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ORIGINAL ARTICLE

Digging deep: Is elite beach volleyball athletic performance impaired after a simulated tournament?

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ABSTRACT

Beach volleyball (BVB) tournaments often require elite athletes to compete in multiple matches per day over several consecutive days with limited rest, potentially leading to neuromuscular fatigue (NMF) and reduced performance. This study aimed to evaluate such fatigue. Twelve adult national team BVB players (8 males, 4 females) completed countermovement jump (CMJ) and 8-meter sprint tests before and after two simulated BVB matches, separated by a 2-hour rest period. No statistically significant changes were observed in performance measures at any time point. However, individual variations in CMJ height, which either increased or decreased beyond the smallest worthwhile change and typical error, were noted. These findings suggest that CMJ height alone may not be a reliable indicator of NMF, or that significant NMF does not occur following two BVB matches. Additionally, the validity of using sprint performance on sand to assess post-exercise NMF remains unverified. Future research should aim to include larger samples of elite athletes, address the limitations of simulated match conditions, and utilize more sensitive tools to evaluate NMF.

Keywords: Performance analysis, Neuromuscular fatigue, Elite athletes, Countermovement jump, Fatigue assessment, Sand sports.

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INTRODUCTION

Beach volleyball (BVB) is an Olympic sport characterized by intermittent bouts of high intensity, involving two-player teams competing on a sand court. BVB is not studied as much as other popular sports such as soccer. Although physiological aspects of BVB have been studied (Batista et al., 2008; D'Anastasio et al., 2019; Holtgeerts et al., 2022; Horta et al., 2019; Jimenez-Olmedo et al., 2017; Medeiros et al., 2010; Nunes et al., 2020; Oliveira et al., 2018; Pelzer et al., 2020), the physiological demands and the physiological impact (e.g., blood lactate levels, neuromuscular performance and fatigue) of a BVB match, and specifically a series of consecutive matches (i.e., a tournament), have yet to be thoroughly studied and understood.

The game involves multiple efforts such as maximal vertical jumps for either defending (blocking) or attacking (spiking), and horizontal jumps to receive a ball called digs (Medeiros et al., 2014; Palao et al., 2014; Schmidt et al., 2020; Turpin et al., 2008). Additionally, short distance running and changes of direction (COD) in various planes to cover the area of the play are also required. The low number of players per team increases the intensity of the game since each player has more area to cover and more interactions with the ball are needed. This often creates a situation in which the player that received the ball must quickly set themselves for another hit to spike the ball to the other side.

Intensity is also impacted by the nature of the sand surface (Cetolin et al., 2021; Rago et al., 2018) as players must exert more force for a given action to overcome the high compliance and instability of the sand, compared to a harder surface (Giatsis et al., 2018). High number of jumping and landing efforts, changes of direction, accelerations and decelerations have been shown to lead to increased muscle damage (Highton et al., 2009; Howatson & Milak, 2009; Keane et al., 2015; Souglis et al., 2015) due to multiple eccentric muscle contractions performed at high speeds (Córdova-Martínez et al., 2022) and consequently residual fatigue may incur and performance suffer (Highton et al., 2009; Howatson & Milak, 2009; Keane et al., 2015; Twist & Eston, 2005). However, this effect may be lessened on a sand surface (Arazi et al., 2016; Binnie et al., 2014; Brown et al., 2017; Miyama & Nosaka, 2004).

Strategy and tactics may also impact physiological demands. For example, teams can decide to deliberately attack one of the opposing players throughout the match, potentially leading to a higher workload and resulting in greater acute and prolonged fatigue for the targeted player. This can potentially lead to a longer recovery period (Carroll et al., 2017). However, this has yet to be investigated in BVB.

Therefore, the main purpose of this investigation was to assess and describe the physiological demands and impact of a simulated BVB tournament comprising two matches separated by two hours, in which one player per team was targeted by the opposing team for both matches. This scenario was selected to simulate a "*real-life*" worst-case scenario based on a discussion with the national BVB team's staff. We hypothesized that performance indices will decrease after each match, and that the physiological load imposed on the targeted player will be higher.

