Training Load, Physical Performance, Biochemical Markers, and Psychological Stress During a Short Preparatory Period in Brazilian Elite Male Volleyball Players

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Abstract

Horta, TAG, Bara Filho, MG, Coimbra, DR, Miranda, R, and Werneck, FZ. Training load, physical performance, biochemical markers, and psychological stress during a short preparatory period in Brazilian elite male volleyball players. *J Strength Cond Res* 33(12): 3392–3399, 2019—The aim of this study was to assess the relationship between training load (TL) and physical performance, biochemical markers, and psychological stress during a short preparatory period (SPP) in Brazilian elite male volleyball players. Twelve volleyball players from a team competing in the Brazilian Men's Volleyball Super League were enrolled (26.9 ± 4.6 years). Countermovement jump (CMJ), creatine kinase (CK), testosterone (T), cortisol (Cr), T/Cr ratio, and Recovery and Stress Questionnaire for athletes (RESTQ-Sport) were collected at baseline, after second, fourth, and sixth week. Training load was quantified daily using the rating of perceived exertion. Differences were noted between total weekly training load (TWTL) ($F_{3,33} = 50.907$; $p = 0.0001$), CK ($F_{3,33} = 16.157$; $p = 0.0001$), and T ($F_{3,33} = 3.283$; $p = 0.03$). No differences were seen in CMJ ($F_{3,33} = 1.821$; $p = 0.16$), Cr ($F_{3,33} = 2.409$; $p = 0.08$), or T/Cr ratio ($F_{3,33} = 1.527$; $p = 0.23$). The RESTQ-Sport demonstrated differences between moments in social stress ($F_{3,33} = 2.297$; $p = 0.04$; $\eta^2 = 0.25$), success ($F_{3,33} = 4.350$; $p = 0.01$; $\eta^2 = 0.19$), general well-being ($F_{3,33} = 4.465$; $p = 0.01$; $\eta^2 = 0.36$), and injury ($F_{3,33} = 2.792$; $p = 0.05$; $\eta^2 = 0.62$). The results showed a significant correlations of small to moderate magnitude between TWTL and CK ($r = 0.32$; $p = 0.05$). In conclusion, a short PP in volleyball leads to increased TL, CK level, and psychological stress. Training load was related with the increase of CK, suggesting muscle damage without increased physical performance.

Key Words team sports, rating of perceived exertion, creatine kinase, countermovement jump

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Introduction

Training program aims to improve an athlete's performance by breaking the internal balance through a progressive increase in loads (19,23). However, in practice, the demands of professional sports require athletes to achieve optimal performance over a shorter time period (23). Thus, high training loads (TLs) in the preparation period are being used to improve performance (22). Coaches use planning, monitoring, and organization schemes to manage the training program and assess the different responses of athletes (35). To monitoring the internal response and quantifying the TL, in most sports, the session rating of perceived exertion method (session-RPE) was established as a valid and reliable method (15). In volleyball because of a short preparatory period (SPP) and a long competitive period, TL intensification is used to improve physical performance (17). Moreover, the applications of training program induce biochemical and psychological adaptations specific to the developed modality (22). In this sense, the success of training planning in team sports relies upon the correct monitoring and interpretation of the training adaptations using objective data of physical performance, biochemical markers, and psychological variables (3,10,12,24).

In volleyball, the height and number of vertical jumps is central (1,38,46). Specifically, countermovement jump (CMJ) is the key skill of the serve, block, and attack (44). It has already been established in the literature and by sports staff that CMJ is an important physical performance marker of neuromuscular status in team sports (8,39), including volleyball (27,44–46,48). Furthermore, it is sensitive to changes induced to fatigue or overcompensation (8). Studies with volleyball and futsal athletes verified that changes in vertical jump are observed in longer periods of training (17,18,32,39). However, Aoki et al. (1) observed an increase in CMJ after 9 weeks of a preparatory period in U16 and U19 volleyball athletes.

