doi: 10.4085/1062-6050-0245.21

Monitoring post-match fatigue during a competitive season in elite youth soccer players

Daniel A. Evans¹, Daniel T. Jackson², Adam L. Kelly¹,²,³, Craig A. Williams¹, Alexander B. T. McAuley², Harry Knapman³, and Paul T. Morgan¹,³,⁴

Affiliations

¹Children’s Health and Exercise Research Centre, College of Life & Environmental Sciences, University of Exeter, Exeter, Devon, United Kingdom.
²Faculty of Health, Education and Life Sciences, Birmingham City University, Birmingham, West Midlands, United Kingdom.
³Exeter City Football Club, Exeter, Devon, United Kingdom.
⁴Sport, Exercise & Rehabilitation Sciences, University of Birmingham, Birmingham, West Midlands, United Kingdom.

Correspondence: A. L. Kelly, Department of Sport & Exercise, Birmingham City University, City South Campus, Westbourne Road, Edgbaston, B15 3TN, UK.

E-mail: Adam.Kelly@bcu.ac.uk

Telephone: +44 (0)121 331 7092

Readers should keep in mind that the in-production articles posted in this section may undergo changes in the content and presentation before they appear in forthcoming issues. We recommend regular visits to the site to ensure access to the most current version of the article. Please contact the JAT office (jat@slu.edu) with any questions.
Monitoring post-match fatigue during a competitive season in elite youth soccer players

Abstract

Introduction: Countermovement jump (CMJ) and perceived wellness measures are useful for monitoring fatigue. Fatigue indicators should simultaneously show sensitivity to previous load and demonstrate influence on subsequent physical output; however, this has not been examined. This study examined the efficacy of CMJ and wellness measures to both detect post-match fatigue and predict subsequent physical match output in elite youth soccer.

Methods: Sixteen soccer players (18 ± 1 years) participated in 36 English Football League Youth Alliance League fixtures. Physical match outputs (total distance, high-speed running, very high-speed running, and accelerations and decelerations) were recorded using a 10 Hz global positioning system and 200 Hz accelerometer device during competitive match play. CMJ height and perceived wellness were assessed weekly and daily, respectively, as indirect indicators of fatigue. Four sub-units of wellness (perceived soreness, energy, general stress, and sleep) were measured using customised psychometric questionnaires. Results: Simple linear regression showed that match accelerations and decelerations (AD) were predictive of energy ($R^2 = 0.08, P = 0.001$), stress ($R^2 = 0.09, P < 0.001$), and total wellness ($R^2 = 0.06, P = 0.002$) 2 days post-match. CMJ ($R^2 = 0.05, P = 0.002$), stress ($R^2 = 0.08, P < 0.001$), sleep ($R^2 = 0.03, P = 0.034$), and total wellness ($R^2 = 0.05, P = 0.006$) 5 days pre-match (MD-5) were predictive of AD during the subsequent match. Conclusion: CMJ and wellness may be useful in detecting post-match fatigue. Wellness scores, but not CMJ, on MD-5 influence subsequent match output and therefore may be used to plan and periodise training for the upcoming microcycle.
Keywords: Accelerations; Countermovement Jump; Fatigue; Periodization; Soccer; Training Load.

Key points

- Countermovement jump height and perceived wellness fluctuated in response to match output whereas only perceived wellness influenced subsequent match output.
- The associations between fatigue indicators and match loads/outputs were weak – therefore, changes should be interpreted within the context of a holistic athlete monitoring system.
Introduction

Competitive soccer match-play induces significant fatigue lasting for up to 72 hours, yet soccer players are often required to compete on several occasions within a seven-day period. Unsurprisingly, an imbalance between training and competition stresses, alongside an insufficient recovery period, has been shown to increase risk of illness, injury and, in some cases, lead to overtraining syndrome. As a consequence, the importance of monitoring individual physical ‘load’, fatigue status, and quantification of the physical demands of soccer competition has increased in recent years. Indirect measures of ‘neuromuscular function’, such as jump tests that incorporate the stretch-shortening cycle, and athlete self-report measures, such as subjective wellness questionnaires, have been used in team-sport settings as part of a pragmatic monitoring and testing toolset. In a recent meta-analysis, it was reported that countermovement jump (CMJ) performance and perceived wellness was reduced immediately post- and for up to 72 hours post soccer-specific exercise, highlighting the potential significance of such tools in monitoring recovery from soccer-specific exercise.