MATERIALS AND METHODS

Participants

Twelve adult international level (McKay et al., 2021) athletes (4 females and 8 males) from Israel's national team participated in this investigation (Table 1). The assessments performed in the study were part of regular performance testing which the athletes were familiar with. As the sports science department has an ongoing testing and consulting collaboration with all national teams, and the data for the study was obtained from

regular scheduled testing, no informed consent was needed. The Wingate Institute has an ongoing Helsinki and ethics board approval from Hillel-Yafe Medical Center (approval number: 0011-20-HYCM) for publishing studies resulting from regular testing aimed for consulting the national team.

Table 1. Anthropometric data for all the athletes. Data are presented as means and SD.

	Age (years)	Weight (kg)	Height (cm)	Fat %
Men (n = 8)	22.5 ± 5.3	83.9 ± 8.7	190.9 ± 5.1	8.7 ± 0.6
Women (n = 4)	19.5 ± 1.9	68.2 ± 10.4	175.3 ± 10.9	18.3 ± 2.2

Procedures

The athletes arrived at their training facility at 9 am and were weighed. Then they began their usual pre-game warm up which included a general warm up and a volleyball-specific warm up. Baseline testing battery was performed in the following order: countermovement jump (CMJ), and sprints. Testing procedures took about 10 minutes for the four players to complete, after which they started their match, which was self-referred. Each match consisted of three sets, regardless of the result of the first two sets. This was done to standardize all matches and ensure higher workload on the players to simulate a "*worst-case*" scenario. One player in each team was selected to be targeted by the other team throughout both matches (i.e., all the serves were directed at that player).

Immediately after the match, players reported their subjective rating of perceived exertion (RPE) and repeated the physical testing before taking a 2-hour rest in which they were allowed to eat and drink ad libitum. The second pre-match warm-up was timed so that the second match started exactly two hours after the first match had ended (Figure 1). The durations of sets and matches were recorded and rounded to the nearest minute, and matches were filmed for subsequent analysis, specifically to tally the number of jumps and ball receptions made by each player.

The data collection team was blinded to the results of the matches and to the identity of the targeted player.

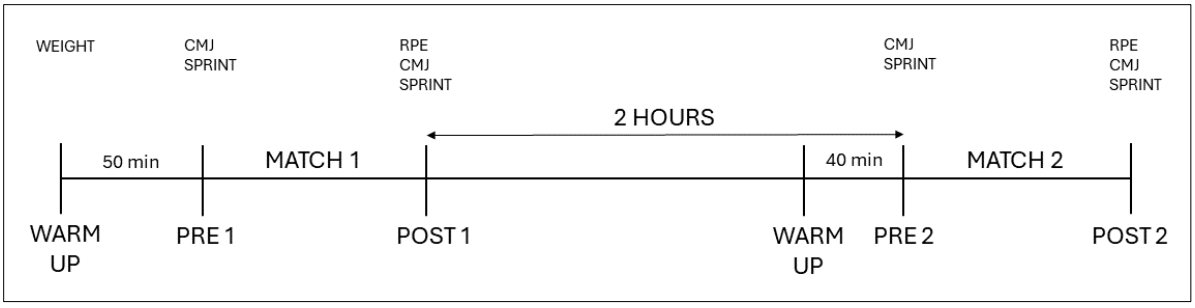

Figure 1. Study procedure and timeline.

Anthropometrics

Athletes' height was measured a week before testing day using a stadiometer (Seca 206, Seca, Hamburg Germany) and rounded to the nearest 0.1 cm. Players' weight was measured in the morning of testing day using an electronic scale and rounded to the nearest 0.1 kg. Athletes' body composition was calculated using a digital skinfold calliper (System 1 model, Skyndex, LLC) by a trained and certified dietician, with skinfold measured in four sites (Biceps, Triceps, Subscapula, Iliac Crest) and body fat percentage calculated using Durnin–Womersley formulas for men and women (Durnin & Womersley, 1974).

