Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 5), Art 152, pp. 1237 - 1243, May 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Mental fatigue measured in real-world sport settings: A case study of world class beach volleyball players

YAGO PESSOA DA COSTA[1]; LEONARDO FORTES[2]; RICELER SANTOS[3]; ERNESTO SOUZA[4]; LAWRENCE HAYES[5]; ELIZABETH SOARES-SILVA[6]; GILMÁRIO RICARTE BATISTA[7].
[1,2,3,4,6,7]Physical Education Department, Federal University of Paraiba, BRAZIL
[5]Sport and Physical Activity Research Institute, University of the West of Scotland, UNITED KINGDOM

Published online: May 31, 2023
(Accepted for publication May 15, 2023)
DOI:10.7752/jpes.2023.05152

Abstract:
This study aimed to investigate mental fatigue experienced by beach volleyball players during Brazilian Beach Volleyball Tournament. The perception of mental fatigue pre-to-post-match, and perception after a win or loss were compared. A secondary aim was to associate mental fatigue with technical-tactical efforts. Seven senior world class beach volleyball players participated. A total of 30 official matches was analyzed, and seven senior world class beach volleyball players participated. The data were collected throughout national Tournaments Elite Top 8, and a digital platform accessed by the athletes' smartphones was used. A digital visual analogic scale (VAS) anchored 0 – 100 was used to measure subjective mental fatigue and technical-tactical effort. A one way repeated measures ANOVA revealed a difference pre-to-post-match for perceived mental fatigue [$F(1.82\ 29.26)= 6.152$; $p= 0.007$; $\eta\rho2 = 0.278$, large effect; power= 0.833] and cubic trend [$F(1.00\ 16.00) = 19.677$; $p < 0.001$; $\eta\rho2 = 0.552$, large effect; power= 0.986]. Moreover, subjective mental fatigue was higher after losing an official match (Win: 54.14 ±23.24 Vs. Loss: 69.66 ±27.24; $p = 0.064$; ES = 0.639, moderate effect), and linear regression identified a relationship between subjective mental fatigue and technical-tactical effort ($R2 = 0.47$; $p < 0.001$). In conclusion, increased mental fatigue was observed in world class beach volleyball players after official matches, and losing a match seemed to augment this response. Moreover, 47% of variation in subjective mental fatigue after an official match was explained by technical-tactical effort. Therefore, athletes should avoid cognitive activities immediately prior to official matches. It is possible that resistance to mental fatigue is a contributor to success in an official beach volleyball match, but this requires further investigation.
Key Words: **cognitive fatigue, mental load, net sports, sport physiology.**

Introduction

Beach volleyball is an open-skill and ball team sport with unique characteristics. For instance, only two players form a team, and substitutions are not permitted. The main physical characteristic are power output, for vertical jump or sprints over small distances (Cortell-Tormo et al., 2011; Natali et al., 2017; Pérez-Turpin et al., 2009), and aerobic endurance to support ~ 80 rallies per match (Magalhães et al., 2011; Palao et al., 2012). The distance covered is ~570-m during official match-play (Bellinger et al., 2021), and the attack has a decisive importance for determinates the winner of the sets (Medeiros et al., 2017). Brazil has a rich history in the sport and this is evidenced when consulting World Championships and Summer Olympics Games results. In addition, the national championships together with American championships (i.e., Association of Volleyball Professionals - AVP) are the most hotly contested national tournaments. Considering the number of cognitive decisions performed as well as repeated physical tasks during official beach volleyball matches, it could be reasonable to assume that an official beach volleyball match causes mental fatigue.