Global positioning software (GPS)-derived physical outputs, such as total distance covered, high-speed distance, and acceleration and deceleration characteristics, allow coaches to more accurately estimate physical load. For example, despite constituting only 12% of distance travelled, high-speed characteristics have received significant attention when analysing competitive performance. This is likely because high-speed actions often dictate the most significant moments of soccer competition. Contemporary models of periodisation promote a balance of recovery and physical load, so to maximise the training stimuli and optimise competitive performance. Within each micro-cycle, higher training loads are prescribed for...
periods whereby sufficient recovery is permitted following a previous match and prior to a subsequent match, while technical and recovery sessions are prescribed on the days within a close proximity to a match as a means to prevent significant accumulation of fatigue. However, despite the prescribed load, player-specific characteristics (i.e., the player- and position-specific demands of sessions and recovery responses) require individualised modifications to the periodised plan. Indeed, an excessive training load without sufficient recovery can increase injury risk and reduce physical match outputs and, thus, competitive performance. Consequently, the identification of fatigue status at the beginning of a microcycle is essential to individualise the planning and periodisation of training within a given cycle.

The influence of fatigue status, as measured by CMJ and perceived wellness, on subsequent physical match output has previously been assessed. For example, Cormack et al. (2013) found that those in a fatigued state maintained total distance and high-speed running but had a reduced contribution of vertical acceleration to an accelerometer-derived ‘Player-Load’, likely because of an impaired ability to sprint, accelerate, and decelerate. However, the majority of previous studies have compared physical match outputs of soccer players in a fatigued versus non-fatigued state without accounting for differences in the magnitude of fatigue status. Further, previous studies have measured fatigue status on days proximal to a match and, thus, not considered the influence of incorporating fatigue measures at the start of a micro-cycle to determine subsequent weekly and per-session training load prescription.

As adolescence is a stage of growth encompassing rapid changes in physical, physiological and psychological development, adolescent athletes may respond differently to a given
training load compared to adults as well as those within their own peer group. Previous research has also reported a high prevalence of non-functional overreaching in elite male youth soccer players, while a consensus statement from the International Olympic Committee has called for more data to inform evidence-based practices relating to minimising injury risk and enhancing wellbeing in youth athletes. Therefore, further investigation is warranted to advance understanding of the training load-recovery cycle in this population.

It is suggested that fatigue indicators should simultaneously show sensitivity to previous load and demonstrate influence on subsequent training or match output; however, research has largely focussed on assessing these factors in isolation. The purpose of the current study was, therefore, to examine the efficacy of CMJ and wellness measures to both detect post-match fatigue and observe subsequent physical match output in elite youth soccer players. It was hypothesised that CMJ and perceived wellness would be sensitive to previous match load and predictive of subsequent physical match output.

**Materials and Methods**

**Participants**

Sixteen outfield under-18 academy youth soccer players (Mean ± SD: 18 ± 1 y, 1.78 ± 0.54 m, 70.2 ± 5.9 kg) from the same team competing in the English Football League Youth Alliance League provided written informed consent to participate in the present study. All participants were briefed with a detailed explanation of the aims and requirements of the investigation, as well as any potential risks. For participants under the age of 18 years, additional parental or guardian consent was acquired. Players were assigned an outfield playing position by the head technical coach. Playing positions were central defenders (CD, n...
= 2), wide defenders (WD, n = 3), central midfielders (CM, n = 6), wide midfielders (WM, n = 4), and strikers (ST, n = 1). All procedures were approved by the Ethics Committee of Sport and Health Sciences (University of Exeter).

**Experimental design**

Data from 36 weekend matches were collected during the competitive season from August 2017 to April 2018. Up to five substitutions were allowed during each match. Only from those playing a full match were included in the study for that week. Where a player had an extended break from match-play (e.g., due to injury or non-selection) data were removed from analysis until they returned to regular match-play. The total number of individual match observations was 211, and the mean number of observations per player was 13.2 ± 5.4. CMJ tests were performed weekly, during each microcycle (see Figure 1), and wellness questionnaires were performed daily throughout the study period. Data were analysed two-fold, such that physical match outputs were used to predict fatigue status 2-days post-match (MD+2) (prospective analysis), while fatigue status 5 days pre-match (MD-5) was used to predict subsequent match output (retrospective analysis). This allowed for concurrent assessment of the efficacy of CMJ and wellness measures to both monitor post-match fatigue and predict subsequent match outputs. Players took part in normal team training throughout the duration of the study, as prescribed by coaching and medical staff, in line with a weekly periodisation model, as previously described.  

**Match output variables**

Match output variables were measured using portable 10 Hz GPS devices with an embedded 200 Hz accelerometer (Polar Team System, Polar, Electro Oy, Finland). 10 Hz GPS devices have previously been demonstrated to exhibit an acceptable level of validity and reliability in
a team-sport setting when assessing the speed of movement within intermittent exercise. For each match, participants wore a chest strap with the GPS device located over the sternum. GPS devices were switched on 15 minutes prior to the warmup and switched off immediately following competition. Data from warmups and during half-time were excluded from the current study. Players wore the same GPS device for each match to prevent inter-device measurement error. Measures of physical match output included: (a) total distance (TD; m), (b) high-speed running (HSR; m ≥ 15 km.h⁻¹), (c) very high-speed running (VHSR; m ≥ 19 km.h⁻¹), and (d) accelerations and decelerations (AD; total number of accelerations and decelerations ≥ 2 m.s⁻²).

