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Within-week and between-week variability of external and internal load demands of professional male volleyball players

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ABSTRACT
Purpose. The aim of the present study was to analyse the within-week variations according to the internal (rate of perceived exertion [RPE], and session-RPE) and external (jump height average, minimum jump, maximal jump, range of jump, number of jumps and density) intensity.
Methods. Twelve male elite/international volleyball athletes from the Portuguese 1st division (age: 21.7 ± 4.19 years of age; experience: 6.2 ± 3.8 years; body mass: 85.7 ± 8.69 kg; height: 192.4 ± 6.25 cm; body mass index: 23.1 ± 1.40 kg/m^2) participated in this study. The players were monitored over 26 microcycles, 101 training sessions, and 20 matches. To assess the workload, the CR10 Borg scale and an inertial measurement unit (IMU) were used.
Results. According to the internal workload, RPE revealed significant differences between MD-4 and MD-2, MD-4 and MD1, MD-3 and MD-1, and MD-2 and MD-1 ($p < 0.05$). In the same line, session RPE showed significant differences between MD-4 and MD-2, MD-4 and MD-1, MD-3 and MD-2, MD-3 and MD-1, and MD-2 and MD-1 ($p < 0.05$). On the other hand, the external load demands revealed statistical differences regarding the number of jumps (MD-4 and MD-2, MD-4 and MD-1, MD-3 and MD-1, and MD-2 and MD-1) and the density of the training sessions (MD-4 and MD-1, and MD-2 and MD-1).
Conclusions. The primary findings of this study suggest that higher-intensity training sessions tend to occur during the middle of the week, with a tapering effect observed as the competition date approaches.
Key words: volleyball, workload, external demands, internal demands, elite male volleyball

Introduction

Volleyball is one of the most popular team sports characterised by intermittent effort, since short and high intensity actions alternate with brief rest periods [1, 2]. As a sport, volleyball stands out for being non-invasive, which leads to it including several and fast jumps [3, 4] to overcome the constraint of the net's height. To manage these demands, the integration of a training monitoring process seems to play an important role, providing relevant data, which can be used to guide coaches' decision-making process and drive further coaching [5–8]. In fact, such feedback regarding the impact of the training and competition on players would help coaches to adjust the training to maintain or improve the performance and to reduce the likelihood of injuries [9–11].

Training could be measured through external and internal demands. The first includes the external stimulus applied to a player, which is independent of their

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internal characteristics [12]. Considering that, on average, a volleyball player performs 54–90 jumps per match and 45–128 jumps per hour of training [13, 14], measuring jump performance has been the most used way of measuring the external intensity. Nevertheless, well-known devices such as microelectromechanical systems are not often used for two main reasons [15]: (i) because they demand a high investment; and (ii) the operational difficulties of this instrument in an indoor context. However, the current technology can measure jumps through a small device that the players wear, providing information about their actions [16, 17].

The training and match demands could also be quantified through the individual (psychobiological) response regarding an external stimulus, i.e., the internal intensity [18]. To quantify this, the heart rate has been used as a marker of exercise intensity [19–22]. However, it has been suggested that this could be a poor indicator of exercise intensity during high-intensity exercise [23], such as interval training or intermittent training [16–18]. In 2001, Foster et al. [24] (and later Foster et al. [25]) proposed the session rating of perceived exertion (session-RPE). This tool includes a scale originally proposed by Borg [26], and is based on the idea that the physiological responses derived from physical stress are followed by proportional perception responses [25]. The RPE value obtained after the training session is multiplied by its total duration, integrating intensity and volume [21]. The session-RPE has been considered one of the most reliable tools for monitoring the training dose for team sports [20, 27, 28], including volleyball [29, 30]. In addition, this method is simple, useful, valid, and inexpensive.

The associations between internal and external demands seem to play an important role in better understanding the dose-response effect to ensure that athletes are progressively and properly stimulated [31, 32]. In a meta-analysis in team sports, weaker magnitudes were found between session-RPE and external intensity, expressing a variance range between ~40 and 100% [31]. The same authors stated that this could suggest that team-sport athletes' responses to training and competition are influenced by several factors [31]. On the other hand, that study was conducted on team sports, while few studies with the same goal exist for volleyball. In fact, the studies conducted in volleyball so far have analysed only the internal (e.g. [33, 34]) or external (e.g. [12, 25]) intensity, or only in matches (e.g. [35]), or in young athletes (e.g. [6]), or for a time period of one season [36].

Given the existing research gap in analysing both internal and external load demands in volleyball players, as well as the importance of comprehending the training dynamics throughout the week, with the aim of identifying the most demanding sessions and aligning training and recovery strategies accordingly, a study that conducts such an analysis can enhance coaches' understanding and improve their ability to determine recovery priorities and set benchmarks for elite teams. Therefore, the aim of the present study was to analyse the within-week variations according to the internal (RPE, session-RPE) and external (jump height average, minimum jump, maximal jump, range of jump, number of jumps and density) intensity.

Material and methods

Study design

This study employed a longitudinal descriptive design with the goal of monitoring the training load demands of elite/international male volleyball players. The observation was conducted throughout the entire competitive period of the Portuguese 1st division league, with the assurance that it did not interfere with the standard coaching staff practices. The study employed convenience sampling, with recruitment involving direct invitations to teams and individual players.

Participants

Twelve male elite/international volleyball athletes (two setters, four middle blockers, four outside hitters, and two opposites) from the Portuguese 1st division (age: 21.7 ± 4.19 years of age; experience: 6.2 ± 3.8 years; body mass: 85.7 ± 8.69 kg; height: 192.4 ± 6.25 cm; body mass index: 23.1 ± 1.40 kg/m^2) participated in this study. The players were monitored over the entire 2020/21 season of the Portuguese Championship, corresponding to a total of 26 microcycles, 101 training sessions and 20 matches (from those matches, 6 were congested fixture). The following inclusion criteria were used throughout the competitive period: (i) players did not have injuries or illnesses during the period of data collection; (ii) only players who completed every training session within a specific week were included in the analysis. If a player missed even one session in a given week, they were not considered in the analysis for that particular week.

The study was conducted in line with the international ethical guidelines for sport and exercise science research recommended by the Declaration of Helsinki [37].

Procedures

To measure the external demand, in every training session, after the warmup, the players wore a belt with a Vert device (My Vert, Fort Lauderdale, FL, USA) until the practice ended. The devices were controlled and transmitted via Bluetooth in real time through the MyVert App (from IOS). At the end of the practice session, the data were exported to a spreadsheet. Depending on the competitive period phase, the training sessions varied between 3 and 7 practices per week (105 ± 12.4 min). The evening practices always started at 7 pm, while the morning training sessions always started at 10 am. Each microcycle was indicated with the number of days until the next match day, such as three days before the match day (MD-3) or one day before the match day (MD-1).