Previous studies mostly characterized mental fatigue as the subjective feeling of tiredness and/or lethargy caused by high cognitive load (e.g., prolonged cognitive demand with low complexity or short-term cognitive demand with high complexity) with attention, inhibitory control, or monotony demand (Boksem & Tops, 2008; Marcora et al., 2009; Smith et al., 2018). Moreover, the sensation emerges according to the intensity and duration of the stimulus (Borghini et al., 2014; Fortes et al., 2020; Gantois et al., 2020; O'Keeffe et al., 2020). In this sense, beach volleyball matches involve cognitive demand for perception, decision-making, and movement adequate to tactical situations (Afonso et al., 2012). Thus, the harmony of the visuomotor brain systems [e.g., retinal photoreceptors and visual brain areas), motor (e.g., supplementary motor area and primary motor cortex), and frontal (e.g., prefrontal cortex)] are fundamentals for performance (Balser et al., 2014; Hülsdünker et al., 2018). Moreover, players must deal with factors that challenge their concentration (i.e., climate alterations, opponent behavior, and own game actions) and use cognitive skills to control these (Stefanello, 2007). The seminal mental fatigue research has focused on the effect of mental fatigue on subsequent physical performance with laboratory approaches (Marcora et al., 2009). In this respect, mental fatigue prior to sports tasks results in impaired visual perception (Van Cutsem et al., 2019), decision-making

Corresponding Author: YAGO PESSOA DA COSTA, E-mail: yago_pessoa@hotmail.com

(Fortes et al., 2020; Gantois et al., 2020), endurance and technical performance (Smith et al., 2015) of players of sports with perceptual-cognitive emphasis. Moreover, contextual effects on mental fatigue, such as travel and fixture congestion exerts a low to moderate effect on mental fatigue levels (Thompson et al., 2020). Specifically, in beach volleyball, a single study found that mentally fatigued young athletes performed worse at attack performance during simulated matches (Domingos-Gomes, 2019). Therefore, it is not known whether world class athletes experience mental fatigue in real-world beach volleyball settings during official tournaments.

To date, two studies have demonstrated increased mental fatigue after official matches in the real-world padel (Díaz-García et al., 2021) and netball (Russell et al., 2020) settings. However, these sports have limited comparability to beach volleyball characteristics. For example, the event duration and team formation (i.e., number of players) are different in beach volleyball. Moreover, in official tournaments it is common for the teams to play two matches per day, and mental fatigue seems not be dissipated immediately after finalizing a cognitive task (Smith et al., 2019). Additionally, it is unclear whether official match outcome and technical-tactical effort are linked with mental fatigue. Thus, the present study aimed to investigate mental fatigue experienced by world class beach volleyball players during matches in a Brazilian Beach Volleyball Tournament, comparing the subjective mental fatigue pre-to-post-match, and according to the official match outcome (i.e. interaction effect). The secondary aim was to associate mental fatigue with technical-tactical efforts. We hypothesized *a priori* that subjective mental fatigue would increase after official beach volleyball matches. Additionally, subjective mental fatigue would increase after a defeat more than after a win, and more after matches with high technical-tactical difficulty more than matches with low technical-tactical difficulty.

Material & methods

Participants

The data analyses were from 30 official matches, and 69 % of these matches were completed after two sets and had a mean of 81 ± 21 rallies per match. Seven senior beach volleyball players volunteered to participate in this study [Female (n=2): age = 24.50 ± 2.12 years; height = 1.73 ± 0.04 m; Male (n=5): age = 28.20 ± 3.96 years; 1.91 ± 0.06 m]. These athletes were considered World Class characterized by participation in national / international competitions and being in the top 20 in the world rankings (McKay et al., 2022). All participants won at least one World Championship (i.e., U19, U21 or Senior), and one represented the Brazil National Team in the Summer Olympics Games – Tokyo 2020. Players were in a competitive period and did not report any injuries or mental disorders that excluded them from participating. The procedures, risks, and benefits were explained to coaches and players before providing written consent. This study followed the Helsinki Declaration, and the local Research Ethics Committee approved the procedures. One player chose to not participate, which explains our analysis of seven participants, not eight.

