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Section: Original Investigation

Article Title: Monitoring Fatigue During the In-Season Competitive Phase in Elite Soccer Players

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Journal: *International Journal of Sports Physiology and Performance*

Acceptance Date: February 10, 2015

DOI: http://dx.doi.org/10.1123/ijspp.2015-0004

"Monitoring Fatigue During the In-Season Competitive Phase in Elite Soccer Players" by Thorpe RT et al.
International Journal of Sports Physiology and Performance

Monitoring fatigue during the in-season competitive phase in elite soccer players

Submission type: Original Investigation

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Running Head: Monitoring fatigue in elite soccer players

Word count: 2723

Abstract word count: 177

Number of figures: 1

Number of tables: 1

Abstract

Purpose: To quantify the relationship between daily training load and a range of potential measures of fatigue in elite soccer players during an in-season competitive phase (17-days). **Methods:** Total high-intensity running distance (THIR), perceived ratings of wellness (fatigue, muscle soreness, sleep quality), counter-movement jump height (CMJ), post-exercise heart rate recovery (HRR) and heart rate variability (Ln rMSSD) were analysed during an in-season competitive period (17 days). General linear models were used to evaluate the influence of daily fluctuation in THIR distance on potential fatigue variables. **Results:** Fluctuations in fatigue ($r=-0.51$; large; $P<0.001$), Ln rMSSD ($r=-0.24$; small; $P=0.04$), and CMJ ($r=0.23$; small; $P=0.04$) were significantly correlated with fluctuations in THIR distance. Correlations between variability in muscle soreness, sleep quality and HRR and THIR distance were negligible and not statistically significant. **Conclusions:** Perceived ratings of fatigue and heart rate variability were sensitive to daily fluctuations in THIR distance in a sample of elite soccer players. Therefore, these particular markers show particular promise as simple, non-invasive assessments of fatigue status in elite soccer players during a short in-season competitive phase.

Key Words: Training load, Performance, Recovery, Wellness

Introduction

The stress associated with training and competition often temporarily impairs a players' physical performance. This impairment may be acute, lasting minutes or hours and may stem from metabolic disturbances and substrate utilisation associated with high-intensity exercise. [1]Alternatively, exercise-induced muscle injury and delayed onset muscle soreness that often follows training with a high eccentric component may lead to impairment lasting several days. [2] The balance between the stress of training and competition and sufficient recovery is therefore of sufficient importance since an imbalance over extended periods of time may contribute to potentially long-term debilitating effects associated with overtraining.[3]

Increasing attention in the literature has centred upon evaluating the effectiveness of a range of monitoring tools which may serve as valid indicators of recovery status in athletes including heart rate derived indices, [4] salivary hormones, neuromuscular indices [5] and subjective wellness scales. [6] A valid marker of recovery should be sensitive to variability in training and match load, [7] consequently, research to date has evaluated the sensitivity of monitoring tools in response to changes in training load over extended periods of time (e.g. weekly/monthly) in endurance sports such as cycling. [8,9] In contrast, limited attempt has been made to determine the effectiveness of these tools for monitoring recovery in elite team sport players. [6,10] Team sport athletes compete on a weekly/bi-weekly basis therefore decisions on player wellness and fatigue are frequently required over extended periods of time. Under such conditions, monitoring tools that are sensitive to more acute (e.g. daily) fluctuations in load may serve as the most effective monitoring tools.

Recent findings indicate that perceived ratings of wellness, [6,10] submaximal heart rate [10] and a vagal-related heart rate variability index [10] are sensitive to subtle changes in daily pre-season training load in elite Australian Rules players. However, to the authors' knowledge, no research to date has evaluated the sensitivity of different monitoring tools to daily fluctuations in training load in elite soccer players. Since differences exist in the physiological demands between team sports it is important to determine which fatigue variables are most sensitive to changes in load associated with specific sports. Furthermore, no attempt has been made to examine such relationships during an in-season competition phase where the overall loading patterns vary markedly compared to the high volume pre-season training periods. [11,12] Therefore, our aim was to quantify the relationships between daily training load and a range of potential measures of fatigue in a sample of elite soccer players during a short in-season competitive phase.

Methods

Subjects

Data were collected from 10 outfield soccer players (19.1±0.6 years; 184±7cm; 75.4±7.6 kg) competing in the English Premier League over a 17-day period (February) during an in-season competition phase.

