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Analyzing the seasonal changes and relationships in training load and wellness in elite volleyball players

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Abstract

The purposes of this study were to: i) analyze the variations of acute and chronic training load and well-being measures during three periods of the season (early, mid and ending); and ii) test the associations between the weekly training load and well-being measures during different periods of the season and overall. Thirteen professional volleyball players from a team competing in the 1st Portuguese volleyball division (age: 31.0 $\pm$ 5.0 years; height: 1.94 $\pm$ 0.07 m; body mass: 88.9 $\pm$ 7.6 kg) were monitored during an entire season. Weekly acute (wAL) and chronic load (wCL), acute:chnonic workload ratio (wACWL) and training monotony (wTM) were calculated during all weeks of the season. The weekly values of muscle soreness (wDOMS), stress (wStress), fatigue (wFatigue), sleep (wSleep) and hooper index (wHI) were also obtained across the season. The mid-season had meaningfully low values of wAL (-26.9%; ES [effect size]: -1.12) and wCL (-28.0%; ES: -2.81), although had greater values of wACWL (+38.9%; ES: 2.81) compared to early season. The wCL (+10.6%; ES: 0.99), wStress (44.6%; ES: 0.87) and wHI (29.0%; ES: 0.62) were meaningfully greater during the end of season than in mid-season. Overall, wAL presented very large correlations with wDOMS (r = 0.80), wSleep (r = 0.72) and wFatigue (r = 0.82), however wCL, wACWL and wTM did not present meaningful associations with well-being variables. The results of this study suggest that the load was meaningfully higher during early season, however stress was higher during the final stages of the season. Overall, it was also found that the acute load is more highly correlated with well-being status and its variations, than chronic load or training monotony.

Keywords: load monitoring; workload; well-being; sports training

Introduction

Utilization of valid and reliable practical tools is imperative for monitoring the training load imposed on the athlete during training sessions, and a fundamental prerequisite to success (1). In fact, monitoring the training load contributes to assuring adequate training adaptation prior to competition, reduces overtraining, and minimizes the risk of nonfunctional overreaching, injury or illness (1,2). Thus, due to the obligations and potential stressors during the season, it is important to monitor player training load and well-being status fastidiously (3). Moreover, monitoring subjective wellness may assist the individualization of training prescription (4).

Recent studies have reported significant relationships between training load and perceived fatigue, muscle soreness, sleep and stress (4–7); primarily considering the increases of training load and the consequences in muscle soreness (8). Moreover, an inappropriate training load can impair improvement in several performance-related physical fitness variables, such as aerobic capacity or strength (9). Most of the available evidence regarding the impact of training in repetitive-explosive sports, such as volleyball, is related to specific parts of the season (10). For instance, it has been reported that monitoring weekly training load has a positive relationship with players wellness status pre and in-season; while in the final month of the season, weekly training load has been associated with increased stress and fatigue levels (11).

Jumping capacity is asserted as one of the most important physical attributes of volleyball players, and given that actions involving vertical jumps occur with elevated frequency in a typical volleyball match (12), a congested match-schedule might conceivably affect volleyball players' workload, recovery, and well-being (13).

There is currently a paucity of investigations assessing volleyball training load and well-being over a season. To the best of our knowledge, previous studies have compared the well-being responses and physical performance in two youth male volleyball teams (i.e. U16 and U19) during 9-week in-season period (14). Results revealed that the U16 group had a higher value for the total mood disturbance and for respective subscales, tension, depression, anger, and fatigue; whilst the vertical jump performance increased following a nine-week training period for U16 and U19 groups (14). Moreover, Clemente et al. (9) investigated the relationships and variance between perceived internal load and wellness status of elite male volleyball players, revealing moderate-to-large correlations between weekly training load and perceived status of muscle soreness, fatigue and stress, and stronger correlations with weekly training loads than daily training load. In addition, Debien et al. (15), in a study that assessed the distribution of internal training load, recovery, and physical performance of professional volleyball players throughout one season, highlighted that, despite the decrease in internal training load during the main competitive period, the correct distribution of weekly internal training load seems is likely very important to optimize recovery of athletes.

Whilst the aforementioned research of Clemente et al and Debien et al, respectively (10,15), has provided informative additions to the literature, there remains a lack of analysis of training load variations during a full-season in professional players, namely, considering the relationships between acute and chronic load with well-being variables. Such analysis is of great practical utility for coaches to effectively manage the progression in training load and adjust the accumulated stimulus to have improvements and avoid injurious acute responses, such as; muscle soreness, sleep, fatigue or stress. Therefore, the purpose of this study was to analyze the variations of acute and chronic training load and well-being measures during three periods of the season (early, mid and ending) and investigate the associations between the weekly training load and well-being measures during different periods of the season and overall.

Methods

Participants

This study included thirteen professional volleyball players in a team competing in the 1st Portuguese volleyball division (age: 31.0 $\pm$ 5.0 years old; height: 1.94 $\pm$ 0.07 m; body mass: 88.9 $\pm$ 7.6 kg). The team reached the finals of the first league in the season. All the players were monitored for perceived effort and well-being status throughout the season, incorporated into their daily routines. The players were monitored over 36 consecutive weeks, including 237 training sessions and 37 official matches. For each week the following inclusion criteria for participating in the study were: i) having clearance to participate in all the training sessions without limitations; ii) players' participation in more than 80% of the training sessions of the week; iii) playing at least 50% of the time in the official weekly matches. All the players voluntarily participated in the study and were previously informed about the study design, implications, risks and benefits, and prior to study commencement, informed consent was attained. The ethical standards for the study in human beings were accomplished as recommended by the Declaration of Helsinki.

Study design

A descriptive longitudinal approach was conducted in this study. An analysis of variation tested the differences of training load and well-being measures between three periods of the season (early [first 11 weeks – 4 weeks of October, 5 weeks of November and 2 weeks of December], mid [second 11 weeks – 2 weeks of December, 4 weeks of January, 4 weeks of February and 1 week of March] and ending [last 11 weeks – 4 weeks of March, 4 weeks of April and 3 weeks of May]). The month of September was not included because it corresponded to pre-season (4 weeks, 34 training sessions and 0 matches). However, the accumulated load was considered to calculate the acute:chronic workload ratio of the first weeks of October. A correlational research design tested the associations between weekly training load measures and the well-being measures during the season. The players were monitored daily across the entire season (Table 1). However, the acute:chronic workload ratio data were considered only beginning after the fourth week of the season. The internal load was assessed using the 10-point scale of rating of perceived exertion multiplied by the length (minutes) of training or match (16). The training load measures of acute load, chronic load, acute:chronic workload ratio and training monotony were calculated weekly (1). The well-being status was assessed daily using the Hooper questionnaire (17) that rates the stress, fatigue, sleep and muscle soreness (DOMS) levels. The ecological validity of the study was ensured, and the researchers did not interfere were daily planning and training routines.

