Influence of Workload and Recovery on Injuries in Elite Male Volleyball Players

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Abstract

Timoteo, TF, Debien, PB, Miloski, B, Werneck, FZ, Gabbett, T, and Filho, MGb. Influence of workload and recovery on injuries in elite male volleyball players. *J Strength Cond Res* XX(X): 000–000, 2018—The aim of this study was to investigate the influence of workload and recovery on injury rates in elite male volleyball players. Data were collected from 14 male professional volleyball players over a 27-week season. Workloads were monitored daily using the session rating of perceived exertion, and recovery status was appraised using the Total Quality Recovery (TQR) scale. The players were exposed to 4,573.31 hours (h) of training and games with an overall injury incidence of 13.99 per 1,000 hours. Overuse accounted for 83% (11.58 injuries/1,000 hours) and trauma accounted for 17% (2.40 injuries per 1,000 hours) of all injuries. There was a higher incidence of injuries ($p = 0.003$), higher weekly workload ($p = 0.008$), and acute:chronic workload ratio (ACWR) ($p < 0.001$) in the pre-season compared with the competitive period. Healthy players had lower ACWR ($p = 0.002$) compared with the injured players. The TQR was higher for the healthy group compared with the injured group ($p < 0.001$). The greater odds of injury was related to higher ACWR (risk factor) ($p = 0.014$) and lower TQR values ($p = 0.004$) (protection factor). Athlete's workloads and the state of recovery may be related to injuries in volleyball. The results presented in this study emphasize the importance of controlling these variables in professional volleyball teams to prevent injuries.

Key Words injury prevention, training monitoring, training load

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Introduction

Accurately monitoring athlete workload is an important component of the training process. An adequate training stimulus contributes to appropriate psychophysiological adaptations (25) and an excessive load can increase the risk of injury (6,14,15,23) and reduce performance (2). The relationship between workload and injury points to the management of workload as an important variable of sports injury prevention (25). For training adaptations to occur as expected, it is necessary to plan both the distribution of the workload, and also adequate recovery (21). Thus, the cause of an injury may be related to an excess of repetitive exertions, without sufficient time to undergo the natural repair process. This imbalance has been highlighted as an important causal factor in overuse injuries (19).

An association between higher workloads and greater injury incidence has been found in several sports including rugby league (11,15), football (2,6), cricket (17), Australian football (23), and basketball (1). Only a few studies have investigated workload variables and determined their relationship to volleyball injuries. Two studies have used training volume (training duration, frequency of jumps, and number of sets played), and related these variables to the frequency of a specific injury (jumper's knee) (3,26). A third study used the number of sessions over a restricted period of 4 weeks in 2 pre-seasons, relating the number of sessions to the number of injury cases after the end of that period (22).

Gabbett (13) has highlighted that sports with less emphasis on physical contact may be better served by an injury prevention program from training monitoring. Despite this, most of the studies that aim to investigate this association do so in contact team sports (2,15,25). To date, no study has comprehensively investigated the relationship between workload variables, recovery, and injury rates in volleyball. Therefore, the objective of this study was to investigate the influence of workload and recovery on injury rates in elite male volleyball players.

Methods

Experimental Approach to the Problem

This study used a longitudinal prospective design to identify the relationship between workload, recovery, and injury incidence in professional volleyball players. Workload data were recorded in all training sessions and games across a 27-week season, (13 weeks of pre-season and 14 weeks of competition). Recovery status, measured by the Total Quality Recovery (TQR) scale, was collected on the first day of training of the week, before the start of training session. Workload and recovery data were compared between injured and uninjured players. The probability of injury in players with higher or lower workload and recovery was assessed using a logistic regression model. To evaluate the predictive capacity of the model, a classification matrix was used. To analyze the sensitivity and specificity of the model, the receiver operating characteristic curve was used.

Subjects

Fourteen male elite volleyball players belonging to a team that competed in the Brazilian "Superliga" participated in the study. The mean ± *SD* age, body mass, and height of the players were 26.7 ± 5.5 years, 95.8 ± 8.2 kg, and 197.0 ± 7.9 cm, respectively. The participants signed a term consenting to their voluntary participation. The study was approved by the Human Research Ethics Committee of the Federal University of Juiz de Fora.