Procedures

Two weeks before the first beach volleyball tournament, players were explained the definition of mental fatigue and familiarized with instruments used to measure subjective mental fatigue and technical-tactical effort. Moreover, they practiced the use of the instruments until the competition to familiarize themselves. Researchers provided feedback when necessary. Data were collected during two national Tournaments Elite Top 8 (i.e., the main Brazilian tournament that competed the eighth best team in accordance with national ranking), and the players accessed the virtual platform to provide answers 30 minutes before warm-up and up to 10 minutes after the end of the match, and always used their own smartphone. In addition, coaches reminded the athletes to respond and knew the definition of mental fatigue.

Variables and instruments

The PsyToolkit Platform [https://www.psytoolkit.org/ (Stoet, 2017)] was used to make the questionnaire. Before reporting the mental and technical-tactical effort it was necessary to input name, match number of the day, and moment of the report (before or after the match). Moreover, the date and time were automatically collected and used to organize the match sequence. Match outcome and rally number was retrieved from the official website of Brazilian Volleyball Confederation.

Mental Fatigue

A digital visual analogic scale (VAS) was used to measure subjective mental fatigue as previously adopted (Thompson et al., 2020). The participants answered "How mentally fatigued do you feel now?" through the slider scale anchored 0 (left) – none at all (i.e., mentally rested) and 100 (right) – maximal (i.e., mentally tired). The mark was to slide a digital point over the line. The subjective mental fatigue levels were classified as 0 – 10 (no fatigue), > 10 to 40 (mild fatigue); >40 to 70 (moderate fatigue); > 70 (severe fatigue) as described by Costa et al. (2022).

Technical-tactical effort

Similar to subjective mental fatigue, the technical-tactical effort was measured using a digital VAS adapted by Barrett et al. (2018). Participants were requested to answer "How was your technical-tactical effort during the match?" through the slider scale anchored 0 (left) – minimum (i.e., used the minimal own technical-tactical skills) and 100 (right) – maximal (i.e., used the maximal own technical-tactical skills). The mark was to slide a digital point over the line.

Statistical analysis

The data had a normal distribution and homogeneity verified by Shapiro-Wilk and Levene tests, respectively. Thus, means and standard deviation (SD) were used for data presentation. The one-way analysis of variance (ANOVA) with repeated measurements was used to compare mental fatigue level in four moments (pre- Vs. post-match; first Vs. second match of the day), and Bonferroni post-hocs tested for paired differences. In addition, independent Student t-tests (between-groups) were used to compare mental fatigue level after match in accordance with outcome (i.e., win or lose). In addition, linear regression univariate was performed between mental fatigue and technical-tactical effort.

The effect size was measured using partial eta-square (η_p^2) from the ANOVA, interpreting the magnitude as described by Mesquita et al. (2019): small - 0.01; moderate - 0.09; and large: 0.25. Moreover, Cohen's d measured effect size for pairwise analyses, interpreted as suggest by Hopkins et al., (2009): trivial – < 0.2; small – 0.2 to 0.5; moderate – 0.6 to 1.1; large – 1.2 to 1.9; very large – 2.0 to 3.9. Moreover, linear regression was performed to check the association between mental fatigue and technical-tactical effort All statistics were performed in SPSS (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp), and we set the alpha level as $p < 0.05$ *a priori*.

Results

Perceived mental fatigue data are visualized in Figure 1. A difference between pre and post-match was observed for the perceived mental fatigue VAS [F(1.82 29.26)= 6.152; p= 0.007; ηρ2 = 0.278, large effect; power= 0.833], and a significant cubic trend was evident [F(1.00 16.00) = 19.677; p < 0.001; ηρ2 = 0.552, large effect; power= 0.986]. No difference was observed in relation to mental fatigue according to match outcome at the p < 0.05 level (Win: 54.14 ±23.24 Vs. Loss: 69.66 ±27.24; p = 0.064; ES = 0.639, moderate effect). Moreover, mental fatigue showed a linear relationship with technical-tactical effort [(R2 = 0.47; p < 0.001) visualized in Figure 2].