Design

Players took part in normal team training throughout the 17-day period as prescribed by the coaching staff. This included two competitive reserve team home matches, twelve training sessions and three rest days. All players were fully familiarised with the assessments in the weeks prior to completion of the main experimental trials. On the day of the fatigue assessments, players arrived at the training ground laboratory having refrained from caffeine intake at least 12-hours prior to each assessment point. Fatigue variables were subsequently taken prior to the players commencing normal training. Only perceived ratings of wellness measurements were taken on match and rest days. All assessments were conducted at the same time of the day in order to avoid the circadian variation in body temperature. [13] Players were not allowed to consume fluid at any time during the fatigue assessments. The study was approved by Liverpool John Moores University Ethics Committee. All players provided written informed consent. Prior to inclusion into the study, players were examined by the club physician and were deemed to be free from illness and injury.

Methodology

Individual player daily training and match load was monitored throughout the 17-day assessment period. Each player was also monitored during each training session and match using a portable global positioning system (GPS) technology (GPSports SPI Pro X 5 Hz, Canberra, Australia). This type of system has previously been shown to provide valid and reliable estimates of instantaneous velocity during acceleration, deceleration, and constant velocity movements during linear, multidirectional and soccer-specific activities. [14,15] All devices were always activated 15-min before the data collection to allow acquisition of satellite signals. [16] The minimum acceptable number of available satellite signals was 8 (range 8-11). [17] Players wore the same GPS device for each session in order to avoid inter-unit error. [17]

A psychometric questionnaire was used daily to assess general indicators of player wellness. [18] The questionnaire was comprised of three questions relating to perceived sleep quality (coefficient of variation 13%, unpublished observations), muscle soreness (coefficient of variation 9%, unpublished observations), and fatigue (coefficient of variation 12%, unpublished observations). Each question scored on a seven-point Likert scale with 1-point increments (scores of 1-7 with 1 and 7 representing very, very poor and very, very good respectively). Countermovement jump (coefficient of variation 4%, unpublished observations) (CMJ) performance was evaluated using a jump mat (Fusion Sport, Queensland, Australia). Participants performed five CMJ efforts in total, two practice and three assessment jumps ensuring the hands were affixed to the hips throughout the jump. The highest jump was used as the criterion measure of performance.

Players completed an indoor submaximal 5-min cycling /5-min recovery test (Keiser, California, USA) as part of the warm up prior to commencing every session. [4] All players were tested together at a fixed exercise intensity of 130 watts (85 rpm). The present intensity was selected to minimize anaerobic energy contribution [19] and to permit a rapid return of heart rate to baseline for short-term heart rate (HR) variability (HRV) measurements. On completion of exercise the players remained seated in silence for 5-min. HRV expressed as the square root of the mean of the sum of squares of differences between adjacent normal R-R intervals (rMSSD, coefficient of variation 28%, unpublished observations) and the natural logarithm of the rMSSD (Ln rMSSD, coefficient of variation 10%, unpublished observations) were calculated as previously described [19] using Polar software (Polar Precision Performance SW 5.20, Polar Electro, Kemple, Finland). Heart rate recovery (HRR) expressed as the absolute (HRR, coefficient of variation 14%, unpublished observations) and relative (%HRR, coefficient of variation 10%, unpublished observations) change in HR between the final 30-sec (average) of the 5-min cycling test and 60 sec after cessation of exercise were calculated as previously described. [19,20]

Thirty-five players from the same group were used to establish the between day coefficient of variation for each fatigue measure. Assessments were undertaken on two separate occasions, 24-hours apart, prior to commencing the pre-season training period. On the day of the first assessment, players arrived at the training ground laboratory having refrained from exercise and caffeine at least 24-hours.

Statistical Analysis

Data were analysed with general linear models, which allowed for the fact that data were collected within-subjects over time. [21] Recently, step-wise regression approaches have been criticised for reliable variable selection in a model. [22,23] Our added problem was the predicted high multicolinearity between the various independent variables in our study.

Therefore, we used a combination of expert knowledge regarding which variables hold superior practical/clinical importance [23] and a multicolinearity correlation coefficient of >0.5 for initial variable selection. Total HIR distance (THIR; >14.4 km/h) was subsequently selected in order to provide an indication of training and match load (independent variable) in the present study. We then quantified the relationships between the various predictors and outcomes using model I (unadjusted model) and model II (fully adjusted model from which partial correlation coefficients and associated 95% confidence intervals for each predictor could be derived). The following criteria were adopted to interpret the magnitude of the correlation (r) between test measures: <0.1 trivial, 0.1 to 0.3 small, 0.3 to 0.5 moderate, 0.5 to 0.7 large, 0.7 to 0.9 very large, and 0.9 to 1.0 almost perfect. [24] The level of statistical significance was set at $p<0.05$ for all tests.