Procedures

The duration of each training session and game was recorded. Using this datum, it was possible to calculate an overall weekly training time. Thirty minutes after the end of training or games, players provided a rating of the intensity of the session using the modified Borg CR-10 session rating of perceived exertion (session-RPE) (10). Athlete's workloads were quantified by multiplying the session-RPE by training session duration (in minutes), resulting in a value in arbitrary units (AU). When there was more than one training session on the day, loads were added, generating the daily workload. From the sum of the daily values in each week, the total weekly workload was calculated. To relate workload with injury rates, the weekly workload of the week before the appearance of injury was considered. From the weekly workload data, the values of monotony (average weekly workload/*SD* of weekly workload) and strain (monotony × weekly workload) were also calculated (10). The acute:chronic workload ratio (ACWR) was also measured. This ratio describes the acute workload (the workload of the past week) in relation to the chronic workload (the 4-week rolling average of workload) (17).

To assess the state of recovery, players completed the TQR scale described by Kentta and Hassmen (19). The scale ranges from 6 to 20, with 6 being the minimum recovery value and 20 the maximum. To relate recovery to injury, TQR were always used on the first training day of the week in which the injury occurred.

An injury was defined as any physical complaint that resulted in an inability of the player to fully take part in training and games, or if the player received assistance from the medical department team, even when participating in training or games (8). In this respect, all injuries that required medical department care were included. The injuries were classified by severity according to the amount of time players missed from training sessions and games, as following: slight (no absence), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), and severe (more than 28 days). The injuries were also classified according to cause (traumatic or overuse), and in the case of traumatic injuries, there was the identification of a specific factor that generated the event (6). Injuries caused by repeated microtrauma without a specific causal event were classified as functional overuse injuries. From the injuries collected each week, the player's data were divided into 3 groups: healthy, traumatic injury, and overuse injury. The same members of the medical department (1 physician and 2 physiotherapists) diagnosed and recorded all the injury data. The medical department performed thorough clinical diagnoses and when necessary, they asked for complementary examinations to confirm an injury.

Statistical Analyses

The incidence of injuries was calculated from the number of injuries per 1,000 training/game hours. Generalized estimating equation (GEE) models, accounting for dependency of within-subject measurements, were used for data analyses. First, we compared weekly workload, ACWR, and injury incidence between the pre-season and competitive periods. Second, we compared variables between injury groups

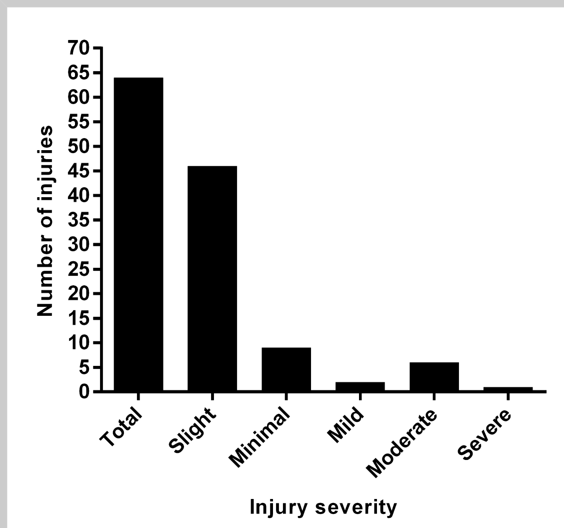

Figure 1. Distribution of injuries according to severity. Injury classification by severity: Slight (no absence), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), and severe (more than 28 days).