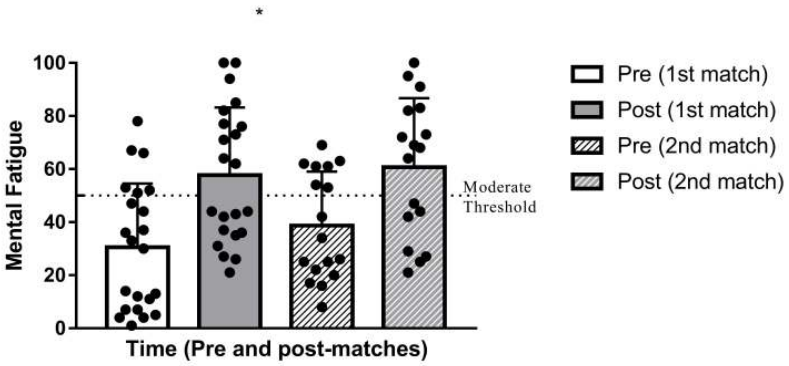

Figure 1. Comparison of mental fatigue feeling pre-to-post match. Note: *Time effect: pre-to-post match p < 0.05

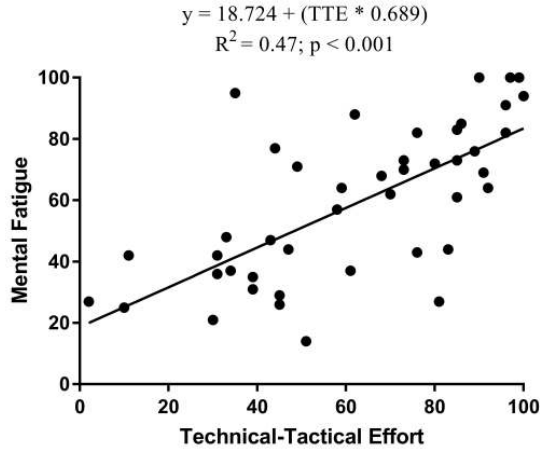

Figure 2. Linear regression univariate between mental fatigue and technical-tactical effort. Note: TTE: technical tactical effort.

Discussion

The present study aimed to investigate subjective mental fatigue experienced by beach volleyball players during the Brazilian Beach Volleyball Tour, before and after the first match of the day, and the second match of the day. We also examined whether subjective mental fatigue associated with technical-tactical efforts. Subjective mental fatigue increased after official matches compared to pre-post-match (mild to moderate fatigue), corroborating our hypothesis. A cubic trend was observed when analyzing two matches on the same day. In other words, this showed that mental fatigue was elevated pre- to post-match and was attenuated in the interval between matches but did not return to initial levels. A moderate effect size of match outcome was observed for mental fatigue VAS, so perhaps losing a match maximized mental fatigue. Moreover, technical-tactical effort explained 47% of mental fatigue variation. Thus, this seems to confirm our second hypothesis. To the best of our knowledge, this is the first study to measure mental fatigue in a real-world sport setting in beach volleyball and relate it to technical-tactical effort.

Mental fatigue is characterized primarily by feelings of fatigue and/or lethargy after performing cognitively demanding tasks (Boksem & Tops, 2008; Marcora et al., 2009). The cognitive requirement in beach volleyball is resultant from the tactical complexity, time pressures, number of actions per match, and the fact that substitutions are not permitted so two players cannot rest within the match time (Costa et al., 2021; Klostermann et al., 2015; Noël et al., 2016). In this sense, specific skills are often "open" (i.e., unpredictable environment that requires motor adaptability) and seem to induce more mental fatigue (Coyne et al., 2021). In comparison to the other cognitive activities, mental fatigue values after beach volleyball in the present study (i.e., ~58) were similar to AX-CPT or Stroop Tasks [i.e., ~54; (Le Mansec et al., 2018; Smith et al., 2015)], and greater than video-gameplay (Fortes et al., 2020). Moreover, the delta perceptual pre – post-match of ~67% seems slightly higher than ~63% observed with netball matches (Russell et al., 2020), but was considerably less than the ~161% reported by soccer players (Thompson et al., 2020). This variation can be explained by the duration of the match and cognitive demands. Netball has a duration of 60 minutes and beach volleyball can reach > 51 minutes in very balanced matches (Palao et al., 2012). Nonetheless, in beach volleyball the tactical construction depends on interaction climate conditions (e.g., wind speed), opponent, and only two players (netball has seven players per team). Moreover, it is commonly that players do not have coaching assistance during beach volleyball. These factors seem to contribute to a high mental load and consequently induce higher levels of mental fatigue in beach volleyball. Despite football having 11 players, the duration of the game is longer (i.e., 90 minutes), and may be more mentally fatiguing.