Countermovement jumps

CMJ performance was determined via jump height and measured using a standardised jump mat (Probotics Inc. 8602 Esslinger CT, Huntsville, Alabama, USA). Jump height was calculated from flight time using the following equation:

\[ h = \frac{f^2 \times g}{8} \]

where \( h \) = jump height, \( f \) = flight time, \( g \) = gravitational acceleration.

Following a standardised warm-up (5-min cycle at 125 W), participants completed 5 × CMJ separated by a 60-s rest period using a standardized protocol. The participants were asked to stand on the jump mat with their feet parallel and approximately shoulder-width apart. Participants then completed a maximal vertical jump, instructed to jump as high as possible, while maintaining hands on hips throughout. CMJ depth was self-selected. Using this experimental set up, pilot testing revealed CMJ height to have a coefficient of variation (CV%) within our lab of 1.5%. An average of the five jumps was calculated for analysis.
Wellness questionnaires

Customised psychometric questionnaires were completed privately prior to any training or exercise to evaluate perceptual items of player wellness throughout the study period. Participants submitted their responses via Google Drive using their personal devices. The questionnaire was designed to be short and specific and was based on previous literature \(^{11,18}\).

The questionnaire was comprised of four items (i.e., perceived soreness, energy, general stress, and sleep), with an additional question relating to any other factors that the player felt was appropriate to share with the medical team. Each item was scored on a scale of 1-10 arbitrary units (AU), with 1 representing the most negative and 10 representing the most positive score. A total wellness score was also calculated by summing together the scores from each item. Each player was provided with specific instruction and education on how to complete the questionnaires and were familiarised with its use during the pre-season period.

Statistical analysis

Z-scores for all match output variables and fatigue indicators were calculated for each player using the following formula: (individual players score – individual players average) / individual players standard deviation. Descriptive data are presented as mean ± SD unless otherwise indicated. Simple univariate linear regression analysis, using z-scores of seasonal data for each player to account for individual variation of both dependent and independent variables, was conducted to determine whether firstly, physical match outputs (i.e., TD, HSR, VHSR, and AD) were associated with fatigue status (i.e., CMJ and wellness) on MD+2 (prospective analysis), and secondly, whether fatigue status was associated with subsequent physical match output on MD-5 (retrospective analysis). The coefficient of determination \((R^2)\) was computed to determine the variance in the dependent variable(s) explainable by the
independent variable(s). Assumptions of linearity, normality of residuals and homoscedasticity were confirmed via graphical inference. Normal distribution was also assessed using the Shapiro-Wilk test. Were assumptions of normality were violated outliers were removed and the model was repeated. For all tests, results were considered statistically significant when $P < 0.05$. All statistical analyses were conducted using R Studio (version 4.0.2).

Results

Descriptive statistics for physical match output are displayed in Table 1. The combined population mean and SD for MD+2 indicators of fatigue status are outlined in Table 2.

Prospective Analysis

Significant negative associations were found between MD+2 AD ($\beta = -0.3$, $P = 0.001$), stress ($\beta = -0.3$, $P < 0.001$), and total wellness ($\beta = -0.25$, $P = 0.002$) with subsequent energy. Match AD explained 8%, 9%, and 6% of the variance in MD+2 energy, stress, and total wellness, respectively. All prospective linear regression analyses are displayed in Table 3.

Retrospective Analysis

A significant positive association was found between MD-5 CMJ ($\beta = 0.22$, $P = 0.002$) and subsequent AD. Furthermore, significant negative associations were found between MD-5 stress ($\beta = -0.28$, $P < 0.001$), sleep ($\beta = -0.17$, $P = 0.034$), and total wellness ($\beta = -0.22$, $P = 0.006$) with subsequent AD. CMJ, stress, sleep, and total wellness explained 5%, 8%, 3%, and 5% of the variance in AD, respectively. All retrospective linear regression analyses are displayed in Table 4.
The purpose of the present study was to investigate associations between physical match output and subsequent CMJ and wellness on MD+2, as well as any associations between CMJ and wellness on MD-5 and subsequent physical match output in under-18 youth soccer players. In agreement with the primary hypotheses, AD was negatively associated with MD+2 energy, stress, and total wellness. Additionally, MD-5 CMJ was positively associated with AD of the subsequent match. However, MD-5 stress, sleep, and total wellness, were negatively associated with AD during the subsequent match. These findings suggest that wellness measures are sensitive in detecting post-match fatigue, and that CMJ performance at the start of the microcycle may be project subsequent match output. Interestingly, this study failed to show any associations between match output and MD+2 CMJ. However, there are factors other than match output and fatigue markers which explain a large proportion of variance in subsequent fatigue and match output. These findings may have important implications for monitoring post-match fatigue and designing the upcoming microcycle in youth soccer players.