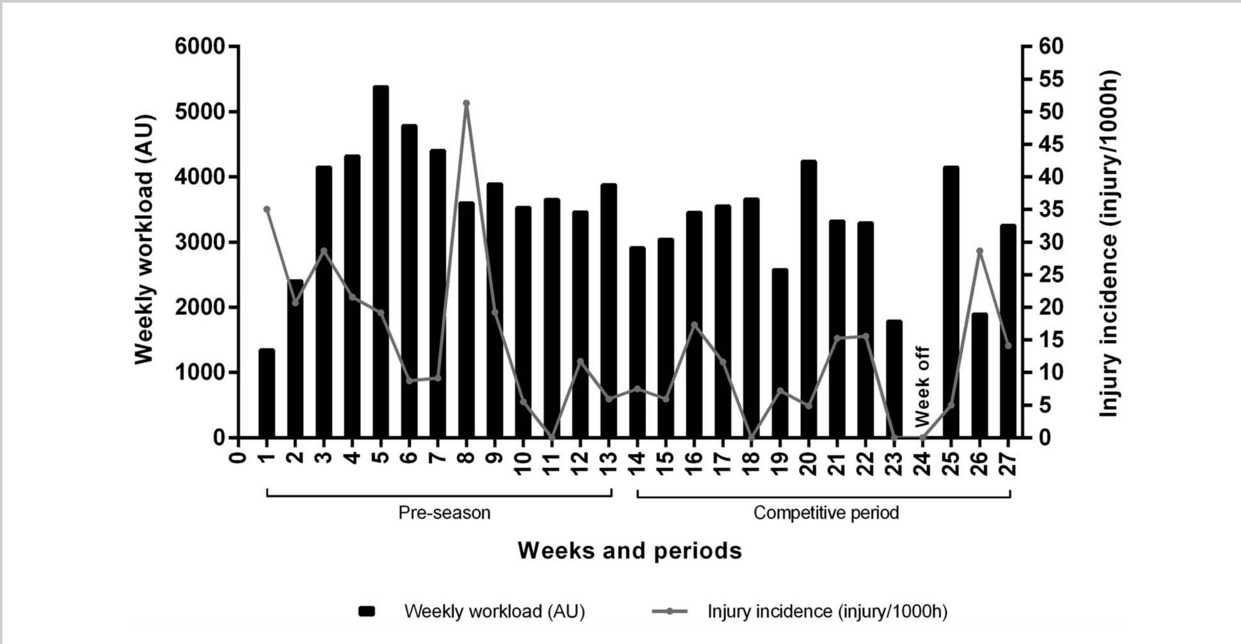

Figure 2. Weekly workload and injury incidence across the 27-week season of elite male volleyball players. AU = arbitrary units.

(no injury, overuse, and trauma) with Bonferroni post hoc test. Cohen's effect size (ES) statistic was also calculated (between 0 and 0.2 = trivial; between 0.2 and 0.6 = small; between 0.6 and 1.2 = moderate; between 1.2 and 2.0 = large; and between 2.0 and 4.0 = very large) (16) for the same variables. Finally, the relationships between ACWR and TQR parameters and their presumed structural correlates were quantified in injury groups (yes or no), using GEE

Table 1. Workload and recovery variables for injured and uninjured players.*

	No injury (NI) ($n = 265$)	Overuse injury (OI) ($n = 47$)	Trauma injury (TI) ($n = 10$)	p, Bonferroni post hoc	Effect size
Session-RPE	4.29 ± 3.81	4.57 ± 1.62	4.38 ± 1.19	0.121	0.07 (NI × OI) 0.02 (NI × TI) 0.05 (OI × TI)
Weekly workload	3,286.24 ± 3,136.82	3,631.17 ± 1756.08	3,240.10 ± 1,072.07	0.278	0.11 (NI × OI) 0.01 (NI × TI) 0.12 (OI × TI)
ACWR	1.00 ± 0.18	1.14 ± 0.24†	1.13 ± 0.38†	†0.002	0.74 (NI × OI) 0.66 (NI × TI) 0.07 (OI × TI)
Monotony	1.34 ± 0.34	1.40 ± 0.41	1.31 ± 0.40	0.565	0.19 (NI × OI) 0.06 (NI × TI) 0.25 (OI × TI)
Strain	4,730.15 ± 4,924.39	5,586.33 ± 3,479.35	4,674.76 ± 2592,43	0.151	0.17 (NI × OI) 0.01 (NI × TI) 0.19 (OI × TI)
TQR	16.67 ± 6.09	15.26 ± 2.66†	14.63 ± 2.20†	†<0.001	0.23 (NI × OI) 0.33 (NI × TI) 0.10 (OI × TI)

*ACWR = acute:chronic workload ratio; Session-RPE = session rating of perceived exertion; TQR = total quality recovery.
†Significant difference between groups. No Injury vs. Injury groups.

models otherwise identical to those used in the group comparison. All analyses were performed in SPSS software version 24.0 (IBM, Corp., Armonk, NY, USA), with a significance level of 5% being adopted.