Instruments

Internal demands

To access the internal intensity, the CR10 Borg scale [38] was used. The aim of the scale was presented to the team, and players had two weeks of familiarisation (applied daily across the pre-competitive phase). Approximately 20 minutes after the end of the training sessions, the players were required to answer the question, 'How hard was your workout?'. The responses were collected individually and privately through individual registration on an Excel spreadsheet specifically designed for the observer. The researcher recorded the answers provided.

In addition to the individual RPE score, we also calculated the session rating of perceived exertion-based training load (sRPE). This metric expresses the training load in arbitrary units (A.U.) and is calculated as the product of the Borg scale rating and the duration of the training session [39]. The sRPE has been applied in several studies and is considered a valid surrogate of internal load [40–44]. The main outcomes extracted for each training session were the individual RPE score and the individual sRPE.

External demands

To assess the external intensity, an accelerometer (inertial measurement unit – IMU) was used. The device provides the number and height of each jump during the training session. With a mean bias that can vary between 3.57 cm and 4.28 cm [16], the device has the reliability needed to analyse all data collected. The IMU, a VERT device (Vert®Classic, MyVert, Florida, FL, USA), was used to monitor the volleyball players and has already been validated through recent research [32, 33, 40].

For each training session, the IMU collected data on the jumps performed. The device was activated at the beginning of the session and recorded the entire duration of the session. Jumps that were detected and registered by the sensor were then included and subsequently analysed. The primary outcomes derived from the data analysis included the number of jumps and the height of each jump. Furthermore, the following calculations were performed for each session: average jump height, minimum jump height, maximum jump height, range of jump heights, total number of jumps, and jump density (number of jumps per unit of time) [42, 43].

Statistical analysis

The data were analysed using the Statistica software (version 13.1; Statsoft, Inc., Tulsa, OK, USA) and the significance level was set at $p < 0.05$. Descriptive statistics are presented using the mean and standard deviation, and as percentages. Tests of normal distribution and homogeneity (Kolmogorov–Smirnov and Levene's, respectively) were conducted on all data before analysis. RPE, session-RPE, minimum jump, maximal jump, range of jump, number of jumps and density measurements were assessed using repeated-measures ANOVA for MD-4, MD-3, MD-2 and MD1. In addition, planned comparisons were performed to evaluate differences between match day (MD). Effect size is indicated with Cohen's *d* for *t*-tests [0.2 (small); 0.5 (medium) and > 0.8 (large)] and partial eta squared for Fs.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Polytechnic Institute of Viana do Castelo ethics committee before the data was collected (approval No.: CTC-ESDL-CE003-2020).

Informed consent

All the players participated in the study voluntarily and were informed about the study's design, implications, risks, and benefits. After receiving this information about the study, they signed an informed consent. They were free to withdraw from the research if they so wished.

Results

Descriptive statistics were calculated for each variable (Table 1).

A repeated-measures ANOVA with mean data of RPE revealed a significant main effect of the MD condition: $F(3.531) = 7.56$, $p = 0.001$, $\eta^2 = 0.04$. A pairwise comparison revealed significant differences between MD-4 and MD-2, MD-4 and MD1, MD-3 and MD-1, and MD-2 and MD-1: $t(11) = 2.26$, $p = 0.03$, $d = 0.17$, $t(11) = 4.69$, $p = 0.001$, $d = 0.41$, $t(11) = 3.45$, $p = 0.001$, $d = 0.32$, and $t(11) = 2.30$, $p = 0.02$, $d = 0.29$, respectively. The comparisons between MD-4 and MD-3, and MD-3 and MD-2 failed to reach statistical significance: $t(11) = 1.16$, $p = 0.24$, $d = 0.15$, and $t(11) = 0.50$, $p = 0.61$, $d = 0.02$, respectively. See Figure 1 (Figure 1.1 and 1.2).

Table 1. Within-week variations (MD-4, MD-3, MD-2 and MD-1) of RPE, session-RPE, jump height average, minimum jump, maximal jump, range of jump, number of jumps and density

	MD-4 (mean ± *SD*)	MD-3 (mean ± *SD*)	MD-2 (mean ± *SD*)	MD-1 (mean ± *SD*)
RPE	7.05 ± 1.58	6.81 ± 1.53	6.77 ± 1.60	6.31 ± 1.55
Session-RPE	600.42 ± 211.02	592.78 ± 223.40	551.14 ± 202.28	485.95 ± 192.69
Min jump	16.24 ± 2.85	16.53 ± 3.69	16.83 ± 4.96	16.83 ± 3.42
Max jump	84.56 ± 16.49	85.61 ± 15.62	84.09 ± 14.68	84.24 ± 15.81
Range of jump	68.32 ± 16.88	69.08 ± 16.18	67.26 ± 16.02	67.41 ± 15.81
Num. of jumps	102.74 ± 43.90	96.48 ± 43.52	91.64 ± 35.58	80.58 ± 30.63
Density	1.21 ± 0.45	1.15 ± 0.49	1.16 ± 0.40	1.07 ± 0.37

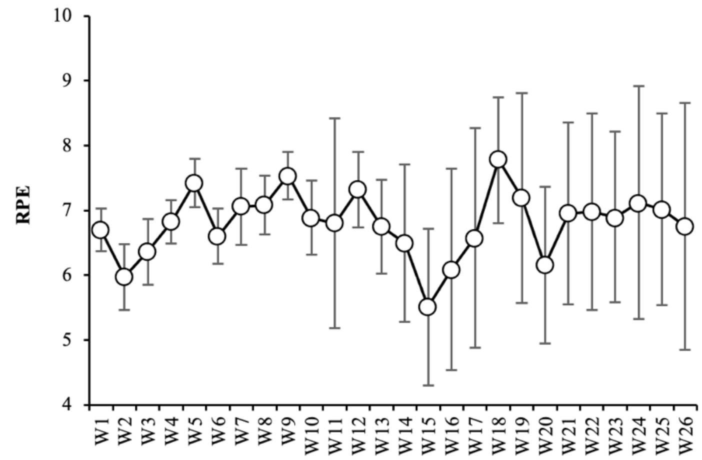

Figure 1.1. RPE (mean ± *SE*) as a function of time (weeks)