It is well documented that an elevated fatigue status is present in cohorts of both amateur and professional male soccer players, assessed via CMJ and wellness questionnaires, is evident for up to 72 hours post-match as a result of soccer match-play. Further, the magnitude of external loading, such as distance covered, during a match is related to the magnitude of the decrement in post-match fatigue status. As such, a relationship between AD and subsequent MD+2 perceived energy, stress, and total wellness was reported in the present study. Similarly, Varley et al. reported a moderate positive relationship (r = 0.52) between accelerations performed and wellness responses 40 hours post-match in elite male soccer.
Given the large neuromuscular and mechanical demands, and resultant decreased force output, structural damage, and soreness associated with acceleration and deceleration actions, these findings were expected. Interestingly, no other match outputs were associated with CMJ or wellness; trivial associations have also been observed with the likes of HSR and TD with wellness measures in elite soccer. However, in agreement with previous literature, the majority of the associations between match output (i.e. TD, HSR and VHSR) and subsequent wellness in the current study were non-significant and/or of a weak magnitude ($R^2 \leq 0.09$). Indeed, previous studies have noted the influence of contextual factors such as match result and location on post-match wellness responses which may confound such dose-response relationships. There is also emerging evidence to suggest that the length of time over which load is evaluated influences the relationship between load and wellness. Importantly, recent research in high-performing youth soccer populations has reported poor reliability of short, customised subjective wellness questionnaires frequently used in applied practice, such as that used in the present study, in both rested and fatigued states. Although, the use of a more continuous scale (e.g., 1-10 versus 1-5) in the current study may have improved the reliability of wellness responses. Response distortion with subjective measures remains a potential cause for poor reliability, particularly in youth athletes who may be more susceptible to peer-to-peer coercion or recall error.

Non-significant relationships were reported between match output and MD+2 CMJ height in the present study. This is in agreement with some but not all previous research. It appears that the use of metrics indicative of jump output, such as height, are less sensitive to fatigue-induced decrements in neuromuscular function than those indicative of jump strategy, such as flight time: contraction time. This is thought to be due to a reorganisation of jump strategy to main similar jump outputs under fatigued conditions. Furthermore, whilst a
jump height is commonly used to assess recovery post-match, the duration of CMJ jump decrement from baseline varies\textsuperscript{31}, and may recover within 48 hours. Moreover, within elite youth soccer, there may be no variation seen in CMJ post-match\textsuperscript{32}. Other potential explanations for the lack of significant associations between physical match output and MD+2 fatigue markers in the present study includes the measures of physical output studied. Traditional external load metrics such as total distance, accelerations/decelerations, and high-speed running thresholds do not reflect the energetic cost of changes in velocity or load incurred during physical contests that do not incur displacement\textsuperscript{26}. Further, it is the internal load, rather than the external load, that has been suggested to determine the fatigue response\textsuperscript{27}. Finally, while the use of Z-scores expresses match output relative to individual norms, the use of individualised external load metrics accounts for the influence of physical fitness on the fatigue response, which may have improved dose-response relationships in the present study\textsuperscript{28}.

To the best of our knowledge, this is the first study to examine the association between fatigue markers at the start of a microcycle (MD-5) and subsequent match output in elite youth soccer players. Significant associations ($R^2 = 0.03 - 0.08$) were found between MD-5 CMJ, stress, sleep, and total wellness and subsequent match AD. A previous study in high-performing field hockey reported relationships between wellness and traditional physical match output metrics normalised to time or ratings of perceived exertion (RPE)\textsuperscript{12}. Ihsan et al.\textsuperscript{11} collected data over a nine-day tournament consisting of six matches, where greater variability (small to large effect size changes) in wellness and match output was observed. In addition, the strength of relationships was greater ($r = -0.87$ to $-0.95$) when match outputs were normalised to both time and RPE\textsuperscript{12}. These factors may explain the disparity in the magnitude of associations between wellness and match output in the present study versus that
of Ihsan et al.\textsuperscript{11}. A number of previous studies have demonstrated the influence of pre-training wellness on physical training outputs\textsuperscript{15,29}. In contrast, in agreement with the present study, Bellinger et al.\textsuperscript{12} showed no influence of pre-match wellness on accelerometer-derived match output and the way in which it is accumulated in elite Australian football players. Indeed, it is possible that players do not self-regulate physical output during match-play based on wellness as they do in training due to greater motivation for maximum effort during competition\textsuperscript{11}.