Results

The variability in training load and fatigue variables over the 17 day period is shown in Figure 1. There was significant day-to-day variation (coefficient of variation) in THIR distance (115%; $p<0.001$). The perceived wellness ratings for fatigue, sleep quality and soreness varied from day-to-day by 16%, 18% and 19% respectively ($p<0.05$). HRR (11%), Ln rMSSD (12%) and countermovement jump (4%) varied to a lesser degree ($p<0.05$).

Partial correlations, least squares regression slope (B) and significance for the relationship between THIR distance and fatigue variables are shown in Table 1. Variability in fatigue ($r=-0.51$; large; $p<0.001$), Ln rMSSD ($r=-0.24$; small; $p=0.04$) and CMJ (0.23; small; $p=0.04$) were correlated to variability in THIR distance covered on the previous days. Correlations between variability in sleep quality, muscle soreness and HRR (%) and THIR distance were trivial to small and not statistically significant (Table 1).

Discussion

The aim of the current study was to quantify how sensitive a range of fatigue variables are to changes in daily training load in a sample of elite soccer players. During a short in-season competitive period, the strongest multivariate-adjusted correlations with daily fluctuations in training load were found to be perceived ratings of wellness compared with the other markers of fatigue measured.

In elite soccer, players are frequently required to compete on a weekly and often bi-weekly basis, therefore the balance between training stimulus/adaptation and recovery is an important consideration for coaches and sport scientists. [25] Over the course of the 17-day period, training was prescribed by the coaches and followed a typical periodized cycle leading up to matches. [26] This was characterised by recovery days following the match, moderate to high loads after 3 to 4 days then moderate to light sessions leading into the forthcoming match. The THIR distance varied by 115% ($p<0.001$), ranging from 1528 m to 235 m during match-play and recovery/low load days respectively.

While the assessment of training load is a popular practice in team sports there is also a requirement to assess the physiological response in attempt to evaluate athlete adaptation, recovery/readiness and fatigue status. [7] The recording of perceived ratings of wellness is a relatively efficient and practical approach to quantify the fatigue/adaptive responses to team sports such as training in AFL. [6,18] In the present study, a moderate-to-strong correlation was observed between the players perceived rating of fatigue and day-to-day variation in THIR distance ($r=-0.51$; $p<0.001$). The slope of the regression model indicated that every ~400m increase in THIR distance led to a one unit decrease in fatigue (Table 1). Nevertheless, whether self-reported fatigue can be used as a valid means to track the fatigue response to training and match load in individual players is not entirely clear at present. We note that the variance in training load explained by all the statistically significant predictors was approximately 37%. The relatively small sample size in the present study would also render prediction intervals for individual players relatively wide. Nevertheless, the present study has helped to identify the variables that are at least correlated to within-player fluctuations in training load in elite soccer players during a typical in-season training period, which is a novel finding.

Daily perceived ratings of sleep quality (r=0.2), fatigue (r=0.2) and muscle soreness (r=0.3) have been found to be statistically significantly correlated with daily training load (training session time x RPE) during the pre-season training period in elite AFL players. [10] In contrast, the relationship between daily training load and perceived ratings of sleep quality and muscle soreness were trivial and non-significant in the present study. This may partly reflect the fact that previous observations in AFL players [10] were made during the pre-season period where the high volume and intensity of training may lead to greater disturbances in perceived ratings of sleep and soreness. In soccer, the high frequency of competition during the in-season phase ensures training is more focused around recovery and maintaining physical fitness which may lead to lesser changes in perceived ratings of sleep and soreness across a typical training week.