Rating of perceived exertion (RPE)

RPE was measured using the Borg CR10 scale (Williams, 2017) immediately after each match. Although the players were familiar with the scale as part of their team's monitoring system, a printed visual scale was presented to them before giving their answer.

Countermovement jump (CMJ)

Neuromuscular fatigue (NMF) is commonly assessed by a CMJ test (Claudino et al., 2017; R. Gathercole et al., 2015; R. J. Gathercole et al., 2015; Taylor et al., 2012) which requires the athlete to perform a maximal vertical jump with their hands on their hips. Jumping was also chosen to assess functional fatigue since it is an integral and imperative part of BVB. The players performed two jumps with their hands on their hips on a hard surface and wearing athletic shoes. Jumps were separated by a 30 second interval. Athletes were instructed to bend their knees and hips to a self-selected depth and jump as high as possible. Jump height was measured using the Optojump system (Microgate, Rome, Italy) to the nearest 0.1 cm and the average of the two jumps was used for analysis (Claudino et al., 2017).

Linear sprint test

Functional performance and NMF are often assessed by linear speed tests such as sprinting for short distances (5-20 m) for their high neuromuscular demands (R. J. Gathercole et al., 2015). Players stood 30 cm before the starting line and the sprint was self-initiated. Players sprinted barefooted for 8 m on sand and 4 and 8 m sprint times were measured using a photoelectric timing gate system (Witty, Microgate, Rome, Italy). Two trials were given for each athlete and time was recorded to the nearest thousand of a second. The best result was used for analysis.

Video analysis

All matches were recorded using a video camera positioned on a tripod. An expert BVB coach reviewed the footage to determine the number of jumps and receptions of each player. This data was used to determine if the designated target player was experiencing a higher workload and if the number of jumps deferred between matches.

Environmental conditions

Temperature (Cº) and humidity (%) were measured using a portable handheld weather meter (Kestrel 5500, Kestrel Instruments, Boothwyn, PA, USA). Both variables were measured at the beginning of the first and second match. Heat index (HI) was calculated using an online calculator (*Heat Index Calculation*, n.d.) and is based on formulas which can be found on the American national weather prediction centre website (*Heat Index Equation*, n.d.).

Statistical analysis

Statistical analysis was performed using JASP software version 0.17.3. A repeated measured analysis of variance (ANOVA) was performed to identify a main effect for time for the selected variables between the four timepoints (PRE 1, POST 1, PRE 2, POST 2), and an interaction effect for sex and strategy (targeted vs non-targeted). Paired sample t-test was used to compare differences in RPE results between POST 1 and POST 2.

To identify individual changes in performance, we compared CMJ height difference between POST 2 and PRE1 (which represents the accumulated fatigue from 2 matches). We then calculated between-subjects SD and the smallest worthwhile change (SWC) was calculated as 0.2 times the SD (Hopkins, 2000; Turner et al., 2021). Typical error was obtained from a reliability study (Comyns et al., 2023) performed with the same

instrument (Hopkins, 2000; Turner et al., 2021). Individual results are presented as both absolute change (in cm) and as percent change for each athlete (the change divided by the baseline result for each athlete).

Significance was set at 5%. All data are presented as mean and standard deviation.

RESULTS

The first round of matches (3 matches with 4 players each) started at 10:26, 10:33 and 11:37, and the second round started at 13:12, 13:28 and 14:31 respectively. The temperature in the beginning of the first match ranged from 23-26 °C with a humidity of 67.3%-67.9% which equates to a HI of 23.1-27.2 °C. For the second match the temperature was 31 °C, and humidity was 48% which equates to a HI of 32.3 °C.

Mean set and match duration were 17.17 ± 2.92 and 51.5 ± 5.32 min, respectively. The mean total duration of the second match was longer than the first match, however, it was not statistically significant (54 ± 4.58 vs. 49 ± 5.57 min, respectively; p = .243, Cohen's d = 0.945). Data are presented in Table 2.