In general, we demonstrated that a residual amount of mental fatigue was carried between matches on the same day. This corroborates data from padel matches (Díaz-García et al., 2021) but no existence of residual mental fatigue in relation to matches in subsequent days was observed, it is possible that the same happens in beach volleyball. Moreover, these authors also reported an impairment in reaction-time in Psychomotor Vigilance Task [i.e., objective mental fatigue indicator (Smith et al., 2019)], which suggests that subjective and objective tools agree. In relation to match outcome, although no difference was observed between mental fatigue after winning or losing a match, the moderate effect suggests that losing a match increases mental fatigue perception. Similar observations have been reported in soccer players who reported greater mental fatigue the next day after a loss (Abbott et al., 2020). Probably, a meaningful difference existed, but the small sample did not have power to show a difference with an alpha < 0.05. Failure can result in discouraging environments (Sonnabend, 2020), and motivation is an important mental fatigue moderator (Martin et al., 2018). Furthermore, we demonstrated a relationship between mental fatigue and technical-tactical effort, which means that the greater the difficulty in winning the match, the more mentally fatigued the athlete ended the match. Therefore, perhaps the increased levels of mental fatigue in defeat are not only related to the negative environment generated, but the greater technical-tactical challenge of the match.

The practical application of the present investigation is to avoid cognitive activities immediately prior to official matches, and time between matches should be used to recover physically and mentally. Mental fatigue was associated with impairment in decision making and technical-tactical performance by review (Costa et al., 2022), and this can occur precisely at the most decisive points where athletes are most mentally fatigued (e.g., near the end of the match). Moreover, after losing a match, coaches can try to motivate players to minimize mental fatigue and improve readiness for subsequent matches. In very balanced matches, it may be that resistance to mental fatigue is a differentiator in winning or losing the match because increased adenosine, and decreased dopamine in the anterior cingulate cortex appears to reduce attention and concentration (Smith et al., 2018). Therefore, in the future, in addition to clarifying this question, substances and techniques that can mitigate mental fatigue can be tested to provided practical recommendations', bus is necessary respect World Anti-Doping Agency (WADA) prohibited list. The main strength of this study is that we investigated perceived mental fatigue in world class athletes 'in the wild'. Yet, this study has limitations which we must acknowledge. Firstly, the present methodology was limited to using a subjective instrument to measure mental fatigue (VAS). However, this tool is sensitive to mental fatigue (Smith et al., 2019), and has adequate internal consistency and temporal stability (Díaz-García et al., 2021). Moreover, we minimized risk of bias and measurement errors by familiarizing athletes and trying to increase metacognitive skills as suggested by Thompson et al., (2019). In the

future, one could try to use cognitive tests or neuroimaging resources (i.e., electroencephalogram), but this could prove difficult in terms of logistics and participant burden.

Conclusions

In conclusion, moderate levels of mental fatigue are reached after official beach volleyball matches. Furthermore, these levels are partly explained (47%) by technical-tactical effort and losing seems to contribute to higher levels of mental fatigue. Therefore, it is plausible to suggest that cognitive activities should be avoided before official matches. In the futurere, sources that can mitigate mental fatigue should be tested. In addition, it may be investigated how levels of mental fatigue discriminate game outcomes and whether more successful athletes are mental fatigue resistant.

Conflicts of interest - The authors declare that there is no conflict of interest.

Funding - This study was financed in part by the "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES)" - Finance Code 001.

