The tracking of morning fatigue status across in-season training weeks in elite soccer players

RT. Thorpe[1,2], AJ. Strudwick[1,2], M. Buchheit[4,5], G. Atkinson[3], B. Drust[2], W. Gregson[2]

[1] Football Medicine and Science Department, Manchester United Football Club, UK

[2]Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, UK

[3] Health and Social Care Institute, Teesside University, UK

[4] Sport Science Department, Myorobie Association, Montvalezan, France

[5] Performance Department, Paris Saint Germain FC

Corresponding Author:

Robin T. Thorpe

Manchester United, Aon Training Complex, Birch Road off Isherwood Road, Carrington, Manchester M31 4BH

E-mail: robin.thorpe@manutd.co.uk

Key Words-Training, Performance, Wellness, Recovery

Word count: 2989

Abstract word count: 250

Number of figures: 1

Number of tables: 1

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RT. Thorpe[1], AJ Strudwick[1], M. Buchheit[3,4], G. Atkinson[2], B. Drust[1], W. Gregson[1]

[1] Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, UK
[2] Health and Social Care Institute, Teesside University, UK
[3] Sport Science Department, Myorobie Association, Montvalezan, France
[4] Performance Department, Paris Saint Germain FC

Abstract

Purpose To quantify the mean daily changes in training and match load and any parallel changes in indicators of morning-measured fatigue across in-season training weeks in elite soccer players.

Methods Following each training session and match, ratings of perceived exertion (s-RPE) were recorded to calculate overall session load (RPE-TL) in 29 English Premier League players from the same team. Morning ratings of fatigue, sleep quality, delayed-onset muscle soreness (DOMS), as well as sub-maximal exercise heart rate (HRex), post-exercise heart rate recovery (HRR%) and variability (HRV) were also recorded pre-match day and one, two and four days post-match. Data were collected for a median duration of 3 weeks (range:1-13) and reduced to a typical weekly cycle including no mid-week match and a weekend match day. Data were analysed using within-subjects linear mixed models.

Results

RPE-TL was approximately 600 AU (95%CI: 546-644) higher on match-day vs the following day ($P<0.001$). RPE-TL progressively decreased by ≈ 60 AU per day over the 3 days prior to a match ($P<0.05$). Morning-measured fatigue, sleep quality and DOMS tracked the changes in RPE-TL, being 35-40% worse on post-match day vs pre-match day ($P<0.001$). Perceived fatigue, sleep quality and DOMS improved by 17-26% from post-match day to three days post-match with further smaller (7-14%) improvements occurring between four days post-match and pre-match day ($P<0.01$). There were no substantial or statistically significant changes in HRex, HRR% and HRV over the weekly cycle ($P>0.05$).

Conclusions Morning-measured ratings of fatigue, sleep quality and DOMS are clearly more sensitive than HR-derived indices to the daily fluctuations in session load experienced by elite soccer players within a standard in-season week.

Introduction

It is important to allow sufficient recovery between training sessions and competitions. An imbalance between training/competition load and recovery may, over extended periods of time contribute to potentially long-term debilitating effects associated with overtraining. [1] Consequently, attention is increasingly being given to the evaluation of monitoring tools which may indicate the general fatigue status of athletes. These indicators include heart rate derived indices, [2] salivary hormones, neuromuscular indices [3] and perceived wellness ratings. [4–6]

A valid marker of fatigue should be sensitive to variability in training load. [7] Researchers have therefore examined the sensitivity of potential measures of fatigue to daily fluctuations in training load in elite team sport athletes. [4–6] For example, in both elite Australian Rules Football [4] and elite soccer [6] players, small to large and statistically significant correlations were reported between fluctuations in daily training load and changes in both perceived ratings of wellness and vagal-related heart rate variability indices. These findings suggest that such measures show particular promise as acute, simple, non-invasive assessments of fatigue status in elite team sport athletes.