Table 2. Set and match durations in minutes.

	Sex	Set 1 (min)	Set 2 (min)	Set 3 (min)	Total duration (min)
Match 1	F	14	19	10	43
	M	19	19	12	50
	M	18	22	14	54
Match 2	F	18	16	16	50
	M	17	25	17	59
	M	16	20	17	53
Mean ± SD		17 ± 1.79	20.2 ± 3.06	14.3 ± 2.88	51.5 ± 5.32

Athletic performance

CMJ

No differences in CMJ were noted between any of the time points. No differences were found for the sub-group analysis of sex or targeted vs non-targeted players. The data suggest that players began the second match in an unfatigued state regarding acute NMF. Data are presented in Table 3.

Individual CMJ height differences (POST2- PRE1) ranged from 3.15 to -5.55 cm and 7.9% to -13.3%. The smallest worthwhile change (SWC) was 0.49 cm and the typical error (i.e. standard error of measurement [SEM]) was 1.04 cm assessed from a reliability study (Comyns et al., 2023). 75% of the athletes had a change that was greater (either positive or negative) than the typical error (Figure 2).

Table 3. CMJ (cm) before and after both matches. with sub-group analysis by targeted vs non-targeted players and sex. Data are presented as means and SD.

	PRE1	POST1	PRE2	POST2
All n = 12	40.3 ± 5.14	39.5 ± 6.03	40.9 ± 6.17	39.8 ± 6.05
Non-targeted n = 6	40.2 ± 6.1	39.9 ± 6.8	40.7 ± 6.9	39.8 ± 6.8
Targeted n = 6	40.4 ± 4.5	39.1 ± 5.7	41.2 ± 6	39.8 ± 5.8
Female n = 4	36.6 ± 6.2	34.7 ± 6.7	36.3 ± 6.5	35.7 ± 7.9
Male n = 8	42.2 ± 3.6	41.9 ± 4.2	43.2 ± 4.8	41.9 ± 4