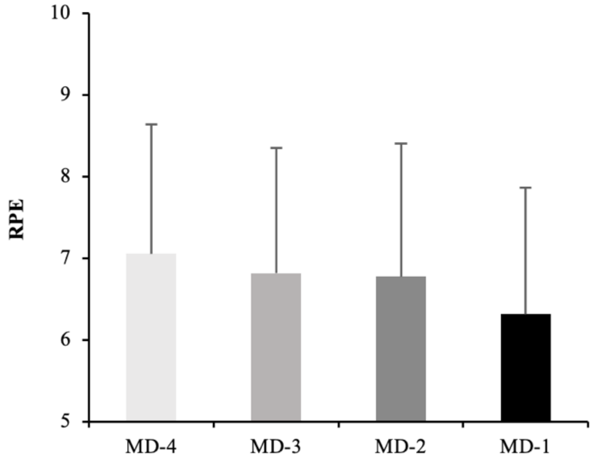

Figure 1.2. Within-week variations of RPE (mean ± *SE*)

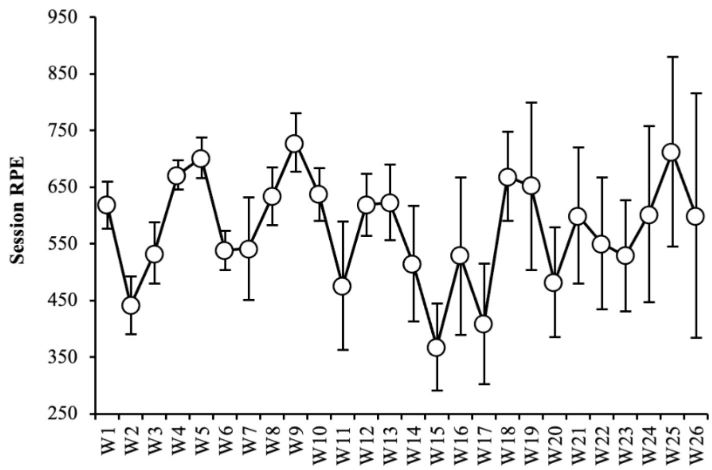

Figure 1.3. Session RPE (mean ± *SE*) as a function of time (weeks)

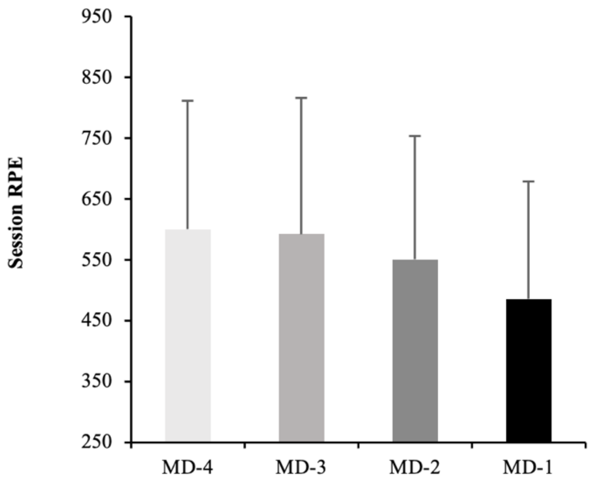

Figure 1.4. Within-week variations of Session RPE (mean ± *SE*)

Figure 1. Between-week variations (W1 to W26) and within-week variations (MD-4, MD-3, MD-2 and MD-1)

In the same line, another repeated-measures ANOVA with mean data of session RPE showed a significant main effect of the MD condition: $F(3.531) = 13.061$, $p = 0.001$, $\eta^2 = 0.07$. In reference to this ANOVA, pairwise comparisons showed significant differences between MD-4 and MD-2, MD-4 and MD1, MD-3 and MD-2, MD-3 and MD-1, and MD-2 and MD-1: $t(11) = 2.59$, $p = 0.01$, $d = 0.43$, $t(11) = 5.33$, $p = 0.001$, $d = 0.56$, $t(11) = 2.26$, $p = 0.02$, $d = 0.38$, $t(11) = 5.52$, $p = 0.001$, $d = 0.51$, and $t(11) = 3.06$, $p = 0.001$, $d = 0.12$, respectively. The comparison between MD-4 and MD-3 failed to reach statistical significance: $t(11) = –0.09$, $p = 0.92$, $d = 0.03$. See Figure 1 (Figure 1.3 and 1.4).

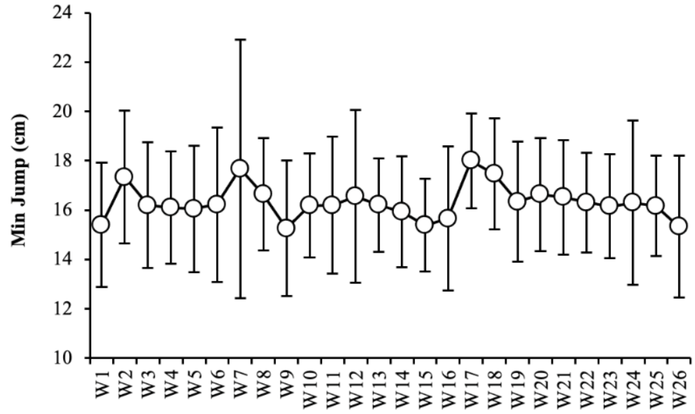

Figure 2.1. Min jump (mean ± *SE*) as a function of time (weeks)

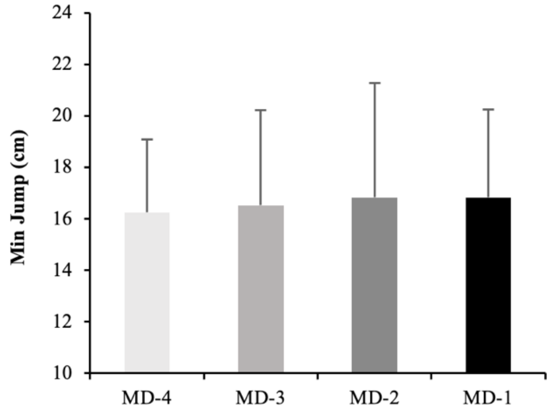

Figure 2.2. Within-week variations of min jump (mean ± *SE*)

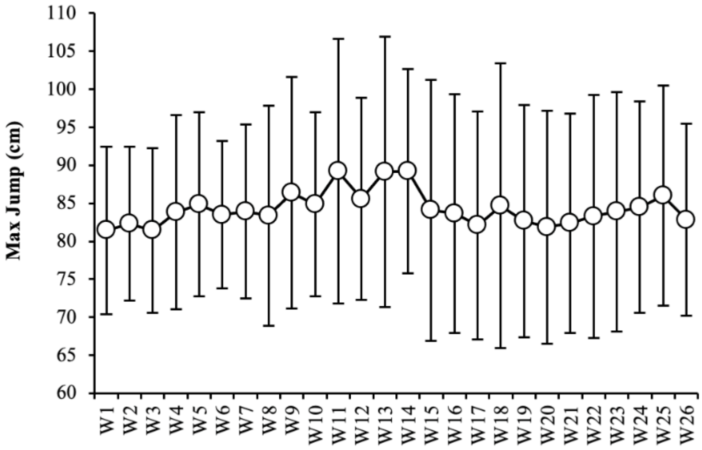

Figure 2.3. Max jump (mean ± *SE*) as a function of time (weeks)