The impact of TL on biochemical markers has also been investigated (32,33,47). The creatine kinase (CK), associated to muscle damage caused by exercise, is used in sport science as a marker to quantify the biochemical responses to changes in the TL (17,40). However, moderate evidence that CK change with acute or chronic TL (40). The CK activity after training seems to vary by exercise type, intensity, and duration as well as the time at which CK is evaluated. Thus, the use of CK to monitoring TL remains under debate (17,32). Testosterone (anabolic), cortisol (catabolic), and testosterone/cortisol ratio (T/Cr) are biochemical markers investigated in the context of sports science associated with stress caused to TL (14,16,32). These measurements reflect metabolic adaptations to TL throughout the different phases of a season in specific sports (29). However, alterations in testosterone and cortisol levels caused by continuous chronic training are still unclear, whereas the T/Cr ratio shows moderate evidence (40).

Self-reported measurements (scales and questionnaires) are valid, practical, and simple for monitoring TL-induced psychological stress (1,17). As they provide relative evidence using different objective measurements (40), the implementation of self-reported measures has been investigated (41,42) and recommended by a large number of studies, included in a recent systematic review (40). The Recovery and Stress Questionnaire for athletes (RESTQ-Sport) has been used for this purpose. The RESTQ-Sport is sensitive to an increase of TL in volleyball (17), and detection of early overreaching in young soccer players (6), and is responsive to acute and chronic TL. Therefore, it is considered one of the most promising self-reporting measures (40).

The need for SPPs in team sport has been noted (17,32). Although, the effects remain inconclusive, the results may help volleyball trainers and sports researchers understand this training program approach. It was hypothesized that increments in the TL during an SPP decrease the physical performance, increase muscle damage and psychological stress, and cause changes in biochemical markers. Thus, the aim of this study was to assess the relationship between TL and physical performance, biochemical markers, and psychological stress during an SPP in Brazilian elite male volleyball players.

Methods

Experimental Approach to the Problem

This 6-week longitudinal study was designed to investigate the TL, physical performance, psychological stress, and biochemical marker status of Brazilian professional elite male volleyball players during the preparatory period. The volleyball players returned from an off-season period during which physical activities were not controlled. The independent variable was the training program implemented during the SPP planned by team staff. This planning was not influenced by the researchers. We analyzed the dependent variables in 4 moments: at baseline, after Training week 2, after Training week 4, and after Training week 6. Each week consisted of resistance training, functional training, technical-tactical training, measurements, and 2 official matches of a preparatory championship (Table 1).

The complete study design is detailed in Figure 1.

Table 1. Schedule of volleyball training sessions in the short preparatory period.*

Day	Period	Week 2	Week 4	Week 6
Monday	Morning	Study collections	Study collections	RT + TTS
	Afternoon	OFF	RT + TTS	TTS
Tuesday	Morning	RT + FT	RT + TTS	RT + TTS
	Afternoon	TTS	Travel	TTS
Wednesday	Morning	RT + TTS	TTS	TTS
	Afternoon	TTS	Official game	OFF
Thursday	Morning	RT	Travel	RT + TTS
	Afternoon	Official game	RT + TTS	TTS
Friday	Morning	OFF	TTS	RT + TTS
	Afternoon	TTS	RT + TTS	TTS
Saturday	Morning	RT + TTS	TTS	TTS
	Afternoon	OFF	OFF	OFF
Sunday	Morning	OFF	OFF	OFF
	Afternoon	OFF	OFF	OFF
N sessions		6	7	10

*RT = resistance training; TTS = technical/tactical skills; FT = functional training.

Subjects

Twelve elite male volleyball players (2 outside hitters, 4 setters, 2 liberos, 2 opposite hitters, and 2 middle hitters) from a team competing in the Brazilian Men's Volleyball Super League were enrolled in the study (mean ± *SD* age, 26.9 ± 4.6 years; mean body mass, 94.9 ± 11.6 kg; mean height, 194.6 ± 8 cm; mean body fat,