Table 1. Characterization of the number of weeks, training sessions and matches during the season.

	October	November	December	January	February	March	April	May
Weeks (n)	4	5	4	4	4	5	4	3
Sessions (n)	31	31	20	29	21	31	27	13
Matches (n)	2	5	5	5	6	6	6	2

Training load monitoring

The Foster 10-point scale (16) was used to monitor the perceived effort of the players after each training session. The ratings were made approximately 30 minutes after each session, in response to the question "how hard was the training session?" The scale varied between 1 (very light activity) to 10 (maximal exertion) and was applied by the same researcher in each training session and game. Players' S-RPE values were collected individually to minimize potentially confounding caused by listening to how other players rated their perceived exertion. All players were familiarized with the scale before the study began (one dedicated session of training about the scales), to maximize the accuracy of the answers.

The collected S-RPE scores were then multiplied by the duration of the session or match in minutes (18), which provided the training and game loads. Subsequently, the following variables were calculated (1): i) the weekly acute training load (wAL), which represents the sum of all training loads of the week; ii) the weekly chronic training load (wCL), which represents the rolling average of training load experience in the previous 4 weeks; iii) the acute:chronic workload ratio (wACWL), that represents the wAL divided by the wCL; and iv) the weekly training monotony (wTM), that represents the mean workload attained across the all training sessions and matches of the week divided by the standard deviation. All variables were calculated in each week of the experimental period.

Well-being monitoring

The Hooper questionnaire, consisting of four items (stress, fatigue, sleep and DOMS) (17), was administered every morning before training sessions. The scale ranged from 1 (very, very low) to 7 (very, very high) for stress, fatigue and DOMS categories, concordant to previous studies (19). In the specific case of sleep quality, the 1 represented very, very good and 7 very, very bad. The Hooper index was calculated for each day, representing the sum of the four rates (i.e. the rate for each item) of the day (11). The same researcher applied the questionnaire and the answers were recorded individually, similarly to training load measures. For each category, the weekly value was calculated based on the sum of all rates of the week.

Statistical analysis

The results were expressed as mean, standard deviation and confidence intervals, unless otherwise stated. The associations between training load measures and well-being variables were made by using the Pearson's correlation test (r) after confirmation of the assumptions of normality of the data The magnitude of the correlations were defined as follows (20): r<0.1, trivial; 0.1<r≤0.3, small; 0.3<r≤0.5, moderate; 0.5<r≤0.7, large; 0.7<r≤0.9, very large; r≥0.9, nearly perfect. The correlations were always represented with90%. confidence intervals. Within-group changes across the three in-season periods were assessed using a one-way ANOVA followed by Tukey post hoc. Partial eta squared (η^2) and standardized effect sizes of Cohen (d) were calculated for subsequent pairwise comparisons. The normality and homogeneity of the sample were tested and verified before executing the inferential tests. The Hopkins' benchmarks were used for the interpretation of the inferences about the of the effect size magnitude (21): d<0.2, trivial; 0.2<d≤0.6, small; 0.6<d≤1.2, moderate; 1.2<d≤2.0, large; d≥2.0, very large.

Results

Weekly acute and chronic load and well-being variations across the season is displayed in figure 1. The highest weekly acute and chronic load, respectively, occurred in week 2 (wAL: 4260.8 A.U.; wCL: 3770 A.U.) and the lowest in week 17 (wAL: 963.2 A.U.; wCL: 2042 A.U.). Coincidently, the lowest weekly values of DOMS (5.5 A.U.), sleep (5.1 A.U.), fatigue (5.3 A.U.), stress (5.6 A.U.) and HI (21.5 A.U.) were observed in the week 17. On the other hand, the highest weekly values of DOMS (25.5 A.U.), sleep (19.3 A.U.), fatigue (23.0 A.U.) and HI (88.2 A.U.) were found in week 23. The highest weekly stress was observed at week 26 (23.2 A.U.).

(a)