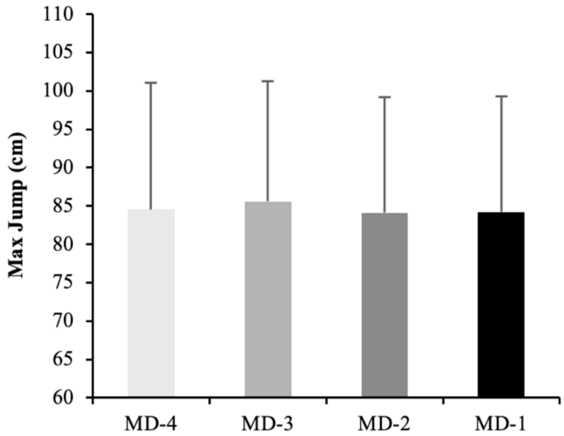

Figure 2.4. Within-week variations of max jump (mean ± *SE*)

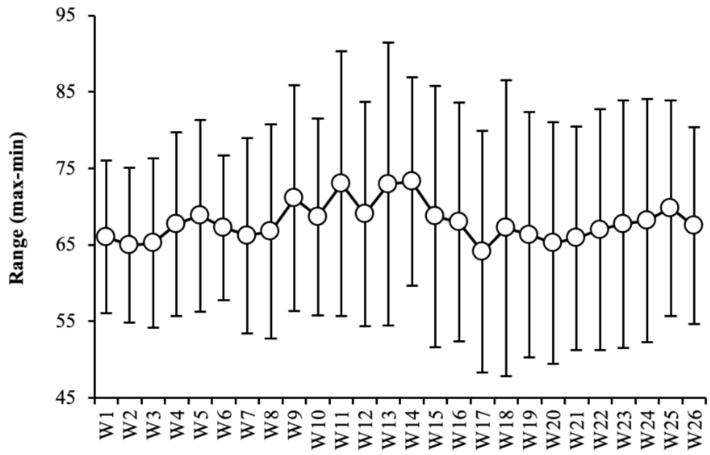

Figure 2.5. Range (mean ± *SE*) as a function of time (weeks)

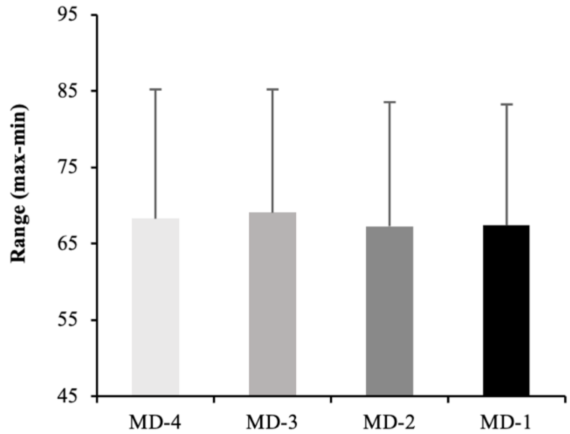

Figure 2.6. Within-week variations of range (mean ± *SE*)

Figure 2. Between-week variations (W1 to W26) and within-week variations (MD-4, MD-3, MD-2 and MD-1)

A new repeated-measures ANOVA with the mean data of the minimum jump did not show a significant main effect of the MD condition: $F(3.531) = 1.51$, $p = 0.20$, $\eta^2 = 0.01$. Posteriorly, pairwise comparisons only showed significant differences between MD-4 and MD-1: $t(11) = -2.03$, $p = 0.04$, $d = -0.18$. Nevertheless, the other comparison between MD-4 and MD-3, MD-4 and MD-2, MD-3 and MD-2, MD-3 and MD-1, and MD-2 and MD-1, did not show statistical significance: $t(11) = 0.23$, $p = 0.81$, $d = -0.09$, $t(11) = -0.47$, $p = 0.63$, $d = -0.14$, $t(11) = -0.85$, $p = 0.39$, $d = -0.06$, $t(11) = 1.91$, $p = 0.06$, $d = 0.08$, and $t(11) = 1.26$ $p = 0.20$, $d = -0.01$, respectively. See Figure 2 (Figure 2.1 and 2.2).

Continuing with the same analysis of the present work, a repeated-measures ANOVA with the mean data of the maximal jump did not show a significant main effect of the MD condition: $F(3.531) = 0.30$, $p = 0.82$, $\eta^2 = 0.001$.

Significant differences were found between MD-4 and MD-2: $t(11) = 0.82$, $p = 0.40$, $d = 0.03$, while no significant differences were found between MD-4 and MD-3: $t(11) = -0.28$, $p = 0.77$, $d = -0.06$; MD-4 and MD-1: $t(11) = 0.24$, $p = 0.80$, $d = 0.01$; MD-3 and MD-2: $t(11) = 1.61$, $p = 0.10$, $d = 0.10$; MD-3 and MD-1: $t(11) = 0.31$, $p = 0.75$, $d = 0.08$; and MD-2 and MD-1: $t(11) = 0.31$, $p = 0.75$, $d = -0.01$. See Figure 2 (Figure 2.3 and 2.4).

Regarding the range of jump, the next repeated-measures ANOVA, this time with the mean data of the range of jump, did not reveal a significant main effect of the MD condition: $F(3.531) = 0.41$, $p = 0.74$, $\eta^2 = 0.001$. In this sense, no pairwise comparisons not showed significant differences: MD-4 and MD-3, MD-4 and MD-2, MD-4 and MD-1, MD-3 and MD-2, MD-3 and MD-1, and MD-2 and MD-1: $t(11) = -0.32$, $p = 0.74$, $d = -0.04$, $t(11) = 0.89$, $p = 0.37$, $d = 0.06$, $t(11) = 0.68$,

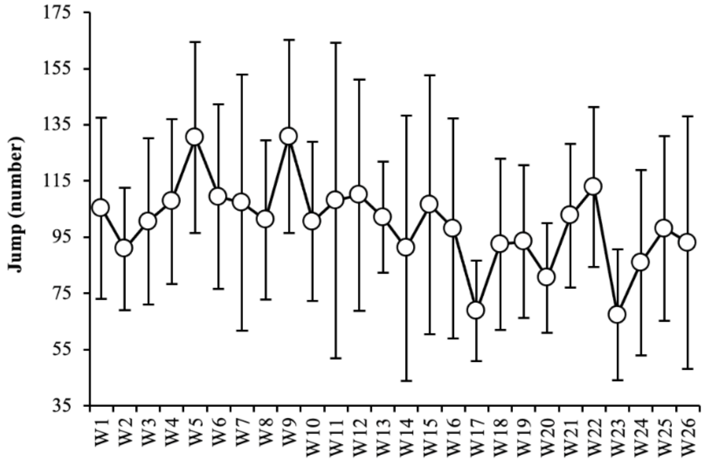

Figure 3.1. Number of jumps (mean value ± *SE*) as a function of time (weeks)