For retrospective analyses in the present study, fatigue status was measured at the start of the microcycle (MD-5), two days after the previous match. As a result, there may have been sufficient time for post-match fatigue to dissipate before the subsequent match, thus having no influence on physical output\textsuperscript{11}, a potential reason as to the negative association between wellness and AD. Furthermore, differences in training load between players may have contributed to different fatigue statuses on match-day, therefore confounding retrospective relationships\textsuperscript{10}. Indeed, players may have self-regulated their training load based on their pre-training neuromuscular fatigue and perceived wellness\textsuperscript{15,16}. Additionally, it is plausible that these weak retrospective relationships may demonstrate successful management (i.e., weekly periodisation) of players displaying elevated fatigue at the start of a microcycle. For example, players with lower-than-normal CMJ and wellness may have been prescribed lower training loads and recovery interventions to mitigate any residual fatigue prior to the upcoming match, which is the ultimate aim of a weekly periodisation model\textsuperscript{7}. Match output is also known to be highly variable and influenced by a host of factors such as own and opponent playing style, team formation, and tactics\textsuperscript{30}. Therefore, these factors may account for a large proportion of the remaining unexplained variance that is beyond the scope of the present study.
The present findings should be considered in light of several limitations. For example, despite being based on previous literature\textsuperscript{11,18}, a rigorous process of study to ensure validity and reliability of the wellness questionnaire in the current study has not been undertaken. Furthermore, the relationship between load and wellness may be non-linear, therefore the use of linear statistical techniques may have limited capacity to model such relationships\textsuperscript{4,18}. The study was also conducted on a relatively small sample of athletes which may have impaired our ability to detect relationships. Moving forward, future studies should consider accounting for other factors, such as nutrition, other sport involvement, and maturity status, to capture a more holistic insight into player readiness status.

**Practical Applications**

Systematic monitoring of wellness may have practical utility for the purposes of monitoring post-match fatigue and informing training for the upcoming microcycle in high-performing youth soccer, while CMJ may only be useful for the latter. For example, based on the dose-response relationships reported between match output and post-match fatigue in the present study, players who perform more accelerations and decelerations during match-play may be prescribed recovery interventions and/or an additional rest period after a match. Further, players with an elevated fatigue status at the start of the microcycle may be prescribed lower loads, modified training and/or recovery strategies during the upcoming microcycle to ensure sufficient physical preparation for the subsequent match. The present study also adds to the literature opposed to the utility of CMJ height in detecting fatigue, and therefore CMJ metrics reflecting jump strategy rather than metrics reflecting jump output may reflect a more appropriate approach. Finally, the relationships reported in this study were of a weak magnitude, highlighting that a large proportion of the variance in post-match fatigue and
match output is accounted for by factors other than match output and fatigue, respectively. Therefore, it is essential that practitioners analyse changes in match output and fatigue status in context with other factors such as recent training load, measurement reliability, and team tactics \(^{18,21,30}\), and that decisions regarding player management are not solely based on CMJ and wellness scores.

**Conclusions**

The present study demonstrated that, in a cohort of high-performing youth soccer players, match AD was predictive of MD+2 energy, stress, and total wellness, as well as MD-5 CMJ, stress, sleep, and total wellness were predictive of AD during the subsequent match. These findings may have important implications for the purpose of monitoring post-match fatigue and designing the upcoming microcycle in high-performing youth soccer. However, these associations were weak, therefore changes in CMJ and wellness should be interpreted within the context of a wider athlete monitoring system.

**Acknowledgements**

The authors would like to thank the players and other remaining staff at Exeter City FC for their participation and support in this project.

**Declaration of interest statement**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Declarations of funding sources:** This work was not sponsored by any funding body external to University of Exeter.
References

1. Silva J, Rumpf M, Hertzog M, et al. Acute and Residual Soccer Match-Related Fatigue: A Systematic Review and Meta-analysis. *Sport Med.* 2018;48(3):539-583.

2. Meeusen R, Duclos M, Foster C, et al. Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the european college of sport science and the American College of Sports Medicine. *Med Sci Sports Exerc.* 2013;45(1):186-205.

3. Harper D, Carling C, Kiely J. High-Intensity Acceleration and Deceleration Demands in Elite Team Sports Competitive Match Play: A Systematic Review and Meta-Analysis of Observational Studies. *Sport Med.* 2019;49(12):1923-1947.

4. Gabbett T, Whyte D, Hartwig T, Wescombe H, Naughton G. The relationship between workloads, physical performance, injury and illness in adolescent male football players. *Sport Med.* 2014;44(7):989-1003.

5. Thorpe R, Atkinson G, Drust B, Gregson W. Monitoring fatigue status in elite team-sport athletes: Implications for practice. *Int J Sports Physiol Perform.* 2017;12:27-34.

6. Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the english premier league. *Int J Sports Med.* 2014;35(13):1095-1100.

7. Walker G, Hawkins R. Structuring a program in elite professional soccer. *Strength Cond J.* 2018;40(3):72-82.

8. Jones C, Griffiths P, Mellalieu S. Training Load and Fatigue Marker Associations with Injury and Illness: A Systematic Review of Longitudinal Studies. *Sport Med.* 2017;47(5):943-974.

9. Cormack S, Mooney M, Morgan W, McGuigan M. Influence of neuromuscular fatigue on accelerometer load in elite Australian football players. *Int J Sports Physiol Perform.*
10. Rowell A, Aughey R, Clubb J, Cormack S. A standardized small sided game can be used to monitor neuromuscular fatigue in professional A-league football players. *Front Physiol*. 2018;9:1-13.

11. Bellinger P, Ferguson C, Newans T, Minahan C. No Influence of Prematch Subjective Wellness Ratings on External Load During Elite Australian Football Match Play. *Int J Sports Physiol Perform*. 2020;15(6):801-807.