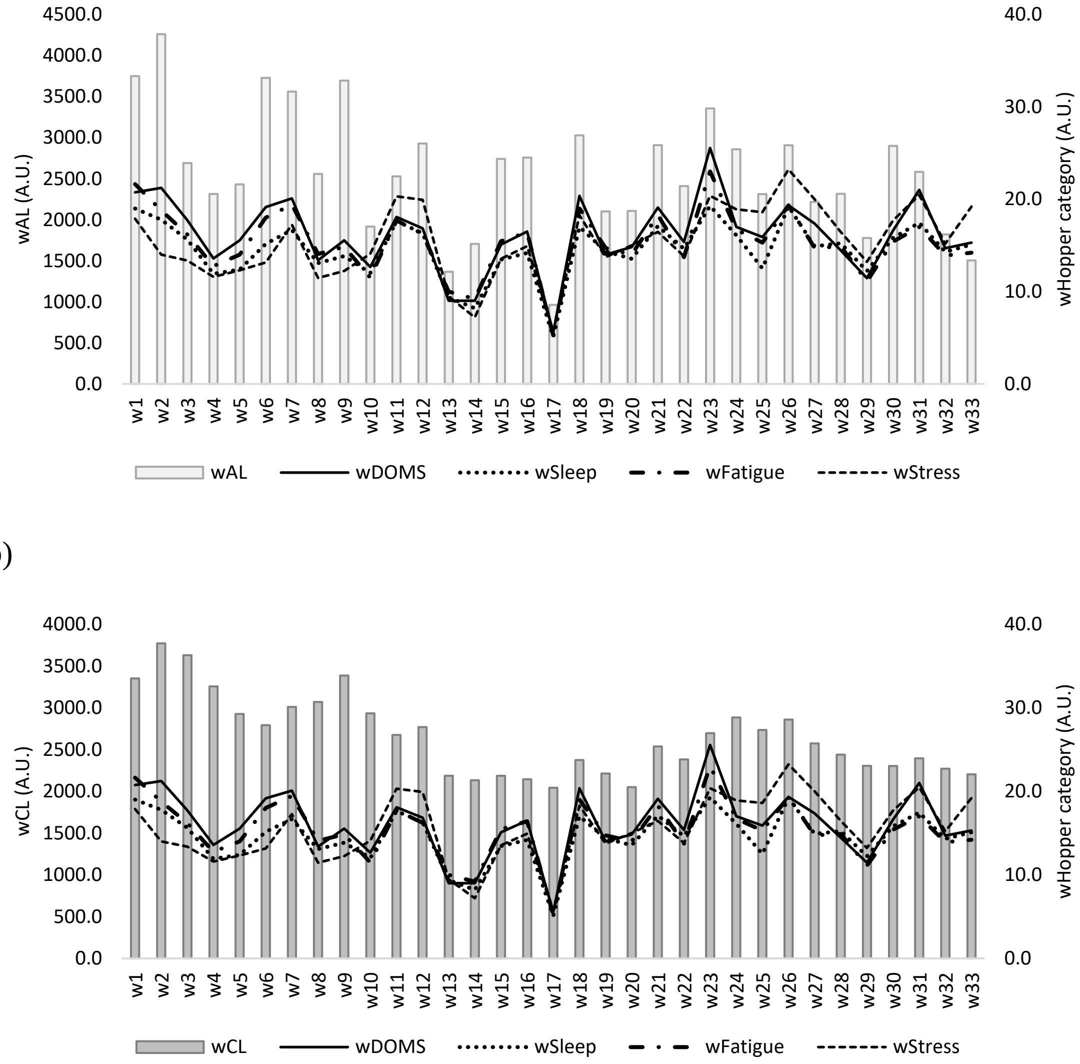


Figure 1. Descriptive statistics of (a) wAL and (b) wCL and their variations during the season considering the weekly averages of well-being categories (Hopper)

Figure 2 demonstrates that the highest weekly ACWL was achieved in week 17 (1.84 A.U.) and the lowest in week 2 (0.99 A.U.). The highest weekly training monotony was achieved in week 1 (7.6 A.U.) and the lowest in week 27 (2.0 A.U.).

(a)

(b)

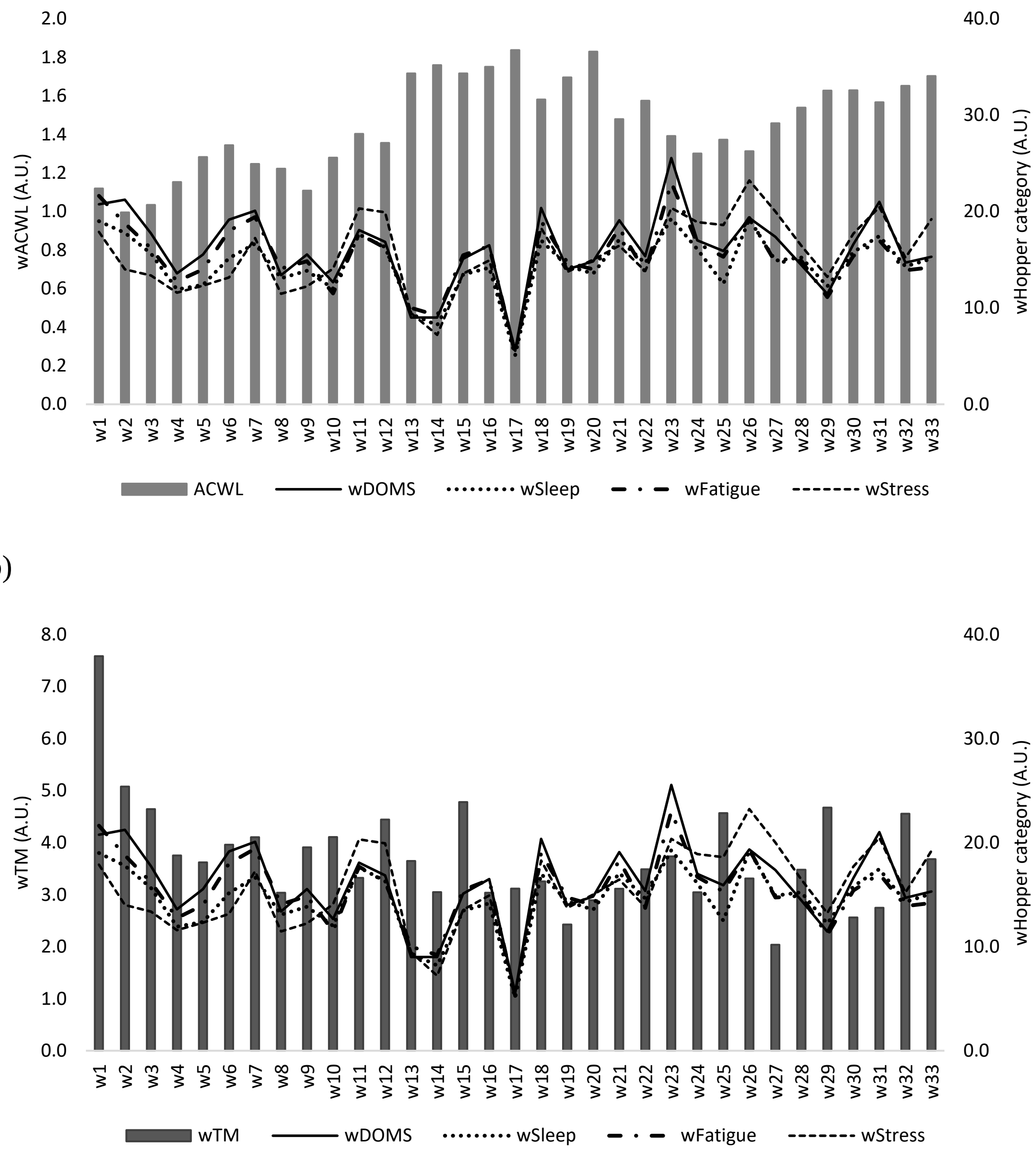


Figure 2. Descriptive statistics of (a) wACWL and (b) wTM and their variations during the season considering the weekly averages of well-being categories (Hopper)

The 33 weeks included in this study were segmented into three periods of the season (early, mid and ending). The comparisons of training load and well-being variables between those periods of the season are detailed in tables 2, 3 and 4.