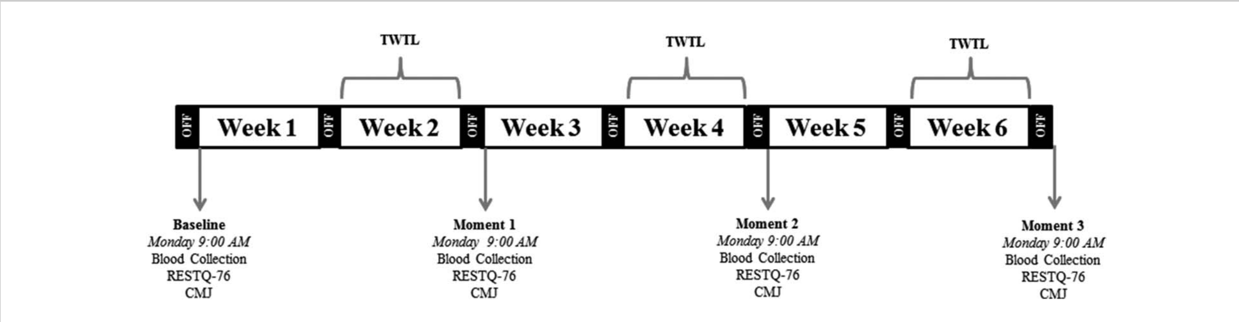

Figure 1. Design of the collection measurements and training load of a short preparatory period in Brazilian elite male volleyball players. TWTL = total weekly training load; RESTQ = Recovery and Stress Questionnaire; CMJ = countermovement jump

14.3 ± 4.8%; mean playing experience, 5 years of official championship). Players trained 5–6 $d \cdot wk^{-1}$ with 1–2 sessions per day for 90–120 minutes per session. Inclusion criteria were attending ≥75% of training sessions, and undergoing all collections. Exclusion criteria were injury or any infectious disease. No athletes were excluded from this study.

The study was approved by the Institutional Local Ethical Committee of Federal University of Juiz de Fora-MG, Brazil (no. 036159/2013) and conducted in accordance with the Declaration of Helsinki. The study proposal was presented to the players, and the possible risks and benefits were explained before their participation. Each athlete signed a written consent form to confirm their voluntary participation and approved the use and disclosure of their information for research purposes.

Procedures

The investigators of the present study had no influence on TL intensification, which was stipulated by the team staff. We analyzed a 6-week SPP. The physical and psychological tests and blood collections were performed on the first day of training (baseline). Thereafter, we performed more 3 collections (M2, M3, and M4) of the same measurements at 14-day intervals. The collections were always made on the same day at the same time (Monday–9:00 AM), approximately 36 hours after the last training session. The TL was monitored using the session-RPE.

Measurement: Training Load. The TL was quantified daily using the session-RPE (15). The athletes answered the question "How was your workout?" by marking their answer on the 10-point RPE scale (2). The product between the value found on the RPE scale and the time of training in minutes was calculated for each session to establish the TL. Values are given in arbitrary units (A.U.). On days with 2 or more training sessions, the TLs were summed to determine daily TL. Total weekly TL (TWTL) was calculated using the sum of all TLs in a week. We analyzed the TWTL of Training week 2, Training week 4, and Training week 6 because these are anterior to the measurement collections.

Physical Performance. First, the athletes performed 15-minute warmup drills that included jogging, jumps, and active stretching. The countermovement jump (CMJ) tests were performed on a jump mat (Cefise, Nova Odessa, Brazil). The maximum jump height was calculated using proprietary software (Jump System 1.0; Cefise, Nova Odessa) based on the flight time of the jumps using the following equation: $h = gt^2/8$, where $g = 9.81\ m \cdot s^{-2}$. The best of 3 jumps was retained for the analysis. The CMJ started in the upright position after a rapid downward phase (no arm swing)(35). The athletes were required to jump vertically with an explosive movement as high as possible. The interval between successive trials was 180 seconds.

Biomarker Status. Blood collection for biochemical markers status was performed by a trained nurse according to the required biosecurity principles. Ten milliliters of blood were collected from the antecubital vein, stored in tubes with a gel separator, and taken to the laboratory to be analyzed the same day. For T, Cr, and CK, the blood sample was centrifuged for 10 minutes at 2,500 rpm, and the obtained serum was analyzed using specialized equipment (Biochemistry 3000 BT Plus kit; Beckman Coulter, Brea, CA, USA). The laboratory has a quality system certified by ABNT/INMETRO/ISO 9001/2000.