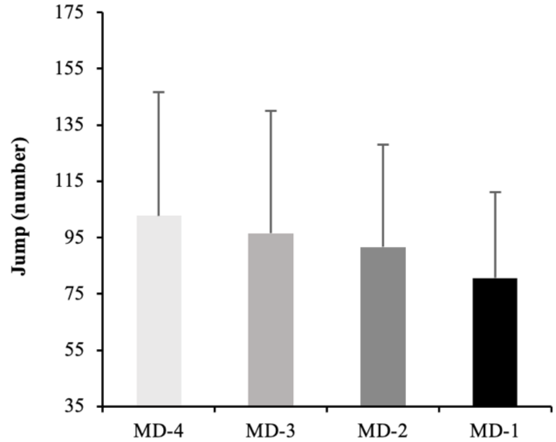

Figure 3.2. Within-week variations of number of jumps (mean value ± *SE*)

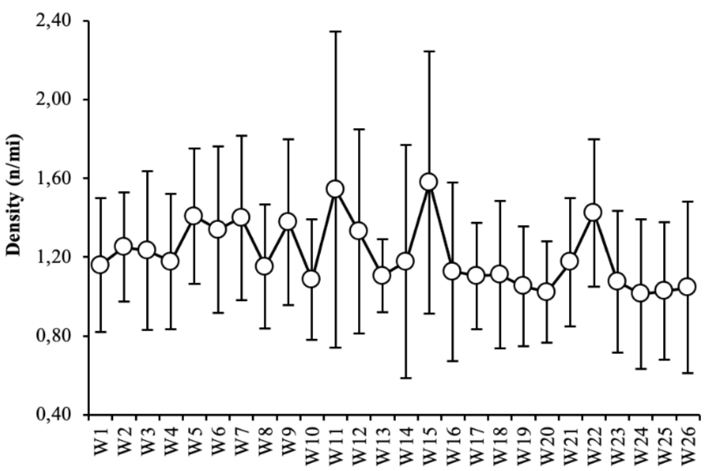

Figure 3.3. Density (mean value ± *SE*) as a function of time (weeks)

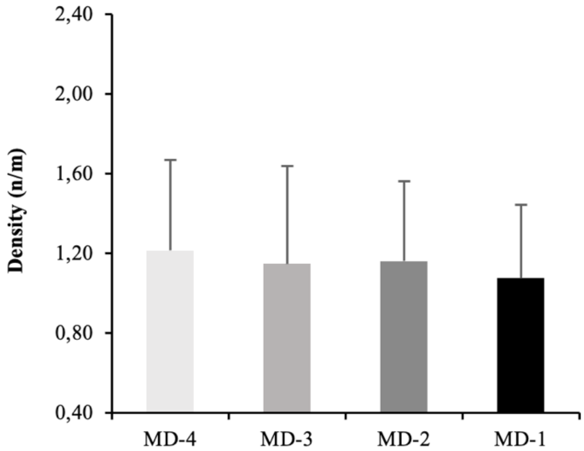

Figure 3.4. Within-week variations of density (mean value ± *SE*)

Figure 3. Between-week variations (W1 to W26) and within-week variations (MD-4, MD-3, MD-2 and MD-1)

$p = 0.49$, $d = 0.05$, $t(11) = 1.77$, $p = 0.07$, $d = 0.11$, $t(11) = 0.73$, $p = 0.46$, $d = 0.10$, and $t(11) = –0.23$, $p = 0.81$, $d = –0.01$, respectively. See Figure 2 (Figure 2.5 and 2.6).

Another repeated-measures ANOVA with the mean data of the number of jumps showed a significant main effect of the MD condition: $F(3.531) = 12.89$, $p = 0.001$, $\eta^2 = 0.06$. Crucially, pairwise comparisons showed significant differences between MD-4 and MD-2, MD-4 and MD-1, MD-3 and MD-1, and MD-2 and MD-1: $t(11) = 2.30$, $p = 0.02$, $d = 0.27$, $t(11) = 5.99$, $p = 0.001$, $d = 0.58$, $t(11) = 4.33$, $p = 0.001$, $d = 0.42$, and $t(11) = 4.55$, $p = 0.001$, $d = 0.33$, respectively. Notwithstanding, the comparison between MD-4 and MD-3, and MD-3 and MD-2 did not reach statistical significance: $t(11) = 0.85$, $p = 0.39$, $d = 0.14$, and $t(11) = 1.57$, $p = 0.11$, $d = 0.12$, respectively. See Figure 3 (Figure 3.1 and Figure 3.2).

Lastly, a repeated-measures ANOVA with the mean data of the density revealed a significant main effect of the MD condition: $F(3.531) = 4.75$, $p = 0.002$, $\eta^2 = 0.02$. In this sense, pairwise comparisons showed significant differences between MD-4 and MD-1, and MD-2 and MD-1: $t(11) = 3.85$, $p = 0.01$, $d = 0.33$, and $t(11) = 3.41$, $p = 0.001$, $d = 0.23$. However, the comparison between MD-4 and MD-3, MD-4 and MD-2, MD-3 and MD-2, and MD-3 and MD-1 did not show significant differences: $t(11) = 1.04$, $p = 0.29$, $d = 0.12$, $t(11) = 0.59$, $p = 0.55$, $d = 0.11$, $t(11) = –0.28$, $p = 0.77$, $d = –0.02$, and $t(11) = 1.96$, $p = 0.55$, $d = 0.18$, respectively. See Figure 3 (Figure 3.3 and Figure 3.4).

Discussion

In this study, the within-week and between-week variations of the internal (RPE, session-RPE) and external (jump height average, minimum jump, maximal jump, range of jump, number of jumps and density) load of professional male volleyball players were analysed. Regarding the internal intensity (RPE and s-RPE), the results revealed significant differences for between- and within-week variations. On the other hand, when the variables of the external intensity were analysed, even though no differences were found in the minimum, maximum and range of jump, significant differences were shown in respect of number of jumps and density. As a general trend, it was observed that the most physically demanding training sessions occurred in the middle of the week, while a tapering strategy was employed, leading to a reduction in training intensity during the sessions that were closer to the matches.