Further evaluation of the validity of potential fatigue measures can be undertaken by examining their sensitivity to prescribed changes in training load over extended periods of time. Whilst these relationships have been examined in individual endurance based sports, [8,9] limited attention has been given to elite team sport athletes, [5] who are required to compete weekly and often bi-weekly across the competition period. In these athletes, a key component of the in-season and within-week training prescription resides around the need to periodise the training load in order to minimise player fatigue ahead of the weekly matches. [10] Gastin and colleagues (2013) [5] recently reported that subjective ratings of physical and psychological wellness (fatigue, muscle strain, hamstring strain, quadriceps strain, pain/stiffness, power, sleep quality, stress and wellbeing) were sensitive to within-week training manipulations (i.e. improved steadily throughout the week to a game day low) in elite Australian Football players. However, to the best of our knowledge, no researcher has examined the sensitivity of simple, non-invasive potential measures of fatigue across in-season training weeks in elite soccer players. Since differences exist in the physiological demands between team sports it is important to determine which potential fatigue variables are sensitive to changes in load associated with specific sports. Therefore, our aim was to quantify any changes in perceived ratings of wellness and objective measures of vagal-related heart rate indices that occur across standard in-season training weeks in elite soccer players.

Methods

Subjects

Twenty-nine soccer players (age 27 ± 5.1 years; height 181 ± 7.1 cm; 78 weight ± 6.1 kg) from the same team competing in the English Premier League participated in this study.

Design

Player training load was assessed on six days; on the pre-match day, match-day and one, two, four and five days after the match across standard training weeks (no mid-week match; median of 3 weeks per player; range = 1-13) during the 2012/2013 in-season competitive period (August to May). Players were required to complete a minimum match duration of 60-

min in order for their weekly data to be included in the present study. Players did not train and were given a day off three days after a match. Players took part in normal team training throughout the period as prescribed by the coaching staff. Players performed a range of recovery interventions the day following the match including low-intensity cycling, foam rolling and hydrotherapy. All players were fully familiarised with the assessments in the weeks prior to completion of the main experimental trials.

Fatigue measures were assessed on the day prior to the match and one, two and four days following the match. On the day of the fatigue assessments (perceived ratings of wellness, sub-maximal heart rate, heart rate recovery and heart rate variability), players arrived at the training ground laboratory having refrained from caffeine and alcohol intake at least 12-hours prior to each assessment point. Fatigue measures were subsequently taken prior to the players commencing normal training. All trials were conducted at the same time of the day in order to avoid the circadian variation in body temperature. [11] 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.

Methods

Training Load Assessment Individual player daily training load was monitored throughout the assessment period. Load (RPE-TL, arbitrary units, AU) was estimated for all players by multiplying total training or match session duration (min) with session ratings of perceived exertion (RPE). [12] Despite several influences, the usefulness of RPE in elite soccer has previously been observed. [13] Player RPE was collected within 20-30-min following cessation of the training session/match. [13]

Perceived ratings of wellness A psychometric questionnaire was used to assess general indicators of player wellness. [6,14] The questionnaire was comprised of three questions relating to perceived overall fatigue, sleep quality and delayed-onset muscle soreness (DOMS) [6,14] Each question was scored on a seven-point scale [scores of 1-7 with 1 and 7 representing very, very poor (negative state of wellness) and very, very good (positive state of wellness) respectively]. Coefficients of variation for the three indices ranged from 9-13 %. [6]

Sub-maximal exercise heart rate (HRex), post-exercise *heart rate recovery (HRR) and heart rate variability (HRV)* Players completed an indoor submaximal 5-min cycling /5-min recovery test (Keiser, California, USA) prior to commencing every session. [2,6] All players were tested together at a fixed exercise intensity of 130 watts (85 rpm). The present intensity was selected in order to minimize anaerobic energy contribution and to permit a rapid return of heart rate to baseline for short-term heart rate (HR) variability (HRV) measurements. [15] On completion of exercise, the players remained seated in silence for 5-min.