Psychological Stress. The RESTQ-Sport was used to assess psychological stress and recovery. The questionnaire has been validated and applied in previous investigations (17,38). The RESTQ-Sport comprises general dimensions of stress and recovery and specific dimensions about the somatic, emotional, behavioral, and social aspects of the stress and recovery processes in sports. It consists of 76 items on 19 subscales with 4 items each. Each item is rated on a Likert-type scale with 7 values ranging from 0 (never) to 6 (always). These items are intended to assess how often the athlete experienced a particular state during the preceding 3 days and nights. The stem of each item is "In the past 3 days per night…." The questionnaire also consists of 19 scales, 7 of

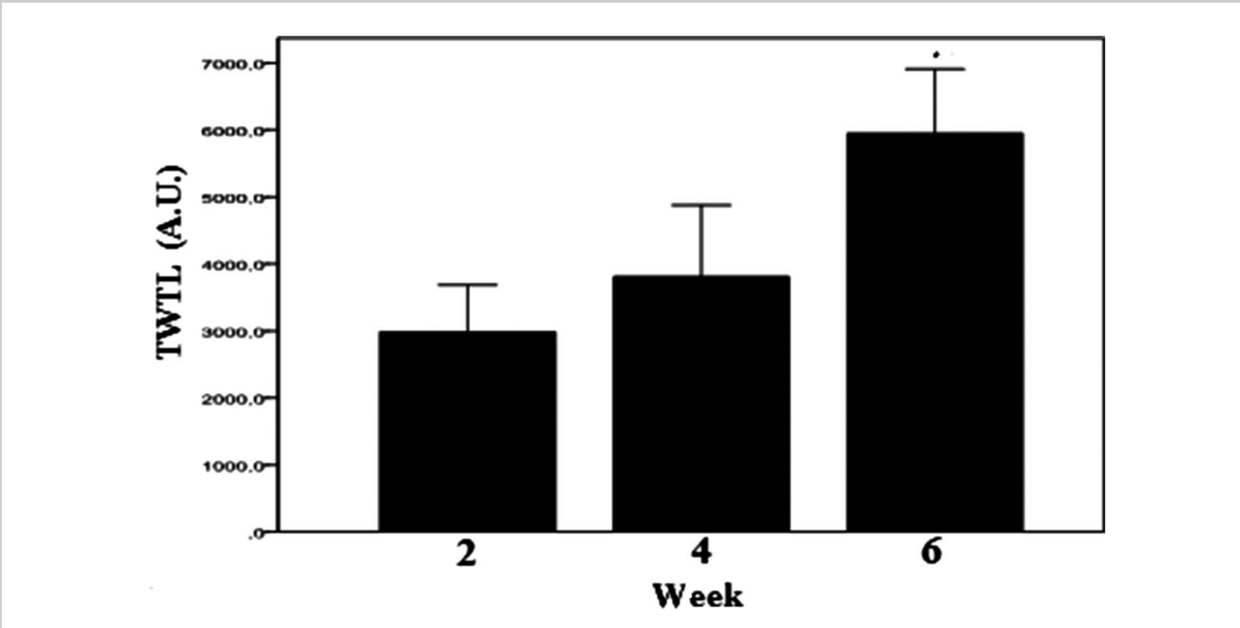

Figure 2. Total weekly training load (TWTL) monitoring of week 2, week 4, and week 6 in a short preparatory period of Brazilian elite male volleyball players. *Significantly different (ANOVA repeated measures) from week 2 and 4; values represent mean ± *SD*.

which are related to general stress subscales (general stress, emotional stress, social stress, conflict/pressure, fatigue, lack of energy, and physical complaints), 5 general recovery subscales (success, social recovery, physical recovery, general well-being, and sleep quality), 3 sport-specific stress subscales (disturbed breaks, emotional exhaustion, and injury), and 4 sport-specific recovery scales (being in shape, personal accomplishment, self-efficacy, and self-regulation).

Statistical Analyses

The data are presented as mean ± *SD*. The data normality was tested using the Shapiro-Wilk test and sphericity of the variance-covariance matrix by Box's M. Repeated measures analysis of variance was used to compare these variables between the different collection times. Bonferroni's honestly significant difference test was used as the post hoc procedure when a difference was detected. Pillai's trace was used for the