Acknowledgment - Thanks to the "Cangaço beach volleyball training center" and the players for their collaboration in this research.

References

Abbott, W., Brownlee, T. E., Naughton, R. J., Clifford, T., Page, R., & Harper, L. D. (2020). Changes in perceptions of mental fatigue during a season in professional under-23 English Premier League soccer players. *Research in Sports Medicine*, *28*(4), 529–539. https://doi.org/10.1080/15438627.2020.1784176

Afonso, J., Garganta, J., & Mesquita, I. (2012). Decision-making in sports: the role of attention, anticipation and memory. *Brazilian Journal of Kinanthropometry and Human Performance*, *14*(5), 592–601. https://doi.org/10.5007/1980-0037.2012v14n5p592

Balser, N., Lorey, B., Pilgramm, S., Naumann, T., Kindermann, S., Stark, R., Zentgraf, K., Williams, A. M., & Munzert, J. (2014). The influence of expertise on brain activation of the action observation network during anticipation of tennis and volleyball serves. *Frontiers in Human Neuroscience*, *8*(1), 1–13. https://doi.org/10.3389/fnhum.2014.00568

Barrett, S., McLaren, S., Spears, I., Ward, P., & Weston, M. (2018). The influence of playing position and contextual factors on soccer players' match differential ratings of perceived exertion: a preliminary investigation. *Sports*, *6*(1). https://doi.org/10.3390/sports6010013

Bellinger, P. M., Newans, T., Whalen, M., & Minahan, C. (2021). Quantifying the activity profile of female beach volleyball tournament match-play. *Journal of Sports Science and Medicine*, *20*(1), 142–148. https://doi.org/10.52082/jssm.2021.142

Boksem, M. A. S., & Tops, M. (2008). Mental fatigue: Costs and benefits. *Brain Research Reviews*, *59*(1), 125–139. https://doi.org/10.1016/j.brainresrev.2008.07.001

Borghini, G., Astolfi, L., Vecchiato, G., Mattia, D., & Babiloni, F. (2014). Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload, fatigue and drowsiness. *Neuroscience & Biobehavioral Reviews*, *44*, 58–75. https://doi.org/10.1016/j.neubiorev.2012.10.003

Cortell-Tormo, J. M., Pérez-Turpin, J. A., Chinchilla, J. J., Cejuela, R., & Suárez, C. (2011). Analysis of movement patterns by elite male players of beach volleyball. *Perceptual and Motor Skills*, *112*(1), 21–28. https://doi.org/10.2466/05.27.PMS.112.1.21-28

Costa, Y., Freitas-júnior, C., Lima-júnior, D. De, Soares-silva, E. L., Hayes, L., & Batista, G. R. (2022). Mental fatigue and ball sports: a narrative review focused on physical, technical, and tactical performance. *Motriz, Journal of Physical Education*, *28*(1), e10220004822. https://doi.org/http://dx.doi.org/10.1590/S1980-657420220004822

Costa, Y. P., Silva, C. B. L., Silva, L. S., Silva, E. L. S., García-De-Alcaraz, A., & Batista, G. R. (2021). Temporal aspects and physical behavior of U-21 female beach volleyball players: A study performed of the FIVB World Championship. *Journal of Physical Education and Sport*, *21*(2), 868–874. https://doi.org/10.7752/jpes.2021.02108

Coyne, J. O. C., Coutts, A. J., Newton, R. U., & Haff, G. G. (2021). The influence of mental fatigue on sessional ratings of perceived exertion in elite open and closed skill sports athletes. *Journal of Strength and Conditioning Research*, *35*(4), 963–969. https://doi.org/10.1519/JSC.0000000000003980

Díaz-García, J., González-Ponce, I., López-Gajardo, M. Á., Van Cutsem, J., Roelands, B., & García-Calvo, T. (2021). How mentally fatiguing are consecutive world padel tour matches? *International Journal of Environmental Research and Public Health*, *18*(17). https://doi.org/10.3390/ijerph18179059

Domingos-Gomes, J. rállison. (2019). *Effect of mental fatigue on performance during a beach volleyball match* (Masters dissertation). Retrieved from <https://repositorio.ufpb.br/jspui/handle/123456789/16736>.