12. Ihsan M, Tan F, Sahrom S, Choo HC, Chia M, Aziz AR. Pre-game perceived wellness highly associates with match running performances during an international field hockey tournament. *Eur J Sport Sci*. 2017;17(5):593-602.

13. Williams C, Winsley R, Pinho G, de Ste Croix M, Lloyd R, Oliver J. Prevalence of non-functional overreaching in elite male and female youth academy football players. *Sci Med Footb*. 2017;1(3):222-228.

14. Bergeron M, Mountjoy M, Armstrong N, et al. International Olympic Committee consensus statement on youth athletic development. *Br J Sports Med*. 2015;49(13):843-851.

15. Govus A, Coutts A, Duffield R, 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 Sports Physiol Perform*. 2018;13(1).

16. Malone S, Mendes B, Hughes B, et al. Decrements in neuromuscular performance and increases in creatine kinase impact training outputs in elite soccer players. *J Strength Cond Res*. 2018;32(5):1342-1351.

17. Jennings D, Cormack S, Coutts A, Boyd L, Aughey R. Variability of GPS units for measuring distance in team sport movements. *Int J Sports Physiol Perform*. 
18. Lathlean T, Gastin P, Newstead S, Finch C. A prospective cohort study of load and wellness (sleep, fatigue, soreness, stress, and mood) in elite junior Australian football players. *Int J Sports Physiol Perform.* 2019;14(6):829-840.

19. Duignan C, Doherty C, Caulfield B, Blake C. Single-item self-report measures of team-sport athlete wellbeing and their relationship with training load: A systematic review. *J Athl Train.* 2020;55(9):944-953.

20. Abbott W, Brownlee T, Harper L, Naughton R, Clifford T. The independent effects of match location, match result and the quality of opposition on subjective wellbeing in under 23 soccer players: a case study. *Res Sport Med.* 2018;26(3):262-275.

21. Fitzpatrick J, Akenhead R, Russell M, Hicks K, Hayes P. Sensitivity and reproducibility of a fatigue response in elite youth football players. *Sci Med Footb.* 2019;3(3):214-220.

22. Saw A, Main L, Gastin P. Monitoring athletes through self-report: Factors influencing implementation. *J Sport Sci Med.* 2014;14(1):137-146.

23. Varley I, Lewin R, Needham R, Thorpe R, Burrey R. Association between Match Activity Variables, Measures of Fatigue and Neuromuscular Performance Capacity Following Elite Competitive Soccer Matches. *J Hum Kinet.* 2017;60(1):93-99.

24. Nedelec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. The influence of soccer playing actions on the recovery kinetics after a soccer match. *J Strength Cond Res.* 2014;28(6):1517-1523.

25. Gathercole R, Sporer B, Stellingwerff T, Sleivert G. Alternative countermovement-jump analysis to quantify acute neuromuscular fatigue. *Int J Sports Physiol Perform.* 2015;10(1):84-92.

26. Boyd LJ, Ball K, Aughey RJ. Quantifying external load in australian football matches
and training using accelerometers. *Int J Sports Physiol Perform*. 2013;8(1):44-51.

27. Impellizzeri F, Rampinini E, Marcora S. Physiological assessment of aerobic training in soccer. *J Sports Sci*. 2005;23(6):583-592.

28. Tomazoli G, Marques J, Farooq A, Silva JR. Estimating Postmatch Fatigue in Soccer: The Effect of Individualization of Speed Thresholds on Perceived Recovery. *Int J Sports Physiol Perform*. 2020;15(9):1216-1222.

29. Malone S, Owen A, Newton M, et al. Wellbeing perception and the impact on external training output among elite soccer players. *J Sci Med Sport*. 2018;21(1):29-34.

30. Carling C. Interpreting physical performance in professional soccer match-play: Should we be more pragmatic in our approach? *Sport Med*. 2013;43(8):655-663.

31. Doeven SH, Brink MS, Kosse SJ, Lemmink KAPM. Postmatch recovery of physical performance and biochemical markers in team ball sports: a systematic review. *BMJ Open Sport & Exercise Medicine*. 2018;4:e000264.

32. Kunz P, Zinner C, Holmberg HC, Sperlich B. Intra- and Post-match Time-Course of Indicators Related to Perceived and Performance Fatigability and Recovery in Elite Youth Soccer Players. *Front Physiol*. 2019;15;10:1383.

33. Malone S, Owen A, Newton M, Mendes B, Tiernan L, Hughes B, Collins K. Wellbeing perception and the impact on external training output among elite soccer players. *J Sci Med Sport*. 2018;21(1):29-34.