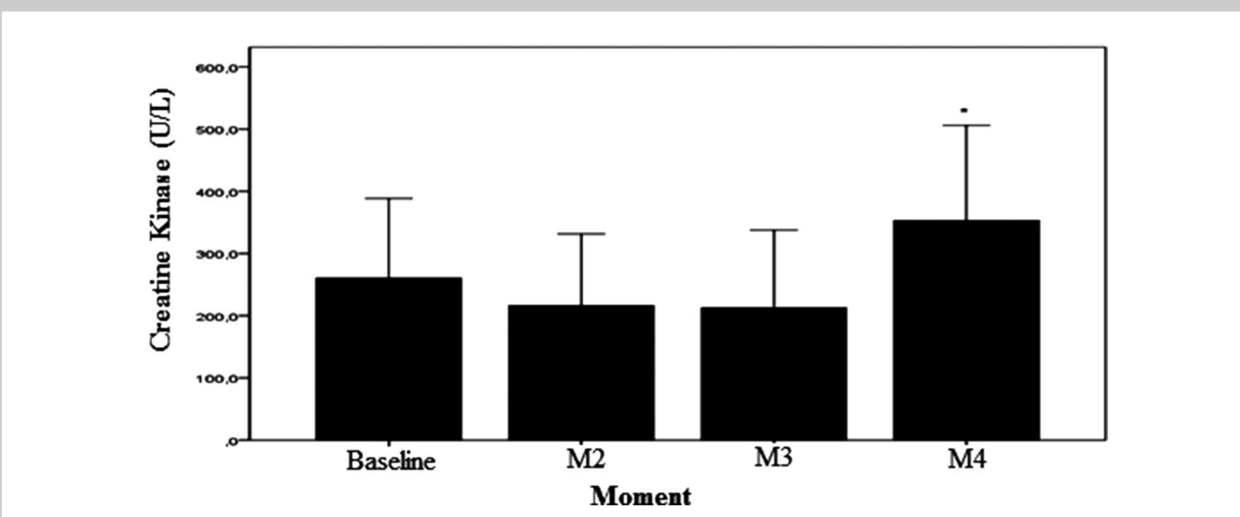

Figure 3. Creatine kinase (CK) level throughout different moments of a short preparatory period in Brazilian elite male volleyball players. *significantly different (ANOVA repeated measures) from baseline, moment 2, and moment 3; values represent mean ± *SD*.

TABLE 2. Countermovement, testosterone, cortisol, and T/Cr in 4 different moments of short preparatory period.*†

	Baseline	M2	M3	M4
Countermovement (cm)	46.92 ± 5.75	45.55 ± 6.16	46.91 ± 5.95	46.94 ± 5.92
Testosterone ($ng \cdot dl^{-1}$)	511 ± 100	559 ± 122	487 ± 117	549 ± 61
Cortisol ($ng \cdot dl^{-1}$)	17.3 ± 7.1	15.5 ± 6.1	14.2 ± 3.6	13.8 ± 3.8
T/Cr	34.8 ± 15.8	39.6 ± 12.7	36.1 ± 12.5	42.3 ± 11.6

*M = moment; T/Cr = testosterone/cortisol ratio.
†Values represent mean ± *SD*.

F statistic. When sphericity was violated, the Epsilon correction factor of Huynh-Feldt was used. Relationship between variables was assessed using Pearson's coefficient. The correlation coefficient strength was interpreted as described by Hopkins et al. (21): 0–0.3 was small, 0.31–0.49 was moderate, 0.5–0.69 was large, 0.7–0.89 was very large, and 0.9–1 was considered nearly perfect. All statistics were analyzed using SPSS software (version 19; SPSS, Inc., Chicago, IL, USA). In all cases, the level of significance was set at 5% ($p \leq 0.05$).

RESULTS

Figure 2 shows the monitoring TWTL of week 2, week 4, and week 6. The results demonstrated main effects over time ($F_{3,33} = 50.907$; $p = 0.0001$) in TWTL between the weeks analyzed in an SPP. The TWTL increased progressively from week 2 (2.981 ± 702 A.U.) to week 6 (5.942 ± 962 A.U.). There was a difference between week 4 and week 6; however, no difference was observed between week 2 and week 4.

Figure 3 shows the CK level throughout the SPP. Creatine kinase level varied significantly over time ($F_{3,33} = 16.157$; $p = 0.0001$). The CK level at week 6 (353 ± 152 $U \cdot L^{-1}$) showed the greatest change from baseline (260 ± 128 $U \cdot L^{-1}$) vs. those of week 2 (216 ± 115 $U \cdot L^{-1}$) and week 4 (212 ± 125 $U \cdot L^{-1}$).