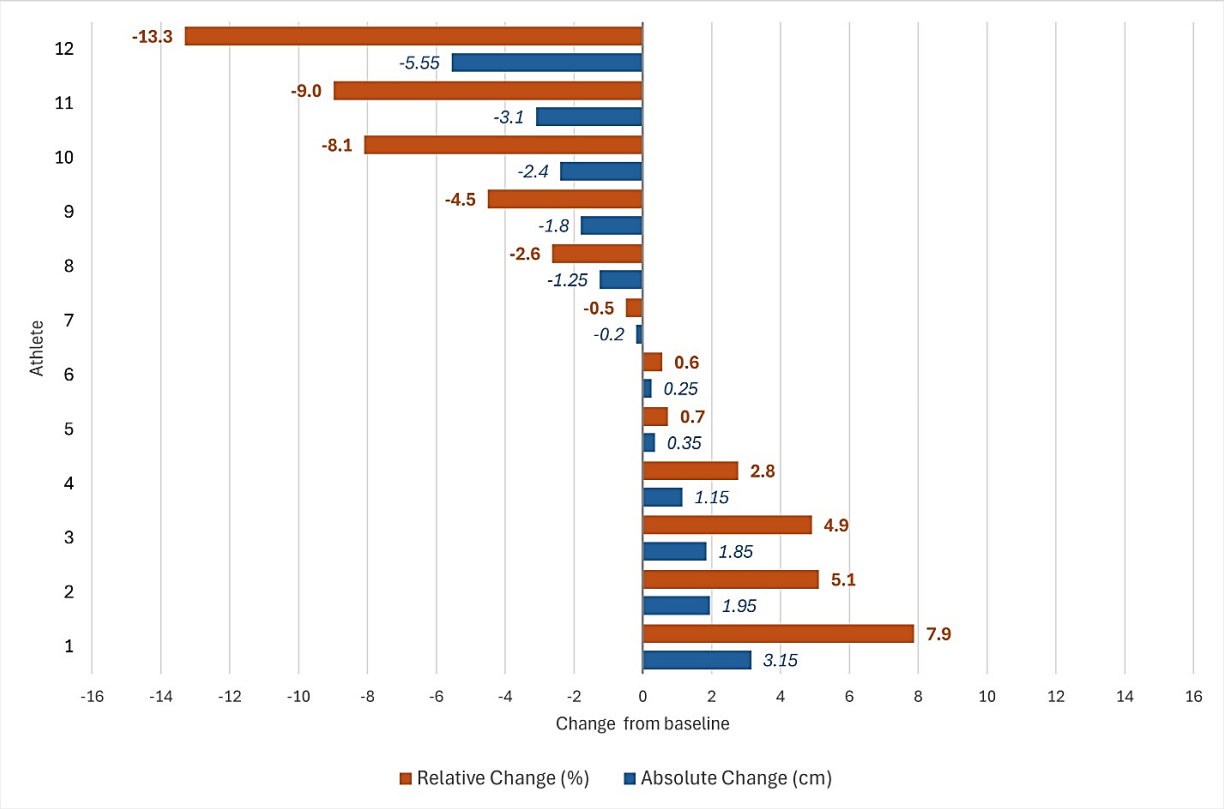

Figure 2. Individual CMJ height differences between POST2 and PRE1. Absolute change is in cm while the individual relative change is in percent from baseline.

Sprint

No differences were found for any of the variables for any of the time points, including all the sub-group analysis (sex and targeted players). Data are presented in Table 4.

Table 4. Sprint times (sec) for 4 (A) and 8 m (B). Data are presented as mean and SD.

A	**4m pre1**	**4m post1**	**4m pre2**	**4m post 2**
All n = 12	1.012 ± 0.086	0.992 ± 0.096	0.985 ± 0.064	0.99 ± 0.071
Non-targeted n = 6	1.03 ± 0.09	1.005 ± 0.114	0.987 ± 0.067	1.005 ± 0.082
Targeted n = 6	0.995 ± 0.087	0.978 ± 0.084	0.983 ± 0.068	0.975 ± 0.063
Female n = 4	1.028 ± 0.046	1.042 ± 0.046	1.02 ± 0.065	1.032 ± 0.043
Male n = 8	1.005 ± 0.103	0.966 ± 0.107	0.968 ± 0.06	0.969 ± 0.075
B	**8m pre1**	**8m post1**	**8m pre2**	**8m post2**
All n = 12	1.702 ± 0.105	1.684 ± 0.127	1.678 ± 0.104	1.671 ± 0.102
Non-targeted n = 6	1.718 ± 0.105	1.707 ± 0.137	1.682 ± 0.102	1.673 ± 0.12
Targeted n = 6	1.687 ± 0.112	1.662 ± 0.125	1.675 ± 0.116	1.668 ± 0.092
Female n = 4	1.748 ± 0.103	1.758 ± 0.082	1.748 ± 0.111	1.738 ± 0.076
Male n = 8	1.68 ± 0.105	1.647 ± 0.134	1.644 ± 0.088	1.637 ± 0.101

Video analysis

Video analysis was performed to determine differences in number of jumps between the two matches and between sexes. Total jumps in match 1 and match 2 were 62.8 ± 23.4 (range = 24-105) and 70 ± 24.6 (range

= 25-110), respectively (p = .033). Total jumps of males and females in match 1 were 69.5 ± 21.9 and 49.5 ± 23.1, respectively, (p > .05), and 75.9 ± 24.4 and 58.2 ± 23.4, respectively, (p > .05), in match 2. Additionally, we found that the targeted player indeed received the majority of the serves (90.2% and 94.2% in the first and second match, respectively).

RPE

RPE increased between POST1 and POST2 (5.2 ± 1.27 vs. 6.9 ± 1.46, respectively; p = .002). RPE was slightly higher for the targeted players compared to the non-targeted players, however, it did not reach statistical significance (POST1: 6 ± 1.05 vs 4.5 ± 1.05; POST2: 7.4 ± 0.8 vs 6.4 ± 1.85, respectively). Also, RPE did not differ by sex although it was higher in the men compared to the women (7.5 ± 1.22 vs 5.7 ± 1.26; p > .05).