Sub-maximal HRex was calculated using the average of the final 30-sec of the cycle test. [16] HRR expressed as the absolute (HRR), and relative (%HRR) 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. [15,17] The coefficients of variation for HRex, HRR and %HRR were 3%, 14% and 10% respectively. [6] HRV was measured during the recovery period and expressed as the natural logarithm of the square root of the mean of the sum of squares of differences between adjacent normal R-R intervals (Ln rMSSD) as previously described [15] using Polar software (Polar Precision Performance SW 5.20, Polar Electro, Kemple, Finland). Ln rMSSD has previously been shown to have greater reliability and validity than spectral indices of HRV over short assessment periods. [18,19]The coefficient of variation for LnrMSSD was 10 % respectively. [6]

Statistical Analyses

It was assumed that if an indicator of fatigue was not, at the very least, sensitive to differences between the different loads on pre-match day and the post-match day, it cannot be considered useful. Therefore, for the purpose of our sample size estimation, our primary comparison was between the pre-match and post-match days. In a previous study, coefficients of variation of approximately 10% have been reported for the indicators of fatigue we studied. [6] Using this information of within-subjects variability, we estimated that a sample size of 29 would allow the detection of a difference in fatigue between pre- and post-match days of approximately 9% (two-tailed paired t-test, 90% statistical power, $p<0.05$).

A within-subjects linear mixed model was used to quantify mean differences between days along with the respective 95% confidence intervals. It is difficult to ascertain the exact relative influence of each study outcome on the actual performance of a soccer team, e.g. the standard effect size of a particular outcome may be high in response to training or an intervention, but the relative influence of this outcome on actual soccer performance may be low, [20] Nevertheless, standardised effect sizes, estimated from the ratio of the mean difference to the pooled standard deviation, were also calculated for each study outcome and interpreted in the discussion section. Effect size (ES) values of 0.2, 0.5 and 0.8 were considered to represent small, moderate and large differences, respectively [21]. When the model residuals were skewed or heteroscedastic, data were log-transformed and re-analysed. We adopted the least significant difference approach to multiple comparisons in line with the advice in [22,23]

Results

Training load: The RPE-TL was greatest on match-day **(**≈ 600 AU)**.** The peak-trough difference in RPE-TL was approximately 550 AU (95% CI 546-644 AU) between match-day and the following day ($p<0.001$). The RPE-TL progressively decreased by ≈ 60 AU per day over the 3 days prior to a match ($p<0.05$) (Figure 1).

Perceived ratings of wellness: All the wellness outcomes showed a 35-40% worsening on the post-match day vs the pre-match day. The 95%CIs for these changes were 1.2-1.6 AU, 1.0-1.5 AU and 1.1-1.5 AU for perceived fatigue, sleep quality and DOMS, respectively ($p<0.001$). Wellness outcomes then improved by 17-26% between post-match day and two days post-match. The 95%Cis for these changes were 0.7-1.1 AU, 0.7-1.2 AU and 0.4-0.9 AU for perceived fatigue, sleep quality, and DOMS. Wellness ratings then remained relatively stable between the second and fourth day post-match. Further smaller (7-14%) improvements occurred between the fourth day post-match and pre-match day ($p<0.01$). The 95% Cis for these changes were 0.2-0.6 AU, 0.1-0.6 AU and 0.4-0.7 AU for perceived fatigue, sleep quality and DOMS (Table 1).

Heart rate indices: There were no substantial or statistically significant changes in HRex, HRR% and HRV over all the weekdays ($p>0.05$) (Table 1).

Discussion

The aim of the present study was to quantify the mean daily changes in training load and parallel changes in potential fatigue measures across in-season training weeks in elite soccer players. The main finding was that perceived ratings of wellness but not HR-derived indices are sensitive to the fluctuations in training load experienced by elite soccer players across in-season training weeks which involve only one match per week (no mid-week match).

Elite soccer players are required to compete on a weekly and often bi-weekly (mid-week game) basis with additional training administered in-between matches. Training load prescribed by coaches should therefore serve to ensure that fatigue is reduced on the days when players are engaged in competition. In the present study, only training weeks containing no mid-week game were used in order to examine changes in fatigue across a 'standard' training week. A clear attempt to periodise training load across the week was currently observed with the lowest load prescribed the day following a match with large (ES >1.3) and statistically significant increases in training load prescribed two and four days following the match. During the two subsequent days (fifth day post-match and pre-match day) there was a moderate (ES=0.7) and statistically significant reduction in training load in the lead into the next game (Figure 1). So far, little information currently exists with regards to the patterns of training load undertaken by elite soccer players. [10,24] Interestingly, the pattern of training load exhibited in the present study differs to that seen in recent observations in Premier League players where only a reduction in daily training load was observed one day prior to a match compared to the other training days. [10] However, Malone and colleagues (2014) analysed all training weeks throughout the in-season competition period including those containing a mid-week game. The combination of this and dissimilarities in coaching philosophy and training methodology likely explain the difference in training load periodization to the current study. Further research is warranted to explore the patterns of training load experienced by elite players across different phases of the season.