In recent years heart rate (HR) indices (HRV and HRR) have been used as a popular method to measure variations in the autonomic nervous system (ANS) in an attempt to understand athlete adaptation/fatigue status. [4] The use of vagal related time domain indices such as Ln rMSSD have been found to have greater reliability and are ideal for assessments over short periods when compared to spectral indices of HRV. [27] In the present study a small significant correlation (r=-0.2; p=0.04) was found between the daily fluctuations in Ln rMSSD and THIR. The slope of the regression model indicated that every ~300m increase in THIR distance led to a decrease of one unit in HRV (Table 1) i.e. more sympathetic dominance the greater the training load. [8,10] However, a non-significant correlation was observed between HRR and daily fluctuations in THIR. Buchheit et al, (2013) found similar yet stronger correlations (r=0.40) with a comparable vagal related parameter HRV (Ln SD1) during a pre-season camp in AFL players. Previous work in elite gymnastics, rugby and rowing have also found correlations with various measures of HRV and daily/total training load using session ratings of perceived exertion. [28–30] Although limited HRV data exists in team sports, the use of vagal related HR indices with endurance athletes is more extensive. [4,31,32] Indeed, based on data derived from endurance sports it is suggested that the use of one single data point could be misleading for practitioners due to the high day-to-day variation in these indices. [32] When data were averaged over a week or using a 7-day rolling average significant large correlations were found with 10-km running performance compared to a single assessment point where negligible relationships were seen. [32] As a consequence, if HR derived assessments of fatigue/adaptation are to be effective in team sports a higher volume of assessments may be required. However, undertaking such measures may prove difficult with the large volume of athletes engaged in team sports. [4]

It is well established that the assessment of neuromuscular function via the use of jump protocols is impaired up to 72-hours post-match, [5] indicating a negative effect on neuromuscular performance. [33] Interestingly a small positive correlation was currently observed (r=0.23) between countermovement jump (CMJ) performance and THIR, suggesting improved performance with increased THIR distance. This could reflect a priming/post-activation potentiation effect of the THIR distance on the neuromuscular system. [34] A small non-significant correlation was previously observed between THIR and CMJ performance over the course of a weeks training in elite adolescent soccer players. [33] The THIR distance reported (36-106 m) was much lower than in the present study (235-1528 m) and may not have been enough to stimulate positive or negative effects on the neuromuscular system. However, irrespective of the underlying mechanisms, these findings collectively indicate that daily monitoring of CMJ provides limited insight into recovery fatigue status of soccer players. Furthermore, elite players are often reluctant to perform maximal and explosive assessments in the days following high training or match loads which may limit its application as a monitoring tool in elite soccer.

Total HIR distance was employed in the present study as an index of training and match load due to its frequent inclusion in attempts to quantify the load incurred by elite players during training and match-play. [11] However, THIR distance will underestimate the true load incurred by the athlete since it does not account for the stress associated with the frequent accelerations and decelerations which occur during soccer. [35] It should be noted, however, that initial analysis in the present study highlighted a large correlation (r=0.57) between THIR distance and session ratings of perceived exertion (sRPE) which has previously been used as a global indicator of internal load in soccer players. [36] A limitation of the present study relates to the use of an absolute (>14.4.km/h) rather than individual thresholds to determine the high-intensity running speed. [37] However, the performance metrics (e.g. maximal speed, maximal aerobic speed and ventilatory thresholds) needed to generate individual speed thresholds were not available in the current sample of elite players.

Practical Applications

Perceived ratings of wellness show particular promise as simple, non-invasive assessments of fatigue status in elite soccer players during an in-season competitive phase

Future research is needed to determine the usefulness of vagal related HRV as a monitoring tool in team sports

Future research is needed to understand more long-term fluctuations in fatigue variables in relation to individual load thresholds in elite soccer players.

Conclusion

Perceived ratings of wellness show particular promise as a simple, non-invasive assessment of fatigue status in elite soccer players during an in-season competitive phase compared to the other markers of fatigue measured.

Acknowledgements

The authors would like to thank Manchester United Football Club for their cooperation and input to this article