DISCUSSION

The main finding of this study was that two BVB matches separated by two hours did not significantly affect any objective functional performance variable measured. The mean duration of matches in our study was consistent with previous research on beach volleyball (Medeiros et al., 2014; Palao et al., 2012; Pérez-Turpin et al., 2019), ranging from approximately 43 to 59 minutes per match and number of jumps ranged from 24-110.

Athletic performance

Our study did not find significant differences in CMJ height between pre-match and post-match assessments. Previous investigations performed in various sports reported similar findings where CMJ performance either increased (Pelzer et al., 2020; Rosario et al., 2015) or was not affected (Moreno-Perez et al., 2020) after a match. In another study, CMJ (with arm swing) height was not affected after a single 3-set match in elite BVB players even though maximal isometric force of knee flexors and extensors decreased (Magalhães et al., 2011).

However, in the same study, 7.5 m and 15 m sprint times measured after the match were slower by 3 and 3.6%, respectively. After a 3 h recovery, sprint times still did not return to baseline levels. While the authors did not address the discrepancy between the results of the CMJ and the sprint test, it is worth noting that although the sprint performance decrements were statistically significant, they were probably functionally negligible (0.04-0.06 sec). The authors did not specify whether their speed assessment was done on sand or hard surface but considering their results in comparison to ours (i.e. much faster times), it seems that their test was performed on hard surface, and this may partially explain the difference from our results, together with the difference in the distance measured.

Sprinting has been identified as a sensitive method for detecting immediate post-exercise NMF, particularly over slightly longer distances (e.g., 20 meters) but also during the acceleration phase (e.g., 10 meters) (R. J. Gathercole et al., 2015). However, it is important to note that, to our knowledge, no study has investigated the efficacy of sprinting on sand for detecting acute NMF. Furthermore, research suggests that the sensitivity of NMF evaluation tests increases when the fatigue is induced in a similar manner to the mode of testing (Alba-Jiménez et al., 2022). Given that jumping is more prevalent than sprinting in BVB, we hypothesize that the CMJ test will be more specific and effective in detecting NMF in this context. However, jumping on sand may cause fatigue through different mechanisms compared to jumping on a hard surface, which is where the testing was performed, even though they are highly correlated (D. Bishop, 2003). For example, training on sand has been shown to cause less muscular damage (Arazi et al., 2016; Binnie et al., 2014; Brown et al.,

2017; Miyama & Nosaka, 2004) and utilize less of the stretch-shortening cycle mechanism (Impellizzeri et al., 2008).

Our results suggest that any acute NMF may not have substantially impacted the athletes' athletic ability during the simulated tournament – possibly via a mechanism of potentiation (Blazevich & Babault, 2019; Zimmermann et al., 2020) – or that the assessments used were not sensitive enough to detect such a change, were it to exist. Bishop et al. (2023) proposed that maximal jump height may be insufficient for detecting NMF. Instead, they recommended using time or duration-based metrics like time to peak power, modified RSI and total phase duration (i.e., time to take off or eccentric phase duration), which may be more effective in identifying immediate NMF. It is possible that athletes may unconsciously alter their jump strategy to achieve similar jump heights, thereby masking the presence of NMF (Yoshida et al., 2024). Consequently, while jump height is a visible outcome, it does not provide insights into the underlying factors influencing that performance (R. J. Gathercole et al., 2015). Additionally, fatigue could manifest in other ways, such as delayed reaction time (Sant'Ana et al., 2017) or impaired decision-making (Almonroeder et al., 2020).