The repeated ANOVA revealed differences between season periods in the variables of wAL (p = 0.031; η^2 = 0.207), wCL (p = 0.001; η^2 = 0.670), wACWL (p = 0.001; η^2 = 0.674), wStress (p = 0.04; η^2 = 0.309). No differences between season periods were found in wTM (p = 0.072; η^2 = 0.161), wDOMS (p = 0.132; η^2 = 0.126), wSleep (p = 0.117; η^2 = 0.133), wFatigue (p = 0.225; η^2 = 0.095) and wHI (p = 0.096; η^2 = 0.145).

The mid-season had meaningful and low values of wAL (-26.9%; ES: -1.12, *large effect*) and wCL (-28.0%; ES: -2.81, *very large effect*), although had greater values of wACWL (+38.9%; ES: 2.81, *very large effect*) compared to early season.

Table 2. Differences between early and mid-season considering the training load and well-being variables.

	Early season (ES) M(SD)	Mid-season (MS) M(SD)	% difference (MS-ES)	*p-value*	Standardized difference (MS-ES) and inference
wAL (A.U.)[a]	3039.71 (770.82)	2274.35 (692.44)	-26.9 [-45.6;-1.9]	0.040	-1.12 [-2.17;-0.07] *Large*
wCL (A.U.)[a]	3162.78 (345.92)	2273.47 (222.33)	-28.0 [-33.7;-21.8]	0.001	-2.81 [-3.51;-2.10] *Very large*
wACWL (A.U.)[a]	1.10 (0.13)	1.66 (0.15)	38.9 [27.9;50.9]	0.001	2.81 [2.10;3.51] *Very large*
wTM (A.U.)	4.28 (1.23)	3.39 (0.69)	-19.9 [-28.7;-10.1]	0.106	-0.84 [-1.28;-0.40] *Moderate*
wDOMS (A.U.)	17.07 (3.09)	14.15 (4.54)	-20.8 [-39.3;3.5]	0.253	-1.16 [-2.48;0.17] *Moderate*
wStress (A.U.)	14.33 (2.89)	13.45 (4.42)	-10.2 [-27.1;10.5]	1.000	-0.53 [-1.54;0.49] *Small*
wFatigue (A.U.)	16.26 (3.11)	13.85 (4.14)	-18.0 [-36.6;6.1]	0.343	-0.94 [-2.16;0.28] *Moderate*
wSleep (A.U.)	15.01 (2.53)	13.02 (3.86)	-16.7 [-34.3;5.5]	0.390	-1.00 [-2.29;0.29] *Moderate*
wHI (A.U.)	61.82 (11.57)	54.46 (16.68)	-15.4 [-33.8;8.1]	0.616	-0.82 [-2.02;0.38] *Moderate*

wAL: weekly acute load; wCL: weekly chronic load; wACWL: weekly acute:chroni work load; wTM: weekly training monotony; wDOMS: weekly muscle soreness; wStress: weekly stress; wFatigue: weekly fatigue; wSleep: weekly sleep; wHI: weekly hooper index

End of season had meaningful and greater values of wACWL (+25.7%; ES: 1.95, large effect) and wStress (+29.8%; ES: 1.27, large effect), however smaller values of wCL (-20.4%; ES: -1.95, large effect), in comparison to early season.

Table 3. Differences between early and mid-season considering the training load and well-being variables.

	Early season (ES) M(SD)	Ending-season (ES) M(SD)	% difference (ES-ES)	*p-value*	Standardized difference (ES-ES) and inference
wAL (A.U.)	3039.71 (770.82)	2413.99 (586.63)	-20.3 [-31.8;-6.9]	0.119	-0.81 [-1.37;-0.26] *Moderate*
wCL (A.U.)	3162.78 (345.92)	2514.30 (245.78)	-20.4 [-23.5;-17.2]	0.001	-1.95 [-2.29;-1.61] *Large*
wACWL (A.U.)	1.10 (0.13)	1.50 (0.14)	25.7 [20.7;30.8]	0.001	1.95 [1.61;2.29] *Large*
wTM (A.U.)	4.28 (1.23)	3.49 (0.87)	-18.5 [-30.6;-4.4]	0.194	-0.77 [-1.38;-0.17] *Moderate*
wDOMS (A.U.)	17.07 (3.09)	17.15 (3.76)	0.0 [-14.6;15.7]	1.000	0.00 [-0.78;0.78] *Trivial*
wStress (A.U.)	14.33 (2.89)	18.48 (2.76)	29.8 [11.5;51.1]	0.025	1.27 [0.53;2.01] *Large*
wFatigue (A.U.)	16.26 (3.11)	15.96 (3.11)	-1.8 [-14.6;12.9]	1.000	-0.09 [-0.75;0.58] *Trivial*
wSleep (A.U.)	15.01 (2.53)	15.65 (2.32)	4.6 [-7.9;18.7]	1.000	0.24 [-0.45;0.94] *Small*
wHI (A.U.)	61.82 (11.57)	67.24 (11.14)	9.2 [-5.7;26.4]	1.000	0.43 [-0.29;1.15] *Small*

wAL: weekly acute load; wCL: weekly chronic load; wACWL: weekly acute:chroni work load; wTM: weekly training monotony; wDOMS: weekly muscle soreness; wStress: weekly stress; wFatigue: weekly fatigue; wSleep: weekly sleep; wHI: weekly hooper index

The wCL (+10.6%; ES: 0.99, moderate effect), wStress (44.6%; ES: 0.87, moderate effect) and wHI (29.0%; ES: 0.62, moderate effect) were meaningful and greater during the end of season, as compared to mid-season.

Table 4. Differences between mid-season and ending-season considering the training load and well-being variables.