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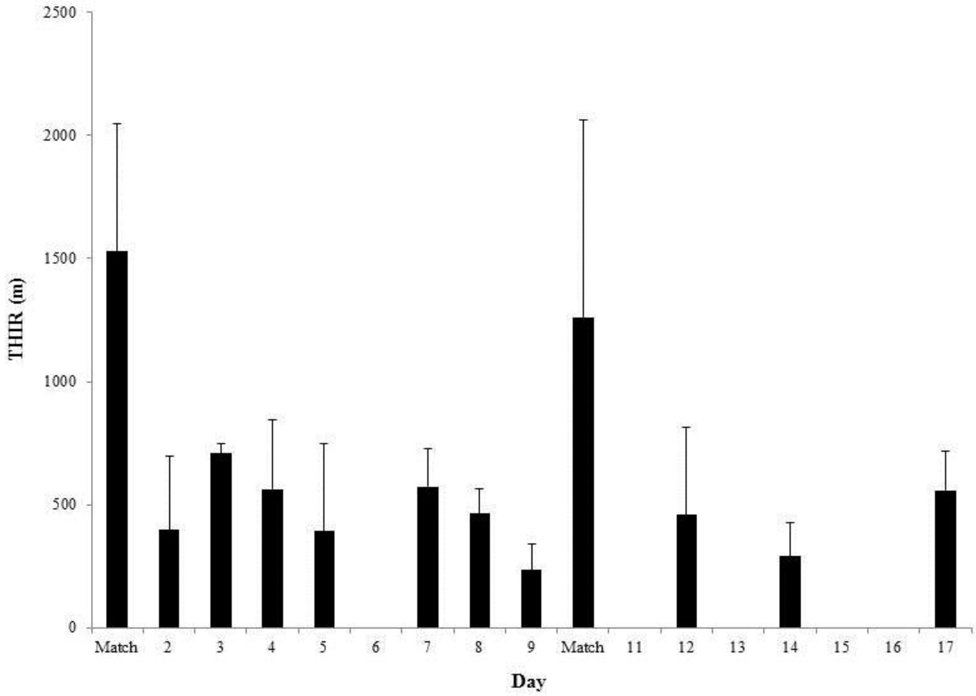

Figure 1. Mean (SD) total high-intensity (THIR) distance (m), during the 17-day period