For example, A study on Canadian football players (Clarke et al., 2015) found evidence for indirect NMF in the CMJ test following a competition by examining variables other than jump height (take-off velocity and peak power, but not peak force). However, Jumping and sprinting has been demonstrated to be affected in various other team sports such as soccer, basketball, and handball immediately after a match and up to 48 and 72 hours (Chatzinikolaou et al., 2014; Doeven et al., 2018; Ronglan et al., 2006; Silva et al., 2018). In individual sports, CMJ performance decreased by 10% and 10-meter sprint performance decreased by 5% among U15 tennis players after playing 2 consecutive tennis matches on the same day (Gallo-Salazar et al., 2017). Similarly, Detanico et al. (2015) reported a 3.2% reduction in CMJ height after 3 successive judo matches of national level athletes, although CMJ power output remained the same. They concluded that jump height is a more sensitive parameter than power output. This supports the notion that different physical and biomechanical measures should be used for different purposes (C. Bishop et al., 2023; R. J. Gathercole et al., 2015), however, it contrasts the claim that jump height is not sensitive in detecting NMF (C. Bishop et al., 2023).

It is noteworthy that while data from studies on various other sports suggests the presence of significant NMF even after a single match, the limited studies on BVB have not reported such conclusive findings (Corvino et al., 2017; Holtgeerts et al., 2022; Magalhães et al., 2011). This presents several possible interpretations: 1) one and two simulated BVB matches do not induce NMF (simulated matches might be of lower intensity than formal matches), particularly in a manner that directly affects visible performance; 2) Our method of assessing NMF may not have been sufficiently sensitive to detect its presence, assuming it exists in BVB; 3) any existing NMF was masked by a potentiation mechanism.

We do not have the capacity to confirm or negate the presence of neuromuscular potentiation in this investigation. However, conditioning activities (CAs) which were found to elicit such potentiation effects (i.e., post-activation performance enhancements - PAPE) are usually of low volume and high intensity (e.g., a heavy set of squats or a ballistic exercise) and overall, of short duration (Boullosa, 2021). It could be argued that a BVB match is of an opposite nature, meaning that the players jump multiple sub-maximal jumps over a long duration (>40 min), however, this assertion needs to be confirmed with the appropriate measuring tools which could measure the height of every jump during the game. Taken together, this would imply that PAPE might be less plausible in this scenario. Since previous investigations have successfully detected the presence of NMF using measures like CMJ height and sprint performance, suggesting it is a sensitive enough tool, whereas studies on BVB have not, we conclude that the first interpretation is more plausible.

Individual performance analysis

When working with elite athletes, providing individualized analysis and training recommendations is crucial, especially for those competing in individual or small team sports like beach volleyball (BVB). Our study aimed to identify performance changes within our cohort by analysing the accumulated fatigue from both matches. The minimal clinically significant difference, or smallest worthwhile change (SWC), in team sports cannot be determined by statistical tests alone and instead relies on expert opinion (Thorpe et al., 2017). It has been suggested that the SWC be calculated as 0.2 times the between-subjects standard deviation (Thorpe et al., 2017). However, if the SWC is smaller than the standard error of measurement (SEM), it cannot be considered a definite change due to the high signal-to-noise ratio. In our study, 75% of participants exceeded both the SEM and the SWC, with some showing improvement while others declined. This variation explains the non-significant results in null hypothesis testing but suggests a meaningful change in performance (Figure 2). Future studies should aim to identify the factors that influence whether outcomes are positive or negative in this context.

Our study introduced a novel and unique simulated situation in which one player per team was targeted by the opposing team throughout both matches. This strategy aimed to simulate a real life "*worst-case*" scenario and assess its performance implications on the targeted player. Video analysis confirmed that the targeted player indeed received the majority of serves during both matches (>90%). Despite being subjected to increased offensive pressure the targeted players did not exhibit significantly higher perceived exertion or experienced decreased performance compared to non-targeted players. This suggests that while the targeted player strategy may increase individual tactical demands and mental stress, it may not necessarily lead to a disproportionate physiological burden on the targeted player.