The comparisons of CMJ ($F_{3,33} = 1.821$; $p = 0.16$), Cr ($F_{3,33} = 2.409$; $p = 0.08$), and T/Cr ratio ($F_{3,33} = 1.527$; $p = 0.23$) did not reveal differences between the 4 moments analyzed in the SPP (Table 2). T ($F_{3,33} = 3.283$; $p = 0.03$) differed on multivariate analysis; however, no difference was observed in the post hoc analysis.

Regarding psychological stress during the SPP, comparisons of the RESTQ-Sport demonstrated the following differences: increase in social stress ($F_{3,33} = 2.297$; $p = 0.04$; $\eta^2 = 0.25$) and injury ($F_{3,33} = 2.792$; $p = 0.05$; $\eta^2 = 0.62$) and reduction in perception of success ($F_{3,33} = 4.350$; $p = 0.01$; $\eta^2 = 0.19$) and general well-being ($F_{3,33} = 4.465$; $p = 0.01$; $\eta^2 = 0.36$). No differences were observed on the other scales. The general well-being value was lower at weeks 2 and 6 than at baseline. The Injury at week 4 was larger than that at baseline.

When we performed the Person's correlation analysis of training load (TWTL), physical performance (CMJ), biochemical markers status (T, Cr, T/Cr ratio, and CK), and psychological stress (RESTQ-Sport), we detected a statistically significant correlation of small to moderate magnitude between TWTL and CK ($r = 0.32$; $p = 0.05$; $n = 36$) at a determination coefficient of 10%. This means that around 10% of the variability in CK could be explained by the training load, which makes us think about the real influence of the result found in practical terms regarding the training process.

DISCUSSION

This study showed an expected increase of TL and CK values during an SPP in Brazilian elite male volleyball players. The results in RESTQ-Sport indicate an increase in psychological stress (increase in social stress and injury with reduction in success and general well-being). However, no significant change was noted in CMJ, T, Cr, and T/Cr ratio, and a small-to-moderate magnitude correlation was found between TL and CK. Thus, our hypothesis was partially confirmed.

The progressive increase in TL demonstrated in this study is in accordance with those reported in other studies of team sports during preparatory period (27,33). Although a progressive increase in TL was expected and customary in the preparatory period for team sports (33), such increases did not affect physical performance, biochemical markers, or psychological stress. In the competitive season, when a TL is deliberately reduced ("tapered") by team staff (17,33), these variables are expected to change (32). However, this deliberate increase in TL without the proper monitoring and control of physical performance, biochemical markers, and psychological effects (the situation of several teams in Brazilian elite sports) can lead to nonfunctional overreaching (10,20,31).

The CMJ results noted here are in accordance with those of other previous studies in team sports (7,17,26,32,47). Similar results were found by Coutts et al. (10) with rugby players and Freitas et al. (17) with volleyball players. Other studies show that the CMJ in the short term does not improve at times of intensified TL, as observed in the preparatory period in volleyball (17) or in-season training microcycles in elite soccer (25). Sheppard et al. (43) found a significant increase in CMJ in volleyball athletes during a 12-month training period. Similarly, some periodization models indicate that an increase in physical performance will occur during the season (4,23,32). Successive weeks with high loads preceding weeks in which the load is tapered result in a gain in CMJ performance (8).

Changes in the T/Cr are associated with a shift in cellular catabolism and anabolism (13,32). In the sports training process, the T/Cr ratio decrease is associated with overreaching (10,11). However, the impact of training load on hormonal responses was previously demonstrated with varied results in relation to the time period analyzed and types of sports modalities (10,12,14,17,20,33,47). In this study, T, Cr, and T/Cr ratio did not change significantly during the SPP. Similarly, Coutts et al. (10) found no difference in T or Cr during a 6-week deliberate overreaching training period in rugby athletes. By contrast, Cordova et al. (12) observed an increase in cortisol levels in volleyball athletes after a 4-month season of training and competition relative to basal levels. By contrast, Mazon et al. (30) reported decreased levels of cortisol and increased free testosterone and T/Cr ratio after 12 months of training in volleyball athletes undergoing selective loads using a periodization model. Thus, our results suggest that SPP was not sufficient to promote a disturbance in the balance of the immune system.