Fortes, L. S., De Lima-Junior, D., Fiorese, L., Nascimento-Júnior, J. R. A., Mortatti, A. L., & Ferreira, M. E. C. (2020). The effect of smartphones and playing video games on decision-making in soccer players: A crossover and randomised study. *Journal of Sports Sciences*, *38*(5), 552–558. https://doi.org/10.1080/02640414.2020.1715181

Gantois, P., Caputo Ferreira, M. E., Lima-Junior, D. de, Nakamura, F. Y., Batista, G. R., Fonseca, F. S., & Fortes, L. de S. (2020). Effects of mental fatigue on passing decision-making performance in professional soccer athletes. *European Journal of Sport Science*, *20*(4), 534–543. https://doi.org/10.1080/17461391.2019.1656781

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Hülsdünker, T., Strüder, H. K., & Mierau, A. (2018). The athletes' visuomotor system–Cortical processes contributing to faster visuomotor reactions. *European Journal of Sport Science*, *18*(7), 955–964. https://doi.org/10.1080/17461391.2018.1468484

Klostermann, A., Vater, C., Kredel, R., & Hossner, E. J. (2015). Perceptual training in beach volleyball defence: Different effects of gaze-path cueing on gaze and decision-making. *Frontiers in Psychology*, *6*(DEC), 1–13. https://doi.org/10.3389/fpsyg.2015.01834

Le Mansec, Y., Pageaux, B., Nordez, A., Dorel, S., & Jubeau, M. (2018). Mental fatigue alters the speed and the accuracy of the ball in table tennis. *Journal of Sports Sciences*, *36*(23), 2751–2759. https://doi.org/10.1080/02640414.2017.1418647

Magalhães, J., Inácio, M., Oliveira, E., Ribeiro, J. C., & Ascensão, A. (2011). Physiological and neuromuscular impact of beach-volleyball with reference to fatigue and recovery. *Journal of Sports Medicine and Physical Fitness*, *51*(1), 66–73.

Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of Applied Physiology*, *106*(3), 857–864. https://doi.org/10.1152/japplphysiol.91324.2008

Martin, K., Meeusen, R., Thompson, K. G., Keegan, R., & Rattray, B. (2018). Mental fatigue impairs endurance performance: a physiological explanation. *Sports Medicine*, *48*(9), 2041–2051. https://doi.org/10.1007/s40279-018-0946-9

McKay, A. K. A., Stellingwerff, T., Smith, E. S., Martin, D. T., Mujika, I., Goosey-Tolfrey, V. L., Sheppard, J., & Burke, L. M. (2022). Defining training and performance caliber: a participant classification framework. *International Journal of Sports Physiology and Performance*, *17*(2), 317–331. https://doi.org/10.1123/ijspp.2021-0451

Medeiros, A. I. A., Marcelino, R., Mesquita, I. M., & Palao, J. M. (2017). Performance differences between winning and losing under-19, under-21 and senior teams in men's beach volleyball. *International Journal of Performance Analysis in Sport*, *17*(1–2), 96–108. https://doi.org/10.1080/24748668.2017.1304029

Mesquita, P. H. C., Lage, G. M., Franchini, E., Romano-Silva, M. A., & Albuquerque, M. R. (2019). Bi-hemispheric anodal transcranial direct current stimulation worsens taekwondo-related performance. *Human Movement Science*, *66*, 578–586. https://doi.org/10.1016/j.humov.2019.06.003

Natali, S., Ferioli, D., LA Torre, A., & Bonato, M. (2017). Physical and technical demands of elite beach volleyball according to playing position and gender. *The Journal of Sports Medicine and Physical Fitness*, *November*, 1–18. https://doi.org/10.23736/S0022-4707.17.07972-5