Perceived ratings of wellness represent an increasingly popular method to assess athlete fatigue. Recent work in both elite soccer [6] and Australian Rules Football [4] players demonstrated that such ratings are sensitive to daily fluctuations in training load. Further information concerning the validity of potential markers of fatigue can be derived by examining their sensitivity to prescribed changes in training load over extended periods of time. Whilst these relationships have been examined in individual endurance based sports [8,9] limited attempt to date has been made to determine the sensitivity of tools for monitoring fatigue over extended periods of time in elite team sport players. [5] In the current study, the between-day changes in perceived wellness across the weekly training cycle closely reflected the prescribed distribution of training load. Moderate-to-large (ES 0.5-2.4) statistically significant changes (35-40 %) in perceived ratings of fatigue, sleep quality and DOMS were observed across the training week with the greatest and least amount of perceived fatigue, sleep quality and DOMS reported on the day following and the day prior to a match respectively (Table 1). These observations are consistent with findings in Australian Football where perceived ratings of fatigue, muscle strain, hamstring strain, quadriceps strain, pain/stiffness, power, sleep quality, stress and wellbeing improved by ~30% throughout the week. [5] Interestingly, previous work in elite soccer examining the sensitivity of perceived ratings of DOMS and sleep quality to acute daily fluctuations in training load failed to observe any association. [6] However, any effect of training and match load on DOMS and sleep quality, in particular the effects of match-play may materialise over a number of days rather than immediately following the session.[25] Collectively, previous observations examining daily sensitivity in elite soccer [6] and Australian Rules players [4,5] combined with the present findings suggest that attempts to fully examine the sensitivity of potential markers of fatigue to changes in training and match load should be undertaken over both acute (daily) and extended periods of time.

The increased perception of fatigue, poor sleep and DOMS currently observed following match play is consistent with changes in biochemical status and reduced physical and neuromuscular performance observed in the hours and days following soccer competition. [24,26–29] In contrast to many of the latter assessments, perceived wellness scales represent a valid, time efficient and non-invasive means through which to derive information pertaining to a players fatigue status. Such characteristics are important during the in-season competitive phase, particularly during periods when players are required to compete in two or three matches over a 7-day period where time constraints may restrict the use of more invasive tests, and maximal performance tests may further debilitate the physical status of players and/or increase the risk of injury. [30] In the present study, perceived ratings of fatigue and DOMS remained similar over the second and fourth day post-match despite a rest day three days after a match. This plateau may be due to the magnitude of the training load assigned two days post-match (224 ± 166 AU) which provided sufficient stimulus to blunt a linear improvement in player fatigue/recovery four days post-match and/or the fact that players were relatively well recovered two days post-match (fatigue 4.6 AU; sleep quality 4.8 AU; DOMS 4.3 AU). Interestingly, the progressive reduction in training load during the three days leading into a match was accompanied by further moderate-to-large (ES 0.6-0.9) statistical significant improvements in perceived wellness the day prior to a match (fatigue 5.0 AU; sleep quality 5.1 AU; DOMS 5.2 AU) which suggests the players were still not fully recovered four days post-match (Table 1). The time required to fully recovery following match play has been shown to vary markedly (24-72hr) depending on the nature of the physiological parameter assessed. [25] Furthermore, the rate of recovery is likely to be influenced by a myriad of factors including the inherent variability in match demands [31] and the athletes level of fitness [32]. Alongside the changes in perceived ratings of fatigue and DOMS, moderate-to-large (ES 0.6-1.4) statistical significant changes in ratings of sleep quality were also observed across the week with the highest and lowest levels of sleep quality observed during the evening of the fifth day post-match and the evening immediately following a match respectively. These changes indicate the severe debilitating effects of the match on perceived ratings of sleep quality. Indeed DOMS, inflammation, nervous system activity and central excitation have all been reported as potential mechanisms of poor sleep following competition. [33] Interestingly, data from elite endurance athletes have frequently shown reductions in sleep quantity the night prior to competition. [34] Perceived ratings of sleep were not measured the night prior to matches in the present study and therefore a reduction may have occurred. Future work is required in order to further understand the effects of training and match load on perceived and objective measures of sleep quality.