Internal demands

RPE revealed statistical differences within-week in MD-4 and MD-2, MD-1; MD-3 and MD-1; and MD-2 and MD-1. The values of RPE decrease throughout the week, which represent similar results to those obtained in other studies that showed that RPE values on MD-3 and MD-2 are represented with higher parameters when compared to MD-1 [42]. Indeed, such results are in line with a previous study [33], which revealed significant differences in RPE values when comparing MD-1 to all other training session days. This demonstrates the concern to increase the training intensity at the beginning of the week so the athletes undergo physiological adaptation, increasing their performance towards the end of the week [42, 46].

Rating of Perceived Exertion, which is a valid and a reliable tool, is dependent on the external load [47–49]. As the external intensity in training sessions and/or in a match increases, there is an increase of the internal intensity, namely on s-RPE [45]. In the present study, the RPE results presented statistical differences between MD-4 and MD-2; MD-3 and MD-2 and MD-1; and finally, between MD-2 and MD-1, for s-RPE. Despite athletes overestimating the intensity of an easy training session proposed by the coach and underestimating the intensity of a heavy training session, internal demands should be one variable to monitor the athlete [41, 50, 51]. Furthermore, it is known that monitoring s-RPE is a valuable tool to provide information regarding how athletes cope with sports-induced stress and to guarantee the best recovery of athletes [29, 39, 52]. Additionally, other recommendations are presented in a systematic review which analysed the periodisation of the workload and recommended implementing more active recovery days in order to improve resistance to fatigue [48].

External demands

Analysing the results, we also found statistical differences in external intensity within-week. These findings are in agreement with the literature, which suggests the need to adapt the microcycle to the team specificity and the period of the competition [53]. In this respect, it is known that the number of jumps increases across the season [54], making it necessary to control the length of the training workload to give to athletes time to recover [1]. On this basis, coaches minimise the training period on MD-1 to minimise the workload due to the impending competition [36]. Similar results were found in studies by Akyildiz et al. [55]

and Lima et al. [43], which tried to analyse the within-week variations and relationships between internal and external workload and found a decrease in the jump load throughout the week when approaching a match day.

Coaches must consider what was analysed in a previous study [30], which assessed the relationships and variance between workload in elite volleyball. When the external load is the same and there is an increase or a decrease in the internal intensity, this may represent a decrease or increase in physical fitness. Moreover, the decrease in the external load within-week improved sleep quality and decreased the fatigue of volleyball athletes [56].

Regarding the number of jumps performed, significant differences were found between MD-4 and MD-2, MD-4 and MD-1, MD-3 and MD-1, and MD-2 and MD-1. However, a previous study [38], which characterised the external and internal training load of professional volleyball players with a focus on intra-week changes, found significant differences between MD-2 and MD-1, registering a higher number of jumps on MD-2. These results are an important highlight, which demonstrate that the number of jumps decreases across the week due to the proximity of the match day [35, 43, 57].

Finally, when the density of the training sessions was analysed, significant differences were found between MD-4 and MD-1, and MD-2 and MD-1. This parameter represents a measure of how compact the workload was [42], in this case, according to the variations as a function of time (weeks) within-week.

Different results were found in a study by Lima et al. [36], which analysed the variations of the internal and external training intensity outcomes organised by days of the week. In this case, the density of the training sessions did not show any significant differences within-week. However, similar results were found in relation to other parameters assessed, such as jump height average, minimum and maximum jump, range of jump and number of jumps.

Despite the results presented, this study has limitations that could be remedied in further studies: (i) only one team was assessed; (ii) we did not analyse the workload according the player role; (iii) only the competitive phase was analysed; (iv) no relationship was analysed between training weeks; (v) Physical fitness training workload was not included in the data; and (vi) some well-being parameters were not included in this study, such as stress, fatigue, mood or soreness. Taking into account the aforementioned study limitations, it is essential to expand the number of observed players and teams in order to bolster the sample's statistical power and the generalisability of the results. This expanded sample size will also provide insights into how training impacts athletes in different playing positions, given the diversity of the training drills they undergo. Furthermore, future studies should delve into analysing mechanical work, considering the acceleration and deceleration profiles of the athletes. Lastly, researchers should consider examining which specific exercises contribute to the internal and external loads. This approach would help identify the most common drills applied in each session and provide a more comprehensive rationale for the observed outcomes.

In practical terms, this study underscores that training sessions in the middle of the week are notably more physically demanding than those scheduled closer to the competition. Coaches should take this into account when planning recovery strategies, such as dietary adjustments to accommodate the increased demands on these days. Additionally, it might be beneficial to introduce well-being and recovery perception monitoring strategies. Coaches can also explore various recovery techniques to alleviate the impact of these intense training sessions, ultimately enhancing athletes' performance in subsequent training sessions.

Conclusions

This study examined the within-week and between-week variations in internal and external load among professional male volleyball players. It was evident that both internal (RPE and s-RPE) and external load parameters displayed significant variations within the week. RPE values decreased as the week progressed, aligning with the need for athletes to adapt physiologically and improve performance throughout the week.

On the external load front, differences were observed in the number of jumps and density of training sessions within the week. Coaches should adapt training schedules to minimise the external load in proximity to competition, thereby optimising player recovery and performance. Moreover, the decrease in the number of jumps towards match day suggests the need for controlled workload management.