Noël, B., Hüttermann, S., van der Kamp, J., & Memmert, D. (2016). Courting on the beach: how team position implicitly influences decision-making in beach volleyball serves. *Journal of Cognitive Psychology*, *28*(7), 868–876. https://doi.org/10.1080/20445911.2016.1194847

O'Keeffe, K., Hodder, S., & Lloyd, A. (2020). A comparison of methods used for inducing mental fatigue in performance research: individualised, dual-task and short duration cognitive tests are most effective. *Ergonomics*, *63*(1), 1–12. https://doi.org/10.1080/00140139.2019.1687940

Palao, J. M., Valades, D., & Ortega, E. (2012). Match duration and number of rallies in men's and women's 2000-2010 FIVB world tour beach volleyball. *Journal of Human Kinetics*, *34*(1), 99–104. https://doi.org/10.2478/v10078-012-0068-7

Pérez-Turpin, J. A., Cortell-Tormo, J. M., Suárez-Llorca, C., Chinchilla-Mira, J. J., & Cejuela-Anta, R. (2009). Gross movement patterns in elite female beach volleyball. *Kinesiology*, *41*(2), 212–219.

Russell, S., Jenkins, D., Halson, S., & Kelly, V. (2020). Changes in subjective mental and physical fatigue during netball games in elite development athletes. *Journal of Science and Medicine in Sport*, *23*(6), 615–620. https://doi.org/10.1016/j.jsams.2019.12.017

Smith, M. R., Chai, R., Nguyen, H. T., Marcora, S. M., & Coutts, A. J. (2019). Comparing the Effects of Three Cognitive Tasks on Indicators of Mental Fatigue. *The Journal of Psychology*, *153*(8), 759–783. https://doi.org/10.1080/00223980.2019.1611530

Smith, M. R., Coutts, A. J., Merlini, M., Deprez, D., Lenoir, M., & Marcora, S. M. (2015). Mental fatigue impairs soccer-specific physical and technical performance. *Medicine and Science in Sports and Exercise*, *48*(2), 267–276. https://doi.org/10.1249/MSS.0000000000000762

Smith, M. R., Thompson, C., Marcora, S. M., Skorski, S., Meyer, T., & Coutts, A. J. (2018). Mental Fatigue and Soccer: Current Knowledge and Future Directions. *Sports Medicine*, *48*(7), 1525–1532. https://doi.org/10.1007/s40279-018-0908-2

Sonnabend, H. (2020). On discouraging environments in team contests: evidence from top-level beach volleyball. *Managerial and Decision Economics*, *41*(6), 986–997. https://doi.org/10.1002/mde.3153

Stefanello, J. M. F. (2007). Concentration disturbing factors: a study case with the Olympic Beach Volley Champions. *Brazilian Journal of Physical Education and Sport*, *21*(2), 121–133.

Stoet, G. (2017). Psytoolkit: a novel web-based method for running online questionnaires and reaction-time experiments. *Teaching of Psychology*, *44*(1), 24–31. https://doi.org/10.1177/0098628316677643

Thompson, C. J., Fransen, J., Skorski, S., Smith, M. R., Meyer, T., Barrett, S., & Coutts, A. J. (2019). Mental fatigue in football: is it time to shift the goalposts? An evaluation of the current methodology. *Sports Medicine*, *49*(2), 177–183. https://doi.org/10.1007/s40279-018-1016-z

Thompson, C. J., Noon, M., Towlson, C., Perry, J., Coutts, A. J., Harper, L. D., Skorski, S., Smith, M. R., Barrett, S., & Meyer, T. (2020). Understanding the presence of mental fatigue in English academy soccer players. *Journal of Sports Sciences*, *38*(13), 1524–1530. https://doi.org/10.1080/02640414.2020.1746597

Van Cutsem, J., De Pauw, K., Vandervaeren, C., Marcora, S., Meeusen, R., & Roelands, B. (2019). Mental fatigue impairs visuomotor response time in badminton players and controls. *Psychology of Sport and Exercise*, *45*(1), 1–8. https://doi.org/10.1016/j.psychsport.2019.101579