Results

Injury Causes and Severity

During the study period, 64 injuries occurred, 53 of which resulted from functional overuse, whereas 11 were traumatic injuries. Most of the injuries found (72%, 46 injuries) did not result in missed training or game time (Figure 1).

Injury Incidence

Throughout the evaluated season, the players were exposed to a total of 4,573.31 hours of training and games. From this, an incidence of 13.99 injuries per 1,000 hours was found. Overuse accounted for 83% (11.59 injuries per 1,000 hours), whereas trauma accounted for 17% (2.41 injuries per 1,000 hours) of all injuries. Figure 2 presents the weekly workload and the incidence of injuries throughout the 27-week season.

Difference Between Periods of the Season

The weekly workload of the pre-season (3,492.75 ± 2,320.68 AU) was significantly greater than the competitive period (3,207.02 ± 2,423.04 AU, $p = 0.008$, ES = 0.12–trivial). The ACWR of the pre-season was significantly higher than that of the competitive period (1.10 ± 0.09 vs. 0.96 ± 0.10, respectively; $p < 0.001$, ES = 1.47–large). When comparing the incidence of injuries at different times of the season, a statistically significant difference ($p = 0.003$, ES = 0.75–moderate) was observed, with a higher incidence of injuries in the pre-season (18.04 ± 13.21 injuries per 1,000 hours) compared with the competitive period (9.50 ± 8.12 injuries per 1,000 hours).

Difference Between Healthy and Injured Groups

Significant differences were observed between injured and uninjured groups for workload and recovery (Table 1). Players who sustained injuries (both by overuse or trauma) had higher ACWR and lower TQR scores than uninjured players.

Injury Odds

Table 2 summarizes the logistic regression coefficients and their significance in the multivariate model. Acute:chronic workload ratio and TQR were able to significantly classify players as healthy or injured. The highest probability of injury was related to higher ACWR (risk factor) values and lower values of TQR (protection factor). The odds of injury was 3 times greater in players with higher ACWR values.

Discussion

This study investigated the relationship between workloads, recovery, and injury in elite male volleyball players. Injured players experienced higher values of ACWR, and worse recovery (TQR) than the healthy athletes. Furthermore, rapid increase in weekly workload and lower recovery was associated with a greater odds of injury. These results can be used to guide injury prevention actions in elite male volleyball through the monitoring of player's workload.

Volleyball has a lower incidence of injury compared with other sports, especially those that require greater physical contact (4). A study conducted at the London Olympic Games in 2012 highlighted that 50% of the injuries that occurred in volleyball did not result in missed training or game time (8). Likewise, this study observed a high prevalence of these transient injuries (72%). The inclusion of these injuries may explain the higher incidence of injuries (13.99 injuries per 1,000 hours of training/games) compared with other studies with volleyball players. Nevertheless, Verhagen et al. (24) observed an incidence of 3 injuries per 1,000 hours in 20 teams of professional volleyball. Foss et al. (9) also observed a low incidence of injuries in young female volleyball players (3.6 injuries per 1,000 hours). However, in a study using a similar methodology for the identification of injuries, a similar incidence (10.5 injuries per 1,000 hours) was observed in the main world volleyball championships (4). According to Brink et al. (6), the inclusion of this type of injury presents a more realistic view of the medical problems of the sport because it is common for the player to maintain his or her training routine even if injured.

Overuse was reported as the main cause of sports injuries at the London Olympic Games (8). Soft-tissue injuries that do not involve physical contact often occur as a result of "spikes" in workload, as well as of an inadequate recovery. Most of these injuries are avoidable (11,14). In this study, the increase in injury incidence in the 26th week could be explained by the spike in workload in the week before which players were just coming back from a week off. Debien et al. (7) also highlight that the weeks that succeed weeks off

Table 2. Results of GEE model for injury (trauma or overuse) according to ACWR and TQR.*

Variable	Parameter estimation	*SE*	*p*	Odds ratio (CI 95%)
ACWR	1.321	0.537	0.014	3.74 (1.31–10.73)
TQR	−0.359	0.125	0.004	0.70 (0.55–0.89)

*ACWR = acute:chronic workload ratio; CI = confidence interval; GEE = generalized estimating equation; TQR = total quality recovery scale.

are crucial moments in the season and should be precisely monitored to avoid spikes in workload, which may impair the athlete's recovery. Besides that, the high rates of overuse injuries found in this study point to volleyball as a sport that may benefit from prevention strategies that control workload.