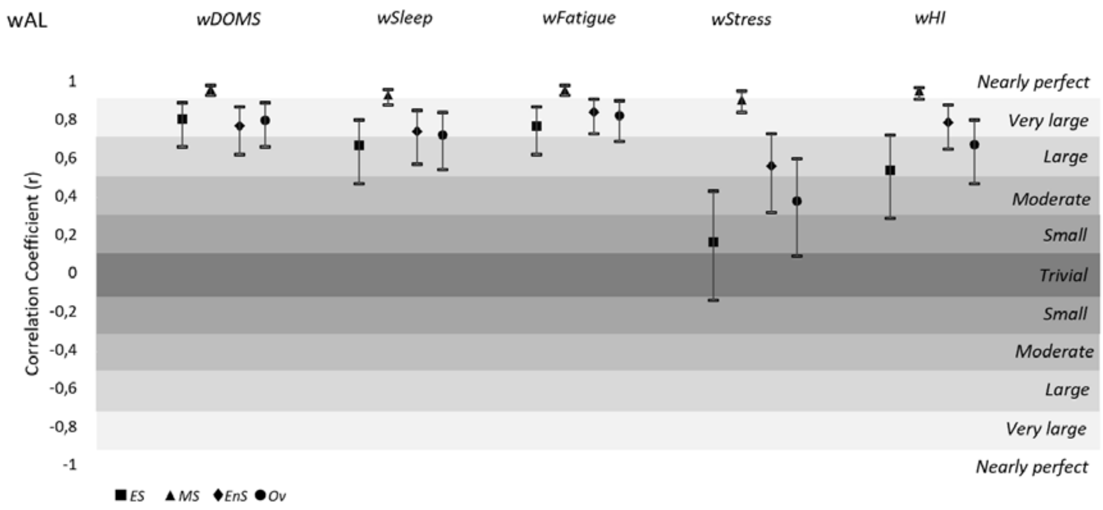
	Mid-season (ES) M(SD)	Ending-season (ES) M(SD)	% difference (MS-ES)	*p-value*	Standardized difference (MS-ES) and inference
wAL (A.U.)	2274.35 (692.44)	2413.99 (586.63)	9.0 [-15.9;41.4]	1.000	0.22 [-0.44;0.87] *Small*
wCL (A.U.)	2273.47 (222.33)	2514.30 (245.78)	10.6 [2.2;19.7]	0.150	0.99 [0.21;1.77] *Moderate*
wACWL (A.U.)	1.66 (0.15)	1.50 (0.14)	-9.6 [-16.4;-2.1]	0.038	-0.99 [-1.77;-0.21] *Moderate*
wTM (A.U.)	3.39 (0.69)	3.49 (0.87)	1.8 [-12.9;18.9]	1.000	0.08 [-0.66;0.83] *Trivial*
wDOMS (A.U.)	14.15 (4.54)	17.15 (3.76)	26.1 [-0.2;59.5]	0.234	0.55 [-0.01;1.10] *Small*
wStress (A.U.)	13.45 (4.42)	18.48 (2.76)	44.6 [14.8;82.2]	0.005	0.87 [0.32;1.41] *Moderate*
wFatigue (A.U.)	13.85 (4.14)	15.96 (3.11)	19.8 [-5.2;51.3]	0.499	0.44 [-0.13;1.01] *Small*
wSleep (A.U.)	13.02 (3.86)	15.65 (2.32)	25.6 [1.8;54.9]	0.145	0.56 [0.04;1.08] *Small*
wHI (A.U.)	54.46 (16.68)	67.24 (11.14)	29.0 [3.4;60.9]	0.097	0.62 [0.08;1.15] *Moderate*

wAL: weekly acute load; wCL: weekly chronic load; wACWL: weekly acute:chroni work load; wTM: weekly training monotony; wDOMS: weekly muscle soreness; wStress: weekly stress; wFatigue: weekly fatigue; wSleep: weekly sleep; wHI: weekly hooper index

Associations between load measures and well-being variables were tested considering the three periods of the season and overall (Figures 3 and 4). Overall, wAL presented very large correlations with wDOMS (r = 0.80, [0.66;0.89]), wSleep (r = 0.72, [0.54;0.84]) and wFatigue (r = 0.82, [0.69;0.90]). In particular, during the mid-season, the recorded relationships of wAL were nearly perfect with the wDOMS (r = 0.96, [0.93;0.98]), wSleep (r = 0.93, [0.88;0.96]), wFatigue (r = 0.96, [0.93;0.98]), wStress (r = 0.91, [0.84;0.95]) and wHI (r = 0.95, [0.91;0.97]).

Overall, wCL did not present any meaningful associations with well-being variables. However, during mid-season, there were very large correlations between wCL and wStress (r = 0.71, [0.53; 0.83]) and large correlations with wDOMS (r = 0.60, [0.37;0.76]), wSleep (r = 0.67, [0.47;0.80]) and wHI (r = 0.65, [0.44;0.79]).

(a)



(b)

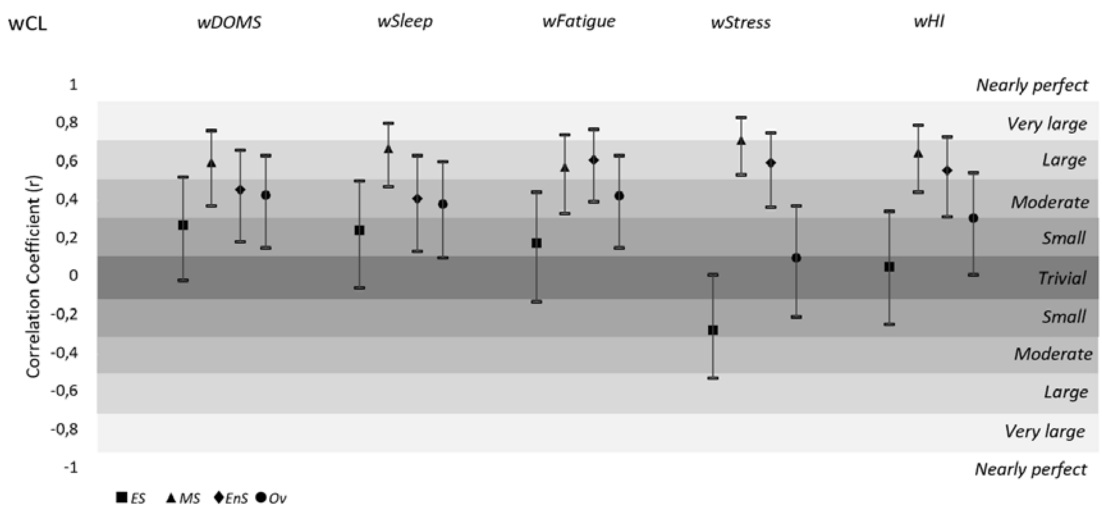
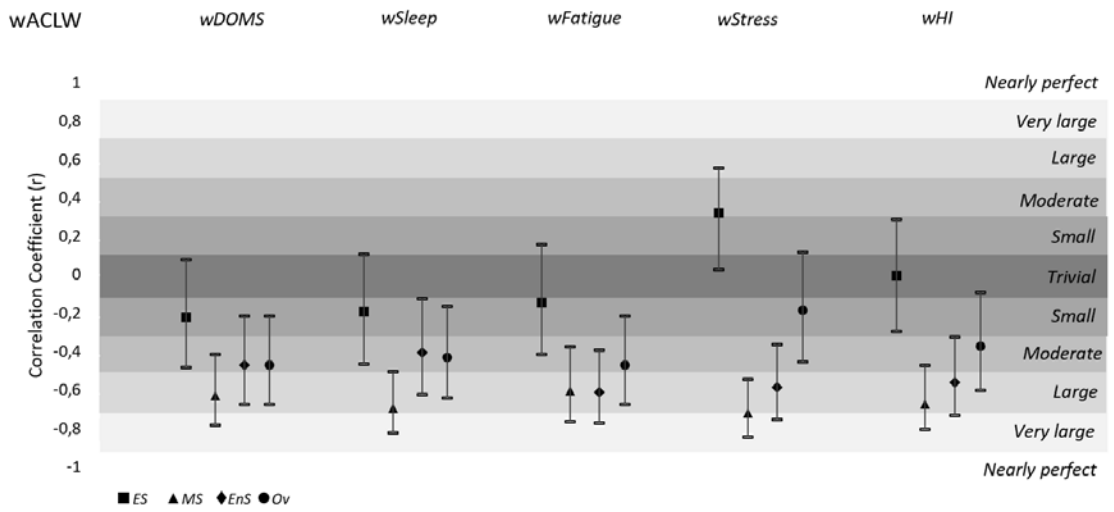