RPE

Subjective perception of effort is a valid and commonly used indicator for internal load in team-sport athletes (McLaren et al., 2018). RPE increased significantly from POST1 to POST2. This could be related either to the cumulative load during the second match, but also to the higher environmental temperature and heat index (HI) during the second match compared to the first match (HI of 32.3 °C vs. 23.1-27.2 °C, respectively) (Flouris & Schlader, 2015; Maw et al., 1993). Although RPE tended to be higher for targeted players compared to non-targeted players, this difference did not reach statistical significance. Interestingly, despite the players reporting higher levels of exertion during the second match, their performance remained unaffected. These results align with findings from other studies conducted with young basketball players (Marcolin et al., 2018; Meckel et al., 2009).

While some studies with a similar design to ours had found an increase in RPE (Invernizzi et al., 2015), others did not (Franchini et al., 2019; Tabben et al., 2013). Invernizzi et al. (2015) reported an increase in RPE after 4 simulated karate combats and also a reduced CMJ height of international-level athletes, suggesting that NMF impaired performance. It is plausible that in BVB a close score may lead to increased RPE due to heightened mental stress and greater energy investment per point, as each point becomes crucial (Bellinger et al., 2021). Conversely, a larger score margin may result in lower stress levels for players (Marcelino et al., 2011). However, our study did not track matches point by point, making it impossible to confirm these assertions.

Lastly, comparing simulated matches to official matches is important as athletes may exert less effort in the former due to lower stakes. This phenomenon has been observed in various sports such as football (Silva et al., 2018), karate (Chaabène et al., 2013) and Taekwondo (Bridge et al., 2013).

Limitations

We must acknowledge the limitations of our study, including the small sample size common in studies involving high-level athletes, and the duration of the simulated tournament. This duration may not fully mimic the demands of a real competitive beach volleyball tournament, which can span several consecutive days, potentially leading to fatigue in later stages. In a study by Holtgeerts et al. (2022), performance was not negatively affected by back-to-back matches with a 24-hour gap between them. However, their study involved one match per day and a total of two matches, which may not replicate the intensity of an official tournament which could last up to four consecutive days. Additionally, our short-term investigation limits our ability to assess the long-term effects of targeted player strategies on performance throughout a tournament or season.

CONCLUSION

In contrast to other sports, our study did not find evidence of functional or visible fatigue in a simulated BVB tournament with two matches played two hours apart. This is consistent, in most part, with previous research on BVB match effects. However, the individual analysis approach could provide valuable insights in identifying performance changes that were not apparent in group-level analyses. Evidence suggests that measuring CMJ height alone may not reveal the complex nature of fatigue.

We introduced a new strategic scenario targeting one player, but no performance differences were observed between targeted and non-targeted players.

Future studies should involve larger samples of elite athletes and address simulated tournament limitations by either measuring fatigue in real tournaments or creating more competitive and stressful situations through incentives. Longer studies spanning multiple days with several matches per day could shed light on performance in real-life scenarios.

AUTHOR CONTRIBUTIONS

Conceptualization, Idan Harat, Yaron Genkin and Rotem Kislev-Cohen; Data curation, Idan Harat and Rotem Kislev-Cohen; Formal analysis, Idan Harat; Investigation, Idan Harat; Methodology, Idan Harat, Yaron Genkin and Rotem Kislev-Cohen; Project administration, Rotem Kislev-Cohen; Supervision, Idan Harat and Rotem Kislev-Cohen; Visualization, Idan Harat; Writing – original draft, Idan Harat and Yaron Genkin; Writing – review & editing, Idan Harat, Yaron Genkin and Rotem Kislev-Cohen. All authors approved the final version of the manuscript.

SUPPORTING AGENCIES

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

STATEMENTS AND DECLARATIONS

Ethical considerations

The data for this paper was obtained from regular testing and monitoring which is part of the team's training program. Therefor no special ethical considerations were necessary.

Consent to participate
Not applicable since athletes on the national team were required to participate as part of their training.

Consent for publication
Written consent for publication was obtained from all participants.

DATA AVAILABILITY STATEMENT

The data cannot be shared as it pertains to the physical abilities of competitive national team athletes. The coaching staff has not consented to the release of this data beyond aggregate measures such as means and standard deviations or very general individual data analysis as presented in the paper.

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