2020

Monitoring Wellness, Training Load, and Running Performance During a Major International Female Field Hockey Tournament

Aideen McGuinness
Technological University, aideen.mcguinness@tudublin.ie

Gerard McMahon
Ulster University

Shane Malone
Technological University Dublin, Shane.Malone@TUDublin.ie

See next page for additional authors

Recommended Citation

McGuinness, A., McMahon, G. & Malone, S. (2020). Monitoring Wellness, Training Load, and Running Performance During a Major International Female Field Hockey Tournament. *The Journal of Strength and Conditioning Research*, vol. 34, no. 8, September, 2018. doi:10.1519/JSC.0000000000002835

Authors

Aideen McGuinness, Gerard McMahon, Shane Malone, Darren Kenna, David Passmore, and Kieran Collins

Monitoring Wellness, Training Load, and Running Performance During a Major International Female Field Hockey Tournament

Article *in* The Journal of Strength and Conditioning Research · September 2018

DOI: 10.1519/JSC.0000000000002835

Monitoring Wellness, Training Load, and Running Performance During a Major International Female Field Hockey Tournament

Aideen McGuinness,[1] Gerard McMahon,[2] Shane Malone,[1,3] Darren Kenna,[4] David Passmore,[5] and Kieran Collins[1]

[1]*Institute of Technology Tallaght, Dublin, Ireland;* [2]*Sport Northern Ireland, Belfast, United Kingdom;* [3]*The Tom Reilly Building, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom;* [4]*Setanta College, Thurles Enterprise Center, Tipperary, Ireland; and* [5]*Dublin City University, Dublin, Ireland*

Abstract

McGuinness, McMahon, G, A, Malone, S, Kenna, D, Passmore, D, and Collins, K. Monitoring wellness, training load, and running performance during a major international female field hockey tournament. *J Strength Cond Res* XX(X): 000–000, 2018—The current observational study quantified players' activity profiles during a major international female field hockey tournament and determined whether an association exists between well-being measures and running performance within elite female hockey players. Elite female field hockey players (23 ± 3 years; 162.6 ± 13 cm; and 66 ± 6 kg) participated in the study. Participants running performance was monitored using global positioning system technology (S5; Catapult Innovations, Scoresby, Victoria, Australia), with daily well-being questionnaires used to quantify player responses during the tournament. Thresholds for the magnitude of the observed change for each variable were determined using the Hopkins Spreadsheets for analysis of controlled trials. Relative distance ($m \cdot min^{-1}$) was *likely* lower when compared with game 1 in game 7. Relative high speed ($m \cdot min^{-1}$ >16 $km \cdot h^{-1}$) was *likely* lower in games 5, 6, and 7 when compared with game 1. Subjective load was *very likely* higher in game 2 and *very likely* lower in game 3 when compared with game 1. Mood and sleep quality were *likely* lower in game 1 when compared with game 4 and game 7. Muscle soreness was *likely* higher when compared with game 1 in game 7. During the tournament, it was observed that a decrease in players' daily well-being was accompanied by changes in running performance. Furthermore, changes to players' muscle soreness and sleep quality result in decreased players' high-speed running performance during match-play. Therefore, to prevent the observed effects, coaches should adopt strategies to enhance sleep quality and incorporate specific recovery modalities to reduce musculoskeletal soreness.

Key Words team sport, high-speed running, GPS, intermittent exercise, muscle soreness

Address correspondence to Aideen McGuinness, mcguinnessaideen@gmail.com.

00(00)/1–9

Journal of Strength and Conditioning Research

Introduction

Field hockey can be best described as a stick-and-ball team sport consisting of high-speed running superimposed on low-speed periods of running where technical and tactical components are intertwined with changes of direction (27). Similar to other team sports, competitive match-play requires players to perform both offensive and defensive skills across various speed thresholds (24,27,30,35). Competitive match-play consists of 2 teams of 11 playing a total of 4 quarters (Q; 15 minutes). During match-play, there is a 2-minute break separating the first 2 quarters (Q1 and Q2). A similar break separates the last 2 quarters (Q3 and Q4). Half time consist of a 7-minute break between Q2 and Q3, equating to a total playing time of 60 minutes. At a national level, players strive to compete at the 3 major international competitions (World League, World Cup, and The Olympic Games). Typically, tournaments require the athletes to play on average 7 games across a 10-day period, with many schedules requiring teams to play 3 games in 4 days (14,16,26). The current schedule offers athletes limited time to recover between games.