Figure 3. Correlations between (a) wAL and (b) wCL and the well-being categories during the early season (ES), mid-season (MS), ending season (EnS) and overall (Ov).

Overall, wACWL was not meaningfully correlated with well-being measures. However, during mid-season, there were negative large associations with wDOMS (r = -0.63, [-0.78;-0.41]), wSleep (r = -0.69, [-0.82;-0.50]), wFatigue (r = -0.60, [-0.76;-0.37]) and wHI (r = -0.67, [-0.80;-0.47]) and very large negative associations with wStress (r = -0.72, [-0.84;-0.54]).

The wTM had a large correlation with wDOMS (r = 0.59, [0.36;0.75]), wSleep (r = 0.63, [0.41;0.78]), wFatigue (r = 0.64, [0.43;0.79]), and wHI (r = 0.58, [0.35;0.75]) during the early season. However, overall, no meaningful correlations were observed between wTM and well-being measures.

(a)



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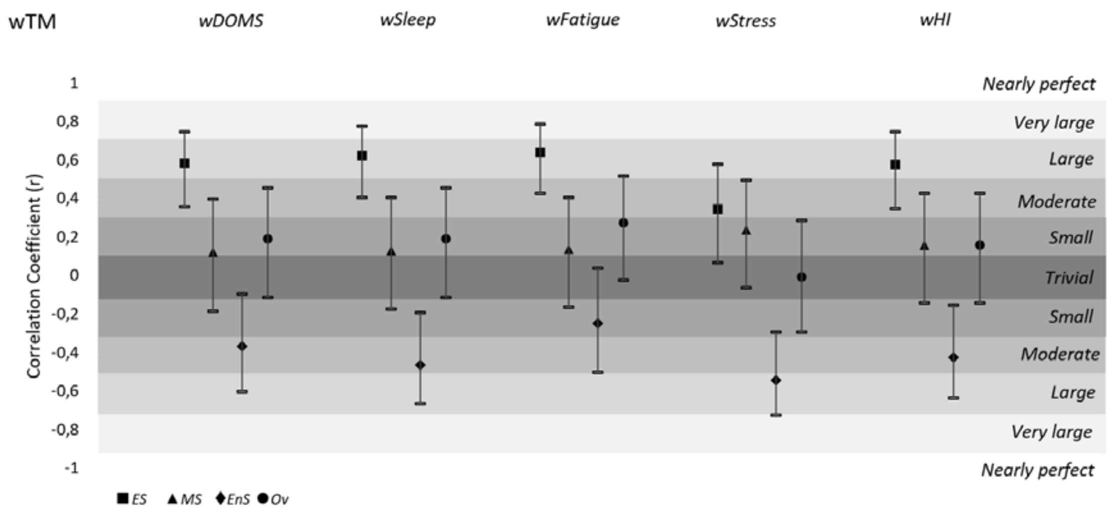

Figure 4. Correlations between (a) wACWL and (b) wTM and the well-being categories during the early season (ES), mid-season (MS), ending season (EnS) and overall (Ov).

Discussion

This study aimed to analyze the variations of acute and chronic training load and well-being measures during three periods of the season (early, mid and ending), in addition to investigating the associations between the weekly training load and well-being measures during different periods and the overall season. Higher wAL and wCL were observed in the first period, significantly diminishing between the first and the second period. Conversely, wACWL presented a higher value in the second period (with a very large effect), consistently presenting significant values between periods. In the well-being measurements, wStress registered greater values in the last stage of the season. Regarding the second aim of the present study, it was noticed that well-being measurements were more strongly correlated with wAL than with wCL, wACWL and wTM.

The higher wAL and wCL values in the first period of the season may be attributable to the training load players experienced during the pre-season phase (22). The main characteristic of this period is the high training volume, with a large component of fitness development (as endurance, strength and speed) (23). Conversely, the third period comprises the most specific training sessions (technical and tactical skills) and sport specific endurance (22). Therefore, the significant decrease in the wCL observed when comparing the first, with the second and last stages, could be due to a transition from a general to a more specific training sessions regarding the conditioning fitness training, as well as in technical and tactical skills. Moreover, the higher number of matches in those two periods conceivably restricts the coach to increasing work load, leading to a higher number of recovery sessions.

The wACWL, which is a composite measure of both wAL and wCL (24,25), showed the highest value in the second phase of the season, with higher values compared to first and third phase. This ratio (wACWL) gives information about the load rather than the wAL and wCL values alone, since it indicates if the training load achieved in the last week was proportional to the training undertaken over the preceding month (26). The differences noticed among periods indicate that higher imbalances between acute and chronic loads were evident during mid-season. It has been asserted that this value could inform the impact of load in musculoskeletal system and the likelihood of an injury (7,26). Considering the threshold of 1.5 suggested in the literature (27), on average, the athletes appeared to have been at risk of injury in the second period.