**Figure Legends**

Figure 1. Example weekly microcycle demonstrating the timing of fatigue monitoring relative...
to match day.
| MD Code   | MD+2/-5 | MD-4 | MD+3 | MD-2 | MD-1 | MD   | MD+1 |
|-----------|---------|------|------|------|------|------|------|
| Day       | Mon     | Tues | Wed  | Thurs| Fri  | Sat  | Sun  |
| Fatigue Monitoring | Wellness and CMJ | Wellness | Wellness | Wellness | Wellness | Wellness | Wellness |

Downloaded from http://meridian.allenpress.com/jat/article-pdf/doi/10.4085/1062-6050-0245.21/2905215/10.4085_1062-6050-0245.21.pdf by guest on 26 September 2021
Table 1. Descriptive statistics for physical match output variables according to playing position\textsuperscript{a}.

| Position | TD (m)      | HSR (m)    | VHSR (m)   | AD (#)   |
|----------|-------------|------------|------------|----------|
| CD       | 10229 ± 433 | 1735 ± 282 | 603 ± 137  | 239 ± 43 |
| (n = 45) |             |            |            |          |
| WD       | 10882 ± 510 | 2111 ± 313 | 873 ± 173  | 217 ± 29 |
| (n = 36) |             |            |            |          |
| CM       | 11340 ± 936 | 2214 ± 487 | 751 ± 250  | 217 ± 35 |
| (n = 82) |             |            |            |          |
| WM       | 11150 ± 687 | 2585 ± 456 | 1272 ± 251 | 264 ± 40 |
| (n = 33) |             |            |            |          |
| ST       | 10804 ± 705 | 2662 ± 295 | 1299 ± 160 | 264 ± 35 |
| (n = 15) |             |            |            |          |
| Total    | 10957 ± 840 | 2184 ± 498 | 860 ± 322  | 232 ± 41 |
| (n = 211)|             |            |            |          |

Abbreviation: CD, central defender; WD, wide defender; CM, central midfielder; WM, wide midfielder; ST, striker; Total, all positions combined; TD, total distance; HSR, high-speed running; VHSR, very high-speed running; AD, accelerations and decelerations; n, number of player observations.

\textsuperscript{a} data are displayed as mean ± SD.
Table 2. Seasonal descriptive statistics for MD+2 fatigue indicators.

| Fatigue indicator     | #     | Mean ± SD  |
|-----------------------|-------|------------|
| CMJ (cm)              | 185   | 54.2 ± 7.0 |
| Soreness (AU)         | 153   | 6.9 ± 0.6  |
| Energy (AU)           | 153   | 7.0 ± 0.5  |
| Stress (AU)           | 153   | 7.5 ± 0.9  |
| Sleep (AU)            | 153   | 7.3 ± 0.6  |
| Total wellness (AU)   | 153   | 28.6 ± 1.7 |

Abbreviation: CMJ, countermovement jump; #, number of observations. Soreness, energy, stress, and sleep were recorded on a scale of 1-10. Total wellness is calculated by summing together the scores from each item’s score on a given day.
Table 3. Linear regression analysis of physical match output and subsequent measures of fatigue (MD+2) (prospective analysis).

| Fatigue indicator | Predictor | $F$ statistic | Intercept | $\beta$ | $R^2$ |
|-------------------|-----------|--------------|-----------|--------|-------|
| CMJ               | TD        | $F(1,182) = 1.8, P = 0.177$ | -0.07     | -0.10  | 0.01  |
|                   | HSR       | $F(1,182) = 0.1, P = 0.822$ | -0.06     | 0.02   | 0.00  |
|                   | VHSR      | $F(1,182) = 0.2, P = 0.636$ | -0.06     | 0.04   | 0.00  |
|                   | AD        | $F(1,182) = 0.1, P = 0.768$ | -0.06     | 0.02   | 0.00  |
| Soreness          | TD        | $F(1,143) = 0.3, P = 0.568$ | 0.00      | -0.05  | 0.00  |
|                   | HSR       | $F(1,143) = 0.2, P = 0.693$ | 0.00      | 0.03   | 0.00  |
|                   | VHSR      | $F(1,143) = 0.2, P = 0.646$ | 0.00      | 0.04   | 0.00  |
|                   | AD        | $F(1,143) = 1.1, P = 0.298$ | -0.01     | -0.09  | 0.01  |
| Energy            | TD        | $F(1,119) = 3.6, P = 0.060$ | 0.00      | -0.17  | 0.03  |
|                   | HSR       | $F(1,119) = 0.5, P = 0.464$ | -0.00     | -0.06  | 0.00  |
|                   | VHSR      | $F(1,119) = 0.3, P = 0.571$ | -0.00     | -0.05  | 0.00  |
|                   | AD        | $F(1,119) = 11.0, *P = 0.001$ | -0.02     | -0.30  | 0.08  |
| Stress            | TD        | $F(1,132) = 1.0, P = 0.328$ | 0.00      | -0.09  | 0.01  |
|                   | HSR       | $F(1,132) = 0.7, P = 0.411$ | -0.00     | -0.07  | 0.01  |
|                   | VHSR      | $F(1,132) = 0.5, P = 0.466$ | 0.00      | 0.06   | 0.00  |
|                   | AD        | $F(1,132) = 13.1, *P < 0.001$ | -0.03     | -0.30  | 0.09  |
| Sleep             | TD        | $F(1,150) = 0.2, P = 0.695$ | 0.00      | -0.03  | 0.00  |
|                   | HSR       | $F(1,150) = 0.2, P = 0.627$ | -0.00     | -0.04  | 0.00  |
|                   | VHSR      | $F(1,150) = 0.9, P = 0.335$ | -0.00     | -0.08  | 0.01  |
|                   | AD        | $F(1,150) = 0.0, P = 0.994$ | 0.00      | 0.00   | 0.00  |
| Total wellness    | TD        | $F(1,150) = 1.5, P = 0.220$ | 0.00      | -0.10  | 0.01  |
|                   | HSR       | $F(1,150) = 0.5, P = 0.486$ | -0.00     | -0.06  | 0.00  |
|                   | VHSR      | $F(1,150) = 0.0, P = 0.899$ | -0.00     | -0.01  | 0.00  |
|                   | AD        | $F(1,150) = 9.6, *P = 0.002$ | -0.01     | -0.25  | 0.06  |