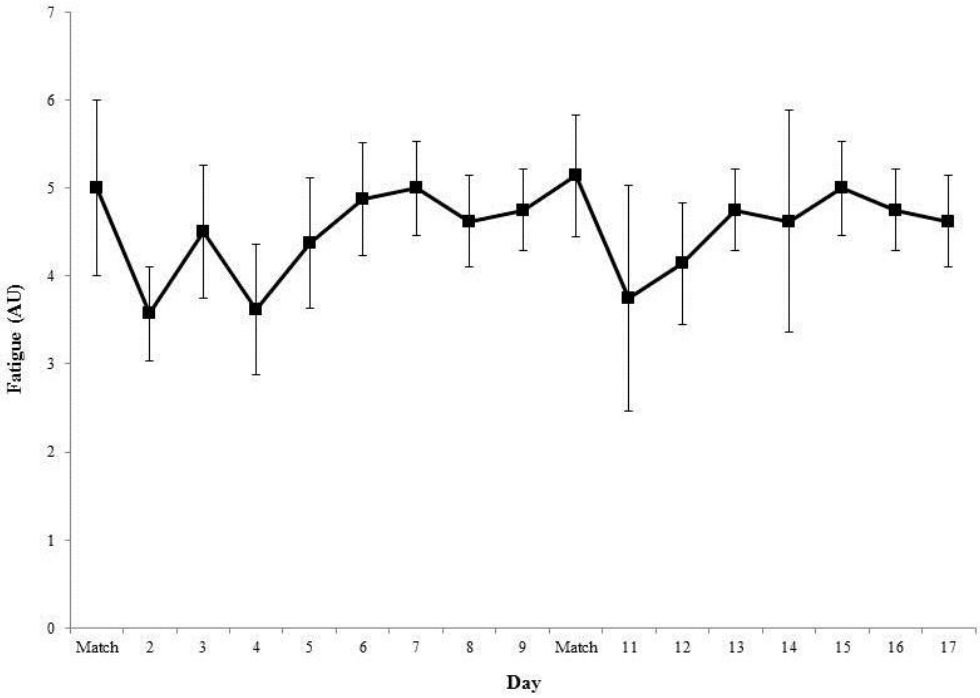

Figure 2. Mean (SD) perceived ratings of fatigue (AU) during the 17-day period

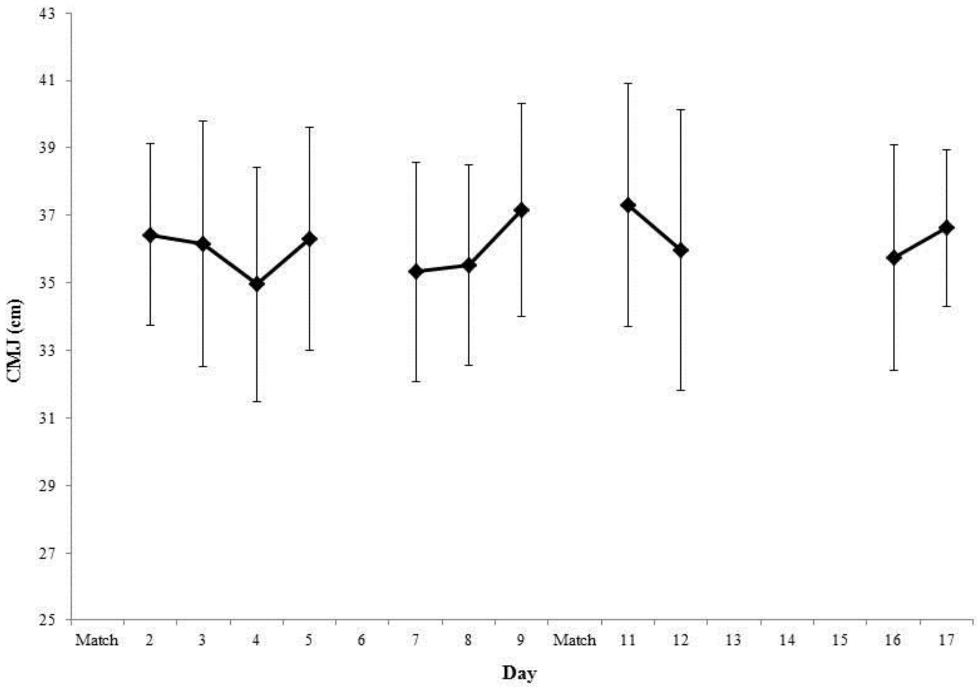

Figure 3. Mean (SD) countermovement jump (cm) during the 17-day period

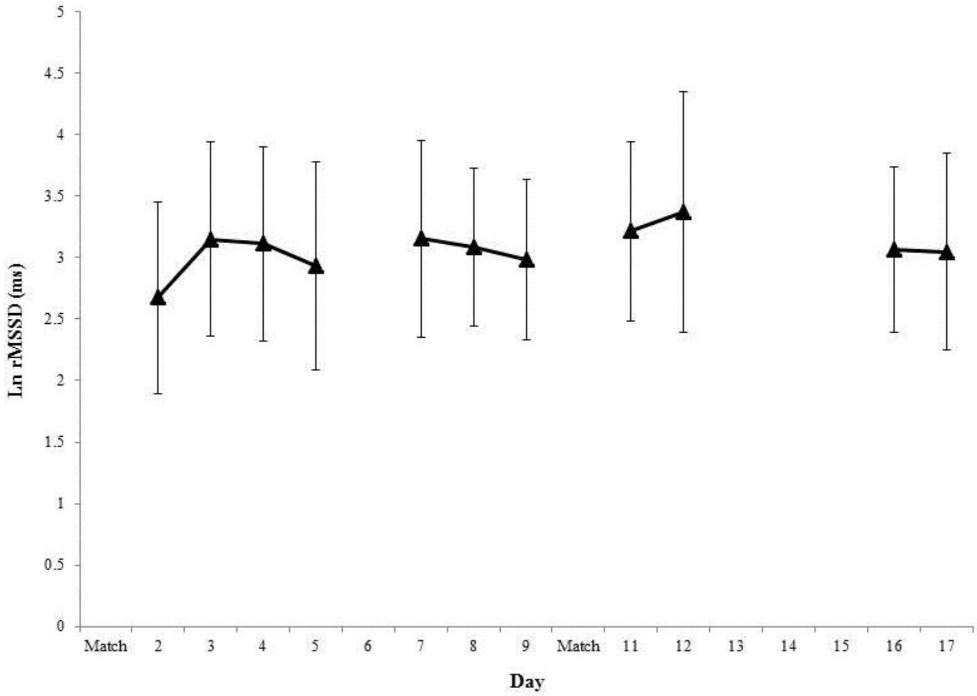

Figure 4. Mean (SD) Ln rMSSD (ms) during the 17-day period

Table 1. Partial correlations (95% CI), least squares regression slope (B) and significance for the relationship between training load (total high-intensity running distance) and fatigue variables

Variable	Correlation Coefficient (95% CI)	Magnitude	B	P-value
Fatigue (AU)	-0.51 (-0.62 to -0.39)	Large	-400.168	p<0.001
Sleep quality (AU)	-0.04 (-0.19 to 0.11)	Trivial	-26.174	p= 0.71
Muscle Soreness (AU)	-0.10 (-0.25 to 0.05)	Trivial/Small	-46.353	p=0.37
CMJ (cm)	0.23 (0.04 to 0.41)	Small	65.905	p=0.04
Ln rMSSD (ms)	-0.24 (-0.42 to -0.05)	Small	-295.131	p=0.04
HRR (%)	0.13 (-0.07 to 0.32)	Trivial/Small	7.844	p=0.26