The increase in wStress in the last stage could be related to approaching the end of the season and because this period included the most important matches, i.e., the finals of the championship. In fact, the stress perception seems to require information about the impact of somatic and cognitive state anxiety of a pre-match situation (28). However, this possible increase in anxiety did not influence the quality of sleep, as no significant difference was observed during the entire season; which is in line with other studies (5,29), suggesting that sleep perception is not sensitive to the working load. Indeed, for elite soccer, it was suggested that in a competitive period (with different training and travel regimen), the perception of sleep quality may only provide information on potential recovery status rather than any association with load (30). As such, wSleep, wFatigue and wDOMS values did not show differences between periods, and is congruent with a previous study in volleyball (10), showing no differences during the season in wFatigue, although statistically significant differences were found when considering wDOMS across the season (i.e. 9 months).

Considering the overall season, a very large effect was observed with wDOMS, wSleep and wFatigue during the mid-season in all well-being measurements. The strongest relationship between well-being measurements and wAL was congruent with other studies in volleyball (10), as well as in other team sports (31). The aforementioned results strengthened the reliability of RPE to quantify the load, showing to be a good indicator for coaches and for the practical applications in team sports training, as previously mentioned (15). However, this association did not always correspond to the same magnitude; for instance, previous studies showed that load had a weak (32) or moderate-to-large (10) association with wDOMS, moderate (10) or no relationship (5,29) with wSleep, and moderate (5) or very-large (10,33) wFatigue. The absence of relationship between wAL and wStress in the overall season was in accordance with a previous study in volleyball (10), where the authors highlighted that this measurement is dependent on the training volume, therefore RPE could be more efficient in monitoring training volume rather than intensity. The same authors (10) also highlighted the typical decrease in volume at the end-season, which also influences the absolute value of load. In addition, studies investigating overtraining have demonstrated that psychological signs are more sensitive and consistent than physiological indicators (34), suggesting that psychological factors are more stress-related than physiological factors.

Conversely, wCL showed no meaningful associations in the entire season, but exhibited very large (wStress) or large (wDOMS, wSleep and wHI) associations, in the mid-season, with well-being variables, except with wFatigue. This lack of association could be because, although the general characteristics of training (e.g. volume, frequency) may have been maintained in each week, the planning is dependent on the features of the forthcoming opponent, leading to different perceptions of each domain of well-being. Moreover, since high-level athletes were included in this study, their perception of fatigue could conceivably be different as they developed their physical fitness (7), as well as their resilience. Similarly, as wACWL is wCL dependent, it displayed very large negative associations with wStress and large negative correlations with the other well-being dimensions during the mid-season period.

Regarding the wTM, significant correlations were only evident in the first period with wDOMS, wSleep, wFatigue and wHI. This result characterizes the specific phase of periodization (pre-season phase), where higher load values were registered, resulting in greater perceptions of muscle soreness and fatigue and worse sleep. The absence of correlation with stress, could be attributed to, or at least mediated by, the lower number of matches played in this period, as well as its importance (in the beginning of the season, creating less pressure).

Although this was the first study to comprehensively examine variations of acute and chronic training load and well-being measures throughout a complete season; some limitations should be considered when interpreting these results. First, the external load (e.g. accelerometer-based metrics) was not considered, and the internal load was only measured subjectively by RPE, which could constrain the real quantification of the physiological impact of training and competition. Another limitation was the fact that the different game positions were not considered. Nevertheless, although some limitations were evident, the present study strengthened the evidence base regarding the reliability of RPE to quantify the load and is relationship with HI, increasing the knowledge about the load variation during a season. Moreover, previous research suggested (35) that there may be differences between the perceptions of coaches and athletes, reinforcing the importance of adopting strategies for monitoring/controlling the load; thus, the authors recommend that more studies are needed in this field, and particularly within volleyball teams.

Conclusions

Results of the present study revealed that acute load, chronic load and training monotony were meaningfully greater during the first third of the season, however, acute:chronic workload ratio was higher during the second third. Considering the well-being status, it was found that the last third of the season imposed a meaningfully greater level of stress, concomitant to small-to-moderately higher levels of DOMS and poor sleep. It was highlighted that the loading variable was more strongly correlated with well-being markers and, in particular case of the second third of the season, displayed near-perfect correlations with DOMS, sleep, fatigue and stress. This suggests that coaches should be aware that the acute load may be a determining factor in well-being variations, to a greater extent than the accumulated load over the preceding four weeks, or even the within-week loading fluctuations (training monotony).

Practical Applications

Coaches should be aware of the major importance of acute load on well-being responses of players, namely, trying to minimize the consequences of extreme and sudden progressions in load that may be closely related with increases in parameters such as muscle soreness, compromising the immediate performance. It was also revealed drastic progressions in the load, where ACWR was greater than 1.5 in mid and ending phases of the season, should be carefully interpreted by the coaches; moreover, a concerted effort should be made to avoid sudden progressions aiming to minimize the increments between 5 and 10% avoid crossing the threshold of 1.2 in the ACWR.

References

1. Haddad M, Stylianides G, Djaoui L, Dellal A, Chamari K. Session-RPE Method for Training Load Monitoring: Validity, Ecological Usefulness, and Influencing Factors. Front Neurosci [Internet]. 2017 Nov 2;11. Available from: http://journal.frontiersin.org/article/10.3389/fnins.2017.00612/full
2. Bourdon PC, Cardinale M, Murray A, Gastin P, Kellmann M, Varley MC, et al. Monitoring Athlete Training Loads: Consensus Statement. Int J Sports Physiol Perform [Internet]. 2017 Apr;12(Suppl 2):S2-161-S2-170. Available from: http://journals.humankinetics.com/doi/10.1123/IJSPP.2017-0208
3. Conte D, Kolb N, Scanlan AT, Santolamazza F. Monitoring Training Load and Well-Being During the In-Season Phase in National Collegiate Athletic Association Division I Men ’ s Basketball. Int J Sport Physiol Performance13. 2018;1067–74.
4. Govus A, Coutts AJ, Murray A, Fullagar H. Relationship between Pre-Training Subjective Wellness Measures , Player Load and rating of perceived exertion training load in American College Football. Int J Sport. 2017;(May).
5. 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 [Internet]. 2016 Oct 7;24(4):387–94. Available from: https://www.tandfonline.com/doi/full/10.1080/15438627.2016.1239579
6. Drew MK, Finch CF, Drew MK. The Relationship Between Training Load and Injury , Illness and Soreness : A Systematic and Literature Review. Sport Med. 2016;
7. Jaspers A, Brink MS, Probst SGM, Frencken WGP, Helsen WF. Relationships Between Training Load Indicators and Training Outcomes in Professional

Soccer. Sport Med [Internet]. 2017 Mar 26;47(3):533–44. Available from: http://link.springer.com/10.1007/s40279-016-0591-0

8. Mielgo-Ayuso J, Zourdos MC, Clemente-Suárez VJ, Calleja-González J, Shipherd AM. Can psychological well-being scales and hormone levels be used to predict acute performance of anaerobic training tasks in elite female volleyball players? Physiol Behav [Internet]. 2017 Oct;180:31–8. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0031938417302524

9. Los Arcos A, Martinez-Santos R, Yanci J, Mendiguchia J, Mendez-Villanueva A. Negative Associations between Perceived Training Load , Volume and Changes in Physical Fitness in Professional Soccer Players. J Sport Sci Med. 2015;14(April):394–403.