Abbreviation: TD, total distance; HSR, high-speed running; VHSR, very high-speed running; AD, accelerations and decelerations; CMJ, countermovement jump.

* $P < 0.01$. 

Online First
Table 4. Linear regression analysis of fatigue measures (MD-5) and subsequent physical match output (retrospective analysis).

| Physical match output variable | Predictor | $F$ statistic | Intercept | $\beta$ | $R^2$ |
|-------------------------------|-----------|---------------|-----------|---------|-------|
| TD                            | CMJ       | $F(1,186) = 3.5, P = 0.064$ | -0.02     | 0.14    | 0.02  |
|                               | Soreness  | $F(1,158) = 0.8, P = 0.380$ | -0.01     | 0.07    | 0.00  |
|                               | Energy    | $F(1,143) = 0.5, P = 0.492$ | -0.03     | 0.06    | 0.00  |
|                               | Stress    | $F(1,139) = 3.4, P = 0.068$ | -0.01     | -0.16   | 0.02  |
|                               | Sleep     | $F(1,150) = 0.2, P = 0.628$ | -0.01     | -0.04   | 0.00  |
| Total wellness                |           | $F(1,155) = 0.0, P = 0.843$ | -0.01     | -0.02   | 0.00  |
| HSR                           | CMJ       | $F(1,186) = 1.2, P = 0.267$ | -0.02     | 0.08    | 0.01  |
|                               | Soreness  | $F(1,158) = 0.7, P = 0.415$ | -0.00     | 0.07    | 0.00  |
|                               | Energy    | $F(1,143) = 0.9, P = 0.346$ | 0.01      | 0.08    | 0.01  |
|                               | Stress    | $F(1,139) = 3.0, P = 0.087$ | -0.00     | -0.15   | 0.02  |
|                               | Sleep     | $F(1,150) = 0.3, P = 0.560$ | 0.01      | -0.05   | 0.00  |
| Total wellness                |           | $F(1,155) = 0.1, P = 0.776$ | 0.01      | -0.02   | 0.00  |
| VHSR                          | CMJ       | $F(1,186) = 1.4, P = 0.240$ | -0.01     | 0.09    | 0.01  |
|                               | Soreness  | $F(1,158) = 0.8, P = 0.366$ | 0.03      | 0.07    | 0.01  |
|                               | Energy    | $F(1,143) = 0.7, P = 0.413$ | 0.02      | 0.07    | 0.00  |
|                               | Stress    | $F(1,139) = 0.0, P = 0.876$ | 0.03      | 0.01    | 0.00  |
|                               | Sleep     | $F(1,150) = 0.0, P = 0.981$ | 0.02      | 0.00    | 0.00  |
| Total wellness                |           | $F(1,155) = 0.5, P = 0.468$ | 0.02      | 0.06    | 0.00  |
| AD                            | CMJ       | $F(1,186) = 10.1, ^aP = 0.002$ | 0.01      | 0.22    | 0.05  |
|                               | Soreness  | $F(1,158) = 0.1, P = 0.804$ | -0.04     | -0.02   | 0.00  |
|                               | Energy    | $F(1,143) = 0.8, P = 0.358$ | -0.05     | -0.08   | 0.01  |
|                               | Stress    | $F(1,139) = 12.0, \ P < 0.001$ | -0.05     | -0.28   | 0.08  |
|                               | Sleep     | $F(1,150) = 4.6, ^aP = 0.034$ | -0.03     | -0.17   | 0.03  |
| Total wellness                |           | $F(1,155) = 7.8, ^bP = 0.006$ | -0.03     | -0.22   | 0.05  |

Abbreviation: TD, total distance; HSR, high-speed running; VHSR, very high-speed running; AD, accelerations and decelerations; CMJ, countermovement jump.

$^a P < 0.05$.

$^b P < 0.01$. 