Studies suggest that increased physical stress (i.e., intensity and duration of training sessions and games) is related to increased injury incidence (11,15). Recent studies have also analyzed the ratio between acute and chronic loads (i.e. ACWR) and injury. Higher ACWR have been associated with higher injury risk in rugby league (18), cricket (17), and football (5). Our results also demonstrated this association because higher ACWR increased more than 3 times the odds of injury. Furthermore, injured volleyball players exhibit higher ACWR compared with healthy players. Our finding corroborate the recent literature of sports science stating that "spikes" in workload contribute to injury risk in elite players and highlights the ACWR as a variable of great importance in the workload monitoring related to injury prevention (5,18). In general, the literature indicates the pre-season as a time when players are submitted to the highest workload and, consequently, elevated injury rates have been observed in that period (12,15,20). Possible reasons for these findings are: (a) low fitness at the start of the pre-season, (b) low chronic workload before beginning the pre-season, and (c) "spikes" in weekly workload. Debien et al. (7) found that preparatory periods of a professional volleyball season showed higher ACWR and weekly workload than the competitive periods. In agreement with these results, we observed in this study statistically larger workloads and ACWR in volleyball pre-season, as well as a higher incidence of injury compared with competitive period.

Another important factor influencing sports injuries is the balance between workload and the quality of player recovery. In a study with football players, Brink et al. (6) used the Recovery-Stress Questionnaire for athletes (RESTQ-Sport) to measure recovery, and found no difference between the injured and healthy groups except for the subscale "injuries." It is important to emphasize that this study applied the recovery scale only once each month, and the authors suggested that a greater frequency of data collection may be required to more accurately measure the relationship between recovery and injury. Despite the use of another instrument (TQR), this study performed weekly collections of recovery data and found a difference between injured and healthy groups. Regardless of the cause, the players who suffered injury were less recovered compared with noninjured players. Furthermore, in both groups, the TQR presented values close to the descriptor 15, which means that the players were well recovered (19). In addition, the odds of injury was inversely proportional to the values of TQR (i.e. the less recovered the player, the greater the odds of sustaining an injury). Even without the injury data, a recent investigation with professional male volleyball players found similar results that 2 weeks in a row of recovery decrease (measured with TQR) seem to be related with higher ACWR ($\sim$1.5) (7).

Although our findings provide important new information on the relationship between workload, recovery, and injury in elite volleyball, there are some limitations that warrant discussion. First, it is acknowledged that data were collected on a small sample of players (i.e. one team) and over a short duration (i.e. one season). Furthermore, our findings are specific to elite male volleyball players, and should not be generalized to adolescent or female players. Future studies investigating the relationship between workload, recovery, and injury in volleyball should attempt to use larger samples over a longer period, and include female and adolescent athletes.

This is the first study to investigate the relationship between workload, recovery, and injury in elite male volleyball players. These results demonstrate greater odds of injury in players with higher ACWR and who were less recovered at the beginning of the training week. In addition, players who suffered injuries had higher ACWR than uninjured players in the previous week. Therefore, it is concluded that both workload and recovery status may be related to volleyball injuries. The results presented in this study confirm the importance of managing workload and recovery status in professional male volleyball teams to minimize the odds of injuries.

Practical Applications

This study provides initial guidelines on the relationship between workload, recovery, and injuries in volleyball. These findings can justify daily use of monitoring workload and recovery in elite male volleyball to reduce injury odds. Coaches and medical staff should consider high ACWR and poor recovery as risk factors for injury in elite male volleyball. Special care must be taken during the pre-season because this is the period of highest training loads and also highest injury incidence. By monitoring these variables, strategies can be developed to optimize training load and recovery in professional male volleyball players.

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