Recently, players' activity profiles across quarters of match-play have been reported through global positioning systems (GPS) (28). McGuinness et al. (26) reported that the average total distance (TD) covered during match-play was 4,847 ± 583 m (127.6 ± 15.6 $m \cdot min^{-1}$), Interestingly, it was observed that high-intensity distance (HID) (m; >16 $km \cdot h^{-1}$) decreased between the first (154 ± 58 m) and second (124 ± 46 m) Q with a significant increase reported between the second and fourth (156 ± 49 m) Q. Defenders were observed to cover more TD (5,181 ± 607 m) than the

Table 1. The global activity profiles and wellness scores on the day of each game during a major international female field hockey tournament.*†

	Team avg.	Game 1	Game 2	Game 3	Game 4	Game 5	Game 6	Game 7
Running performance								
Time on feet (min)	45.9 ± 6.2	45.0 ± 7.7	49.7 ± 9.5	44.3 ± 7.0	43.2 ± 3.9	43.6 ± 4.9	47.2 ± 5.8	48.2 ± 4.8
Total distance (m)	5,147 ± 628	5,135 ± 646	5,566 ± 920	5,104 ± 790	5,001 ± 427	5,030 ± 541	5,090 ± 543	5,100 ± 529
Total distance ($m \cdot min^{-1}$)	113 ± 8.9	115.8 ± 11.5	113.1 ± 7.4	115.9 ± 9.6	116.3 ± 8.9	115.6 ± 7.6	108.3 ± 7.1	106.1 ± 9.8
High-intensity distance ($m \cdot min^{-1}$)	16.4 ± 5.3	18.1 ± 5.4	17.8 ± 6.0	17.6 ± 6.8	16.3 ± 4.9	14.9 ± 4.1	14.9 ± 4.1	15.0 ± 5.8
Max velocity ($km \cdot h^{-1}$)	24.1 ± 1.3	23.8 ± 1.5	25.1 ± 1.2	24.7 ± 1.8	24.0 ± 1.2	23.5 ± 0.9	24.5 ± 1.1	23.4 ± 1.4
Relative max velocity (%)	89 ± 6	88 ± 6	93 ± 4	92 ± 8	89 ± 7	87 ± 5	91 ± 6	87 ± 4
Wellness								
Load (AU)	350 ± 58	348 ± 61	438 ± 85	295 ± 53	339 ± 42	346 ± 67	339 ± 58	347 ± 45
Mood (AU)	7.7 ± 1.1	8.0 ± 1.1	7.5 ± 1.1	7.9 ± 1.1	7.2 ± 1.6	7.8 ± 1.1	7.8 ± 0.7	7.6 ± 0.8
Muscle soreness (AU)	3.4 ± 1.0	2.8 ± 1.1	3.5 ± 1.0	3.7 ± 1.2	3.2 ± 1.2	3.8 ± 1.0	3.3 ± 1.2	3.6 ± 0.9
Sleep quality (AU)	8.1 ± 0.8	8.2 ± 0.8	8.3 ± 0.8	8.2 ± 0.7	7.8 ± 1.0	8.2 ± 0.7	8.2 ± 0.7	7.6 ± 1.0

*AU = arbitrary unit.
†All data are presented as mean ± *SD*. High-intensity distance ($m \cdot min^{-1}$) corresponds to any movement $>16\ km \cdot h^{-1}$ relative to the time the player spent in. match-play.

midfield (4,740 ± 530 m) and forwards (4,549 ± 546 m). However, forwards were reported to have the highest work rate during match-play (142.2 ± 17.1 $m \cdot min^{-1}$) when compared with the other positional lines of play (defenders 115.1 ± 13.5 $m \cdot min^{-1}$ and midfielders 131.7 ± 14.7 $m \cdot min^{-1}$). Recent literature outlining the demands of a major international field hockey tournament is limited. However, Jennings et al. (16) previously reported that all players' running performance decreased during game 5 when playing 6 games in 9 days. Although when compared with game 1, the forward TD and HID (m; $>15\ km \cdot h^{-1}$) were reported to decrease during game 3, while the midfielders HID varied across all 5 games. Defenders showed relatively no activity profile variation. Spencer et al. (31) reported similar results. It was reported that the time spent walking increased across the high-intensity period, while time spent jogging decreased when players played 3 games in 4 days. However, it is important to note that these observations were reported when the game was played across 2 halves (35 minutes) and may not be observed now that the game is played across 4 quarters.