Heart rate (HR) indices (HRex, HRV and HRR) have recently been proposed as a non-invasive method to measure variations in the autonomic nervous system (ANS) in attempt to understand athlete adaptation/fatigue status. [2] The use of vagal-related time domain indices such as Ln rMSSD compared to spectral indices of HRV have been found to have greater reliability and are ideal for assessments undertaken over shorter periods of time. [18,19] Recent work in elite soccer players observed small (r=0.2), significant correlations between daily fluctuations in training load and Ln rMSSD. [6] Similarly, in Australian Rules Football players undergoing pre-season training, very large (r=0.80) and moderate (r=-0.40) significant correlations were observed between daily training load and sub-maximal heart rate (HRex) and a vagal related index of HRV (LnSD1). [4] In the present study, HRV (LnrMSSD), HRex and HRR (%) remained unchanged across the training week (Table 1) despite the large statistical significant fluctuations in training load (Figure 1). This suggests that in contrast to perceived ratings of wellness, such indices lack the sensitivity to provide information concerning changes in the fatigue status of elite soccer players across in-season training weeks. It should be noted that the average daily training load in the current study (RPE-TL 228) is considerably lower than that reported during an AFL pre-season training camp (RPE-TL 746) where daily readings of HRex and HRV were negatively and positively associated with load respectively. It is therefore possible that the magnitude of the fluctuations in daily training load across the training week in the current study were insufficient to elicit changes in HRex and HRV. [4] Alternatively, the shorter seven-day period over which observations were made in the current study may not have been sufficient to detect any physiological change. Indeed data derived from elite triathletes and adolescent Handball players suggests the use of a single data point could be misleading for practitioners due to the high day-to-day variation in these indices. [35,36] In elite triathletes 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. [37]. Additionally, changes in monthly HRV measurements were not sensitive to changes in performance indices in young Handball players. [36] Future research is needed to establish whether sensitivity of HR indices are seen over longer training periods in elite soccer players.

Conclusion

Perceived ratings of wellness are clearly more sensitive than HR-derived indices to the within-week fluctuations in training load experienced by elite soccer players during typical in-season training weeks. Therefore perceived ratings of wellness show particular promise as simple, non-invasive assessments of fatigue status in elite soccer players throughout typical in-season weeks in elite soccer players.

Acknowledgements

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

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Figure Caption

Figure 1. Training load (AU) across in-season training weeks (mean + SD)

† denotes sig. difference vs match-day. + denotes sig. difference vs pre-match day. * denotes sig. difference vs two days post-match. # denotes sig. difference vs four days post-match..

Table 1. Perceived ratings of fatigue, sleep quality and delayed-onset muscle soreness (DOMS) (AU) and HRex (bpm), HRR (%) and Ln rMSSD (ms) across in-season training weeks (mean + SD).

		Day		
Fatigue measure	**Post-match day**	**2 days post-match**	**4 days post-match**	**Pre-match day**
Fatigue (AU)	3.4 ± 0.6 †	4.4 ± 0.7 † +	4.5 ± 0.7 † +	5.0 ± 0.6
Sleep quality (AU)	3.9 ± 1.2 †	4.8 ± 0.9 † +	4.7 ± 1.0 †	5.2 ± 0.8
DOMS (AU)	3.6 ± 0.6 †	4.3 ± 0.7 † +	4.4 ± 0.7 † +	5.1 ± 0.8
HRex (bpm)	119 ± 13	117 ± 14	119 ± 15	118 ± 13
HRR (%)	72.1 ± 7.7	71.5 ± 7.5	70.2 ± 7.7	70.9 ± 7.1
Ln rMSSD (ms)	3.31 ± 0.71	3.44 ± 0.69	3.28 ± 0.76	3.33 ± 0.64

† denotes sig. difference vs pre-match day. + denotes sig difference vs post-match day. Scores of 1-7 with 1 and 7 representing very, very poor (negative state of wellness) and very, very good (positive state of wellness respectively)