This study highlights the importance of considering the physical demands of training sessions throughout the week, with mid-week sessions being particularly taxing. Coaches should incorporate recovery strategies and well-being monitoring to mitigate the impact of intense training sessions and enhance athletes' overall performance. However, the study has some limitations, suggesting the need for further research with larger and more diverse samples, considering player roles, training phases, and analyses of specific exercises, to provide more comprehensive insights into load management in professional volleyball.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Andrade DM, Fernandes G, Miranda R, Coimbra DR, Bara Filho MG. Training load and recovery in volleyball during a competitive season. J Strength Cond Res. 2021; 35(4):1082–1088. doi: 10.1519/JSC.0000000000002837.
2. Bedo BLS, Cesar GM, Andrade VL, Arruda Moura F, Palucci Vieira LH, Aquino R, et al. Landing mechanics of basketball and volleyball athletes: a kinematic approach. Hum Mov. 2022;23(1):80–88; doi: 10.5114/hm.2021.104189.
3. Gabbett TJ. Do skill-based conditioning games offer a specific training stimulus for junior elite volleyball players? J Strength Cond Res. 2008;22(2):508–517; doi: 10.1519/JSC.0b013e3181634550.
4. Ziv G, Lidor R. Vertical jump in female and male volleyball players: a review of observational and experimental studies. Scand J Med Sci Sports. 2010;20(4):556–567; doi: 10.1111/j.1600-0838.2009.01083.x.
5. Borresen J, Lambert MI. The quantification of training load, the training response and the effect on performance. Sport Med. 2009;39:779–795; doi: 10.2165/11317780-000000000-00000.
6. Kiely J. Periodization Paradigms in the 21st century: evidence-led or tradition-driven? Int J Sports Physiol Perform. 2012;7(3):242–250; doi: 10.1123/ijspp.7.3.242.
7. Lovell TWJ, Sirotic AC, Impellizzeri FM, Coutts AJ. Factors affecting perception of effort (session rating of perceived exertion) during rugby league training. Int J Sports Physiol Perform. 2013;8(1):62–69; doi: 10.1123/ijspp.8.1.62.
8. Dolo K, Grgantov Z, Jelaska I. Testing dynamic balance in youth female volleyball players: development, reliability and usefulness. Hum Mov. 2023;24(3):78–84; doi: 10.5114/hm.2023.116635.
9. Clemente FM, Mendes B, Nikolaidis PT, Calvete F, Carriço S, Owen AL. Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. Physiol Behav. 2017;179:262–7; doi: 10.1016/j.physbeh.2017.06.021.
10. Issurin VB. New horizons for the methodology and physiology of training periodization. Sport Med. 2010; 40(3):189–206; doi: 10.2165/11319770-000000000-00000.
11. Moalla W, Fessi MS, Farhat F, Nouira S, Wong DP, Dupont G. Relationship between daily training load and psychometric status of professional soccer players. Res Sport Med. 2016;24(4):387–394; doi: 10.1080/15438627.2016.1239579.
12. Halson SL. Monitoring Training Load to Understand Fatigue in Athletes. Sport Med. 2014;44(suppl 2):139–147; doi: 10.1007/s40279-014-0253-z.
13. Bahr MA, Bahr R. Jump frequency may contribute to risk of jumper's knee: a study of interindividual and sex differences in a total of 11,943 jumps video recorded during training and matches in young elite volleyball players. Br J Sport Med. 2014;48(17):1322–1326; doi: 10.1136/bjsports-2014-093593.
14. Sheppard JM, Gabbett TJ, Stanganelli LCR. An analysis of playing positions in elite men's volleyball: Considerations for competition demands and physiologic characteristics. J strength Cond Res. 2009;23(6):1858–66; doi: 10.1519/JSC.0b013e3181b45c6a.
15. Lopes JA, da Silva KA, Reeberg Stanganelli LC. Periodization of volleyball training: characterization of training loads distribution in different macrocycles of Brazilian national U-19 male players. Hum Mov. 2021; 22(1):33–41; doi: 10.5114/hm.2021.98462.
16. Charlton PC, Kenneally-Dabrowski C, Sheppard J, Spratford W. A simple method for quantifying jump loads in volleyball athletes. J Sci Med Sport. 2017; 20(3):241–245; doi: 10.1016/j.jsams.2016.07.007.
17. Mahmoud I, Othman AAA, Abdelrasoul E, Stergiou P, Katz L. The Reliability of a Real Time Wearable Sensing Device to Measure Vertical Jump. Procedia Eng. 2015; 112:467–472; doi: 10.1016/j.proeng.2015.07.226.
18. Soligard T, Schwellnus M, Alonso J-M, Bahr R, Clarsen B, Dijkstra HP, et al. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. Br J Sports Med. 2016;50(17):1030–1041; doi: 10.1136/bjsports-2016-096581.
19. Alexiou H, Coutts AJ. A comparison of methods used for quantifying internal training load in women soccer players. Int J Sports Physiol Perform. 2008;3(3):320–330; doi: 10.1123/ijspp.3.3.320.
20. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. Med Sci Sports Exerc. 2004;36(6):1042–1047; doi: 10.1249/01.mss.0000128199.23901.2f.
21. Minganti C, Capranica L, Meeusen R, Amici S, Piacentini MF. The validity of sessionrating of perceived exertion method for quantifying training load in teamgym. J Strength Cond Res. 2010;24(11):3063–3068; doi: 10.1519/JSC.0b013e3181cc26b9.
22. Rodríguez-Marroyo JA, García-López J, Juneau C-É, Villa JG. Workload demands in professional multi-stage cycling races of varying duration. Br J Sports Med. 2009;43(3):180–185; doi: 10.1136/bjsm.2007.043125.
23. Rodríguez-Marroyo JA, Villa G, García-López J, Foster C. Comparison of heart rate and session rating of