An increase in CK was observed after a preparatory period, suggesting a catabolic state and increased muscular damage. Freitas et al. (17) described an increase in CK after an intensification period in volleyball, and Cordova et al. (12) found that CK levels were significantly higher at the end of the volleyball season. However, a 4-month period was analyzed. In our study, the blood collection was performed approximately 36 hours after training at 14-day intervals. Thus, we speculate that this reflects the CK accumulation over the last week. However, the acute and chronic effects of training raise important questions in the field of sport periodization (5,19,23,43,44).

As expected, psychological stress was increased at the end of the preparatory period. In the evaluation of subjective stress and recovery of athletes using the RESTQ-Sport, 4 of the 9 scores (social stress, success, general well-being, and injury) showed significant increases during the SPP. Freitas et al. (17) found an increase in the fatigue, self-efficacy, and injury scores during an enhanced schedule of training in male volleyball players during the preparatory period, whereas Noce et al. (36) reported that the general well-being and injury scores increased during the training period, compared with those at rest during a volleyball session. Overall, the results of this study suggest that the RESTQ-Sport is sensitive to an increase in the training load. Thus, we agree with other studies of team sports that RESTQ-Sport is a practical tool for early detection of overtraining syndrome (6) and can be useful for coaches in monitoring stress and recovery in the preparatory period and in-session training (9,40). However, because of the high number of items ($n = 76$), for practical use, we should consider applying the RESTQ-Sport independent subscales, which may offer greater sensitivity and utility for monitoring athlete stress and recovery.

A small-to-moderate magnitude correlation (21) was found between TWTL and CK, similarly to Freitas et al. (17). The CK increased significantly from the baseline value after the sixth week of the SPP. The week with the highest TWTL load accumulation of 5,942 (A.U.) was also that with the highest mean CK value. CK is an important marker of muscle wasting because its increased plasma blood plasma levels may correspond to a state of muscle damage because of TL accumulation (29,44). According to Hartmann and Mester (20), CK values between 200 and 250 $U \cdot L^{-1}$ are considered normal for male athletes. According to Martínez-Amat et al. (28), values >500 $U \cdot L^{-1}$ can be used as parameters to indicate the presence of muscle damage. Silva et al. (47) reported average values (CK, 337 $U \cdot L^{-1}$) 30 days into the competitive period. Studying soccer players, Freitas et al. (17) presented values between 231 and 671 $U \cdot L^{-1}$ during the 21-day preparatory period. These serum concentrations of CK remain elevated for a few days, thus reflecting the cumulative effect of previous training sessions.

Saw et al. (40) showed moderate evidence of association in the general stress and emotional stress scales between the RESTQ-Sport and CK. Although an association between RESTQ-Sport and TL and between CK and TL was found, this study did not find an association relation between RESTQ-Sport and CK as expected.

This study analyzed only an SPP of a Brazilian elite volleyball team. Nevertheless, this is common for most volleyball teams in Brazil. Another limitation was that we did not continue monitoring all season long. However, the aim of this study was to provide an analysis of the preparatory period, crucial to competitive period success. Controlling variables (food intake, sleep, medication, and rest activities) may also be a limitation of this study, although in other studies (32), such control improves the study's ecological validity.

In conclusion, the results of this study showed greater TL at the end of the volleyball preparatory period. Creatine kinase and psychological stress (Social Stress, Success, General Well-being, and Injury) followed the same pattern. By contrast, CMJ and hormonal responses (T, Cr and T/Cr ratio) did not change after an SPP. Future research could compare preparatory periods with different durations and distinct periodization models to verify the findings.

Practical Applications

An SPP is needed in elite sports. However, the presented study showed that an SPP was sufficient to increase the perceived TL, CK, and psychological stress, but no changes were observed in physical performance of elite volleyball athletes. Furthermore, the results demonstrated that an increase in perceived TL was related with the increase in CK. Monitoring TL with a simple tool like the RPE-session may help coaches control preparatory period outcomes and avoid negative results such as injuries or overtraining. Although physical performance did not increase in the period studied (believed to occur in-session), we suggest that coaches and staff should plan and organize training in the preparatory period using intensified loads, because the monitoring of a training load with least psychological stress makes it possible to avoid overtraining syndrome.

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