10. Clemente FM, Mendes B, Palao JM, Silvério A, Calvete F, Nakamura FY. Seasonal player wellness and its longitudinal association with internal training load : study in elite volleyball load : study in elite volleyball. J Sports Med Phys Fitness. 2018;(April).

11. 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 [Internet]. 2017 Oct;179:262–7. Available from: http://linkinghub.elsevier.com/retrieve/pii/S003193841631068X

12. Sheppard JM, Chapman DW, Gough C, McGuigan MR, Newton RU. Twelve-Month Training-Induced Changes in Elite International Volleyball Players. J Strength Cond Res [Internet]. 2009 Oct;23(7):2096–101. Available from: https://insights.ovid.com/crossref?an=00124278-200910000-00026

13. Timoteo T, Seixas MB, Debien P, Miloski B. Impact of consecutive games on workload, state of recovery and well-being of professional volleyball players. J Exerc Physiol. 2017;20(3):130–40.

14. Aoki MS, Arruda AF, 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 [Internet]. 2017 Feb 22;12(1):130–7. Available from: http://journals.sagepub.com/doi/10.1177/1747954116684394

15. Debien P, Coimbra DR, Miranda R. Monitoring Training Load , Recovery , and Performance of Brazilian Professional Volleyball Players During a Season. Int J Sports Physiol Perform. 2018;13(December).

16. 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):109–15.

17. Hooper SL, Mackinnon LT. Monitoring Overtraining in Athletes. Sport Med [Internet]. 1995 Nov;20(5):321–7. Available from: http://link.springer.com/10.2165/00007256-199520050-00003

18. 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):1042–7.

19. Haddad M, Chaouachi A, Wong DP, Castagna C, Hambli M, Hue O, et al. Influence of fatigue, stress, muscle soreness and sleep on perceived exertion during submaximal effort. Physiol Behav [Internet]. 2013 Jul;119:185–9. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0031938413002023

20. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. Med Sci Sport Exerc [Internet]. 2009 Jan;41(1):3–13. Available from: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00005768-200901000-00002

21. Batterham AM, Hopkins WG. Making Meaningful Inferences about Magnitudes. Int J Sports Physiol Perform [Internet]. 2006 Mar;1(1):50–7. Available from: http://journals.humankinetics.com/doi/10.1123/ijspp.1.1.50

22. Issurin VB. New horizons for the methodology and physiology of training periodization. Sports Med [Internet]. 2010 Mar 1 [cited 2015 Apr 16];40(3):189–206. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20199119

23. 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 [Internet]. 2011 Aug;29(11):1161–6. Available from: http://www.tandfonline.com/doi/abs/10.1080/02640414.2011.583671

24. Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. Br J Sports Med [Internet]. 2016 Feb;50(4):231–6. Available from: http://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2015-094817

25. Foster C, Snyder A, Welsh R. Monitoring of Training, Warm Up, and Performance in Athletes. In: Overload, Performance Incompetence, and Regeneration in Sport [Internet]. Boston, MA: Springer US; p. 43–51. Available from: http://link.springer.com/10.1007/978-0-585-34048-7_4

26. Drew MK, Finch CF. The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic and Literature Review. Sport Med [Internet]. 2016 Jun 28;46(6):861–83. Available from: http://link.springer.com/10.1007/s40279-015-0459-8

27. 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 [Internet]. 2016 Sep;50(17):1030–41. Available from: http://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2016-096581

28. Madrigal LA, Wilson PB. Salivary Hormone and Anxiety Responses to Free-Throw Shooting Competition in Collegiate Female Basketball Players. J Clin Sport Psychol [Internet]. 2017 Sep;11(3):240–53. Available from: http://journals.humankinetics.com/doi/10.1123/jcsp.2016-0034

29. Thorpe RT, Strudwick AJ, Buchheit M, Atkinson G, Drust B, Gregson W. Monitoring Fatigue during the In-Season Competitive Phase in Elite Soccer Players. Int J Sports Physiol Perform [Internet]. 2015 Nov;10(8):958–64.

Available from: http://journals.humankinetics.com/doi/10.1123/ijspp.2015-0004

30. 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.

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. Sport Med [Internet]. 2018 Mar 29;48(3):641–58. Available from: http://link.springer.com/10.1007/s40279-017-0830-z

32. Mendes B, Palao JM, Silvério A, Owen A, Carriço S, Calvete F, et al. Daily and weekly training load and wellness status in preparatory, regular and congested weeks: a season-long study in elite volleyball players. Res Sport Med [Internet]. 2018 Oct 2;26(4):462–73. Available from: https://www.tandfonline.com/doi/full/10.1080/15438627.2018.1492393

33. Fessi MS, Nouira S, Dellal A, Owen A, Elloumi M, Moalla W. Changes of the psychophysical state and feeling of wellness of professional soccer players during pre-season and in-season periods. Res Sport Med [Internet]. 2016 Oct 30;24(4):375–86. Available from: https://www.tandfonline.com/doi/full/10.1080/15438627.2016.1222278

34. Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D, et al. Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM). Eur J Sport Sci [Internet]. 2013 Jan;13(1):1–24. Available from: http://www.tandfonline.com/doi/abs/10.1080/17461391.2012.730061

35. Nogueira FC de A, Nogueira RA, Coimbra DR, Miloski B, Freitas VH de, Filho MB. Internal training load: perception of volleyball coaches and athletes. Rev Bras Cineantropometria e Desempenho Hum [Internet]. 2014 Oct 30;16(6):638. Available from: https://periodicos.ufsc.br/index.php/rbcdh/article/view/1980-0037.2014v16n6p638