perceived exertion methods of defining exercise load in cyclists. J Strength Cond Res. 2012;26(8):2249–2257; doi: 10.1519/JSC.0b013e31823a4233.
24. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, et al. A New Approach to monitoring exercise training. J Strength Cond Res. 2001;15(1): 109–115.
25. Foster C, Hoyos J, Earnest C, Lucia A. Regulation of energy expenditure during prolonged athletic competition. Med Sci Sport Exerc. 2005;37(4):670–5; doi: 10.1249/01.mss.0000158183.64465.bf.
26. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sport Exerc. 1982;14(5):377–381. Available from: http://journals.lww.com/00005768-198205000-00012
27. Kellmann M. Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. Scand J Med Sci Sports. 2010;20(suppl 2):95–102; doi: 10.1111/j.1600-0838.2010.01192.x.
28. Jeong T-S, Reilly T, Morton J, Bae S-W, Drust B. Quantification of the physiological loading of one week of "pre-season" and one week of "in-season" training in professional soccer players. J Sports Sci. 2011;29(11):1161–1166; doi: 10.1080/02640414.2011.583671.
29. Timoteo TF, Seixas MB, Falci MFA, Debien PB, Miloski B, Miranda R, et al. Impact of consecutive games on workload, state of recovery and well-being of professional volleyball players. J Exerc Physiol. 2017;20(3):130–140.
30. Aoki MS, Arruda AFS, Freitas CG, Miloski B, Marcelino PR, Drago G, et al. Monitoring training loads, mood states, and jump performance over two periodized training mesocycles in elite young volleyball players. Int J Sports Sci Coach. 2017;12(1):130–137; doi: 10.1177/1747954116684394.
31. McLaren SJ, Macpherson TW, Coutts AJ, Hurst C, Spears IR, Weston M. The relationships between internal and external measures of training load and Intensity in Team Sports: A Meta-analysis. Sports Med. 2018; 48:641–658; doi: 10.1007/s40279-017-0830-z.
32. Freitas VH, Nakamura FY, Miloski B, Samulski D, Bara-Filho MG. Sensitivity of physiological and psychological markers to training load intensification in volleyball players. J Sport Sci Med. 2014;13(3):571–579.
33. Clemente FM, Mendes B, Palao JM, Silvério A, Carriço S, Calvete F, et al. Seasonal player wellness and its longitudinal association with internal training load: study in elite volleyball. J Sports Med Phys Fitness. 2019; 59(3):345–351; doi: 10.23736/S0022-4707.18.08312-3.
34. Rodríguez-Marroyo JA, Medina J, García-López J, García-Tormo JV, Foster C. Correspondence btween training load executed by volleyball players and the one observed by coaches. J Strength Cond Res. 2014;28(6): 1588–1594; doi: 10.1519/JSC.0000000000000324.
35. Lima R, Castro H de O, Afonso J, Costa GDCT, Matos S, Fernandes S, et al. Effects of congested fixture on men's volleyball load demands: interactions with sets played. J Funct Morphol Kinesiol. 2021;6(2):53; doi: 10.3390/jfmk6020053.
36. Lima RF, Silva A, Afonso J, Castro H, Clemente FM. external and internal load and their effects on professional volleyball training. Int J Sports Med. 2020;41(7): 468–474; doi: 10.1055/a-1087-2183.
37. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. JAMA. 2013;310(20):2191–2194; doi: 10.1001/jama.2013.281053.
38. Shariat A, Cleland JA, Danaee M, Alizadeh R, Sangelaji B, Kargarfard M, et al. Borg CR-10 scale as a new approach to monitoring office exercise training. Work. 2018;60(4):549–54; doi: 10.3233/WOR-182762.
39. Debien PB, Mancini M, Coimbra DR, de Freitas DGS, Miranda R, Filho MGB. Monitoring training load, recovery, and performance of Brazilian professional volleyball players during a season. Int J Sports Physiol Perform. 2018;13(9):1182–1189; doi: 10.1123/ijspp.2017-0504.
40. Lupo C, Ungureanu AN, Brustio PR. Session-Rpe is a valuable internal load evaluation method in beach volleyball for both genders, elite and amateur players, conditioning and technical sessions, but limited for tactical training and games. Kinesiology. 2020;52(1):30–38; doi: 10.26582/k.52.1.4.
41. Nogueira FC de A, Nogueira RA, Coimbra DR, Miloski B, de Freitas VH, Filho MB. Internal training load: perception of volleyball coaches and athletes. Rev Bras Cineantropom Desempenho Hum. 2014;16(6):638–47; doi: 10.1590/1980-0037.2014v16n6p638.
42. Afonso J, Nakamura FY, Canário-Lemos R, Peixoto R, Fernandes C, Mota T, et al. A novel approach to Training monotony and acute-chronic workload index: a comparative study in soccer. Front Sport Act Living. 2021;3: 661200; doi:10.3389/fspor.2021.661200.
43. Lima RF, González Férnandez FT, Silva AF, Laporta L, de Oliveira Castro H, Matos S, et al. Within-week variations and relationships between internal and external intensities occurring in male professional volleyball training sessions. Int J Environ Res Public Health. 2022; 19(14):8691; doi: 10.3390/ijerph19148691.
44. Altundag E, Akyildiz Z, Lima R, Castro H de O, Çene E, Akarçeşme C, et al. Relationships between internal and external training load demands and match load demands in elite women volleyball players. Proc Inst Mech Eng Part P J Sport Eng Technol. 2022;0(0); doi: 10.1177/17543371221101232.
45. Oliveira R, Brito JP, Martins A, Mendes B, Marinho DA, Ferraz R, et al. In-season internal and external training load quantification of an elite European soccer team. PLoS One. 2019;14(4):e0209393; doi: 10.1371/journal.pone.0209393.
46. Turner AN. The science and practice of periodization: a brief review. Strength Cond J. 2011;33(1):34–46; doi: 10.1519/SSC.0b013e3182079cdf.
47. Bara Filho MG, de Andrade FC, Nogueira RA, Nakamura FY. Comparisson of different methods of internal load control in volleyball players. Rev Bras Med Esporte. 2013;19(2):143–146.

48. Moreno-Villanueva A, Rico-González M, Pino-Ortega J. Monitoring of internal and external loads to interpret acute and chronic fatigue in indoor team sports: A systematic review. Int J Sport Sci Coach. 2022;17(6):1531–1552; doi: 10.1177/17479541221096396.
49. Timoteo TF, Debien PB, Miloski B, Werneck FZ, Gabbett T, Bara Filho MG. Influence of workload and recovery on injuries in elite male volleyball players. J Strength Cond Res. 2021;35(3):791–796; doi: 10.1519/JSC.0000000000002754.
50. Cabral LL, Nakamura FY, Stefanello JMF, Pessoa LCV, Smirmaul BPC, Pereira G. Initial validity and reliability of the Portuguese Borg rating of perceived exertion 6–20 scale. Meas Phys Educ Exerc Sci. 2020;24(2):103–114; doi: 10.1080/1091367X.2019.1710709.
51. Wallace LK, Slattery KM, Coutts AJ. The ecological validity and application of the session-RPE method for quantifying training loads in swimming. J Strength Cond Res. 2009;23(1):33–38; doi: 10.1519/JSC.0b013e3181874512.
52. Moreira A, Freitas CG, Nakamura FY, Drago G, Drago M, Aoki MS. Effect of match importance on salivary cortisol and immunoglobulin a responses in elite young volleyball players. J Strength Cond Res. 2013;27(1):202–207; doi: 10.1519/JSC.0b013e31825183d9.
53. La Scala Teixeira CV, Evangelista AL, Pereira PE de A, Da Silva-Grigoletto ME, Bocalini DS, Behm DG. Complexity: a novel load progression strategy in strength training. Front Physiol. 2019;10; doi: 10.3389/fphys.2019.00839.
54. de Alcaraz AG, Valadés D, Palao JM. Evolution of game demands from young to elite players in men's volleyball. Int J Sports Physiol Perform. 2017;12(6):788–95; doi: 10.1123/ijspp.2016-0027.
55. Akyildiz Z, de Oliveira Castro H, Çene E, Laporta L, Parim C, Altundag E, et al. Within-week differences in external training load demands in elite volleyball players. BMC Sports Sci Med Rehabil. 2022;14(1):188; doi: 10.1186/s13102-022-00568-1.
56. Rebelo A, Pereira JR, Martinho DV, Amorim G, Lima R, Santos JV. Training load, neuromuscular fatigue, and well-being of elite male volleyball athletes during an in-season mesocycle. Int J Sports Physiol Perform. 2023; 18(4):354–362; doi: 10.1123/ijspp.2022-0279.
57. Pisa MF, Zecchin AM, Gomes LG, Puggina EF. External load in male professional volleyball: a systematic review. Balt J Health Phys Act. 2022;14(2):7; doi: 10.29359/BJHPA.14.2.07.