover, although there was no significant difference between the conditions, the average time in the control condition was below the "certainly meaningful change" threshold only in the control condition, suggesting that performance was better in this condition than in the mathematics condition. This seems to confirm the hypothesis, even though the effect of mental fatigue is minimal.

The solving of simple mathematics promoted an increase of ~54.81% (pre= 43.00; post= 66.57) in the subjective perception of mental fatigue. In absolute terms, these results were similar to those observed with amateur soccer players after performing 30 minutes of Stroop Tasks [VAS = 64.0 (Kunrath et al., 2020)] and young soccer players [VAS: U14 ~ 62; U16 ~ 67; U18 ~ 74 (Filipas et al., 2021)]. In another direction, no difference was found in fatigue and vigor measured by Brums after Stroop and Arithmetic test with young row athletes (Filipas et al., 2018). The discrepancy can be explained by three main reasons. Firstly, the rowers were pre-pubertal, which can differentiate brain activation compared to post-pubertal (Adleman et al., 2002), the participants in our research had already reached their peak height velocity approximately 2 – 3 years prior (maturity offset = 3.0 ±0.47), which suggests that they were in the postpubertal stage; Secondly, it is likely that rowers have better endurance abilities, giving them better resistance to mental fatigue (Martin et al., 2016); Thirdly, specifically in the Arithmetic test, it is possible that participants did not engage sufficiently since the accuracy was 46.35%, in our study the accuracy was 85.71%. Furthermore, the ability of the Brums to measure mental fatigue is questionable because the instrument is designed to assess other constructs [i.e., training load (Rohlfs et al., 2008)].

In terms of neural aspects, performing addition and multiplication operations improves cognitive effort (Davis et al., 2005). In this sense, maintaining these tasks for at least 30 minutes may promote an increase in adenosine due to the impossibility of fast resynthesizing ATP, as a result, executive functions are attenuated and consequently sports performance (Smith et al., 2018). Moreover, mathematical problem-solving requires self-control to motivate oneself to carry out the task, and this was associated with activation of the anterior cingulate cortex and the insular cortex (Arsalidou et al., 2018). Especially the anterior cingulate cortex is fundamental to executive functions and sports performance (Smith et al., 2018). Furthermore, the right medial frontal gyrus and the left precuneus, which are associated with visual functions, are also activated during math tasks (Arsalidou et al., 2018), which can impair visual processing in the subsequent sports task. In addition, theoretical classes can evoke negative states such as sleepiness and boredom (Kotnik et al., 2024).

As a result of neural changes and psychological states, mental fatigue impaired performance in tests involving specific sports skills. For instance, athletes performed worse in the Loughborough Soccer Passing and Shooting Tests when mentally fatigued (by review Grgic et al., 2022). However, Filipas et al. (2021) showed that mental fatigue impaired passing and shorting performance of U18 players, but not U14 and U16 (although there was a tendency for better performance in the control condition). In the current study, no significant difference was found in the time to complete the ball control volleyball task. This may have occurred because the participants were around 16 years old. According to Filipas et al. (2021), players aged 16 or younger may not be strongly affected by mental fatigue. Furthermore, the volleyball task was performed within a short time frame, making it less susceptible to the effects of mental fatigue (Costa et al., 2022). On the other hand, the number of participants may have influenced the significance of the test since the posteriori power observed was low (current power = 0.484).

A more sensible approach (i.e., the smallest worthwhile change) suggests that mental fatigue affected performance, as the average time in the control condition was below the “certainly meaningful change” threshold. Furthermore, other studies have failed to demonstrate the effect of mental fatigue on short-term tasks. For instance, the countermovement jump of badminton players (Kosack et al., 2020) and repeated Wingate test in trained adults (Duncan et al., 2015) were not impaired by mental fatigue. Moreover, cricketers mentally fatigued performed worse in a speed test (i.e., cricket run-two), however, an average of 5 attempts was used for analysis (Veness et al., 2017). It is reasonable to assume that the discrepancy between the control and experimental conditions would have increased if the volleyball players had made more attempts.

Finally, it is important to note that the participants in this study were classified as “Trained/Developmental” athletes, characterized by a well-established identification with a specific sport, where the primary objective of the training engagement is participation in official competitions (McKay et al., 2022). Therefore, is recommended sports scientists and coaches need to investigate and control factors that are crucial to both acute performance and long-term development. On the other hand, while attending classes immediately before a training session may negatively impact young volleyball players, engaging in sports as physical activity (1–2 hours per week) appears to be beneficial for academic performance (Owen et al., 2022). Thus, the interdependence between these variables requires further investigation.

The practical recommendations based on our data suggest a need to avoid mathematics tasks before a volleyball training session or official match because can increase mental fatigue and impair sports performance. Coaches can try implementing a 2-hour break after a study session. In addition, it is recommended to consider the school load (e.g. exam week) when applying training loads. Completely, it is important to note that certain limitations. Mental fatigue was measured by subjective means. Although this approach is widely used, it is recommended that future studies additionally use behavioral (e.g., response time and accuracy of Stroop task) and/or neurophysiological measurements (e.g., EEG). In addition, the players performed a task with time pressure, and dual-tasking focus is a part of volleyball performance (i.e., use of the forearm technique). However, the cognitive demand during an official match is probably greater, and future studies should investigate the effect of mental fatigue caused by mathematical tasks on match performance, as well as the repeated effect of this exposure on athletic development. In another context, it may also be interesting to investigate the impact of the class subject before the physical education lesson.

CONCLUSION

In conclusion, 30 minutes of mathematical operations involving addition and multiplication increase mental fatigue levels in young female volleyball players. Furthermore, there appears to be a slight reduction in volleyball-specific skills. Coaches working with school-age players should consider implementing rest periods between the end of lessons and the start of training sessions.

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