In recent years, the use of noninvasive forms of player monitoring (e.g., load and psychometric wellness monitoring) has been shown to be a functional method of assessing players' response to training and match-play (7,8,18,27,32). Previous research has shown that coaches need to continually monitor internal training load to show the ramification of a training stimulus (8,18,20). Although, it is important to note that monitoring training load can be problematic on account of individual characteristics. In addition, Bridge et al. (7), reported that players are more likely to report an underestimated exertion in comparison with their individualized heart rate responses depending on the sessions level of enjoyment. Buchheit et al. (8) monitored 18 professional Australian Rules football players during a 2-week high-intensity period. The results reported that although external load increased, it became visible that the players were capable of dealing with these demands, and wellness scores remained stable, while players' running performance was seen to improve. Fluctuation in players' training load was seen to have a negative effect on players' wellness scores the following day, suggesting the need for adequate load monitoring and recovery strategies. Similarly, Thorpe et al. (33) reported that players' wellness scores were a favorable noninvasive method for assessing players' fatigue during a major international female field hockey tournament with large to small correlations being observed between training load (total and high-speed distance) and various fatigue variables. Thornton et al. (32) recorded sleep quality in 31 elite rugby players during a 2-week training camp. Results suggested that during a high-intensity period, the time players spent asleep and the quality of sleep they got were significantly reduced. These decrements were likely due to the changes in location and the shift in intensity. However, these changes had little to no effect on players' running performance.

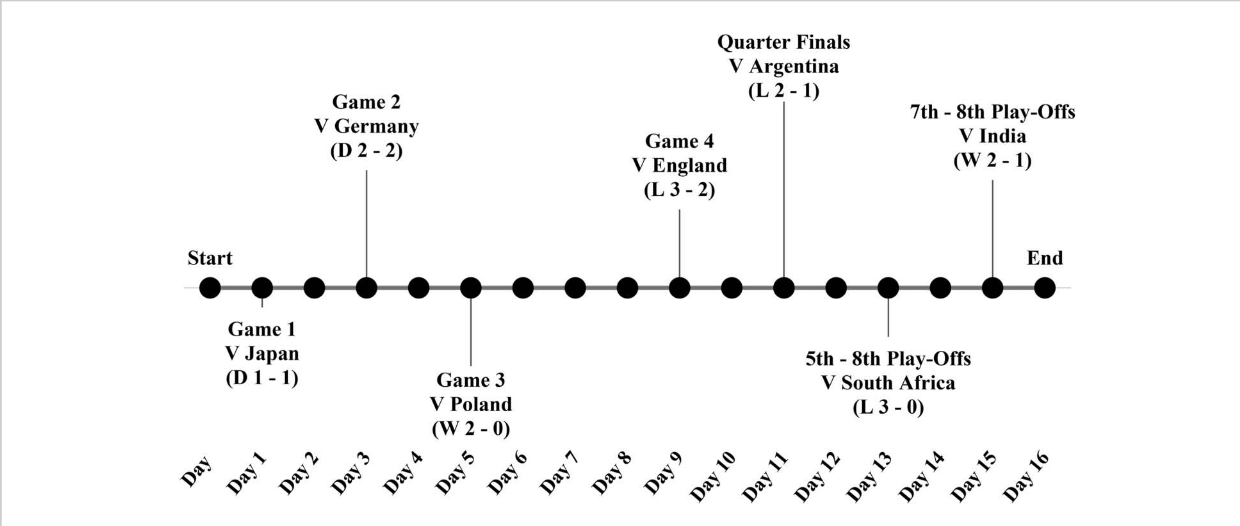

Figure 1. A timeline of the games and opposition played during the international female field hockey tournament.

To the authors' knowledge, little to no research to date has assessed field hockey players' wellness and the effect it has on their running performance during these highly congested training and match-play periods. Therefore, the primary aim of the current observational study was to quantify the global variation in players' activity profiles during a major international female field hockey tournament. Second, we aimed to monitor players' well-being and determine whether an association is apparent between the changes in psychometric wellness measures and changes in match-play running performance.

Methods

Experimental Approach to the Problem

The current observational study was designed to monitor elite female field hockey players during a high intensified

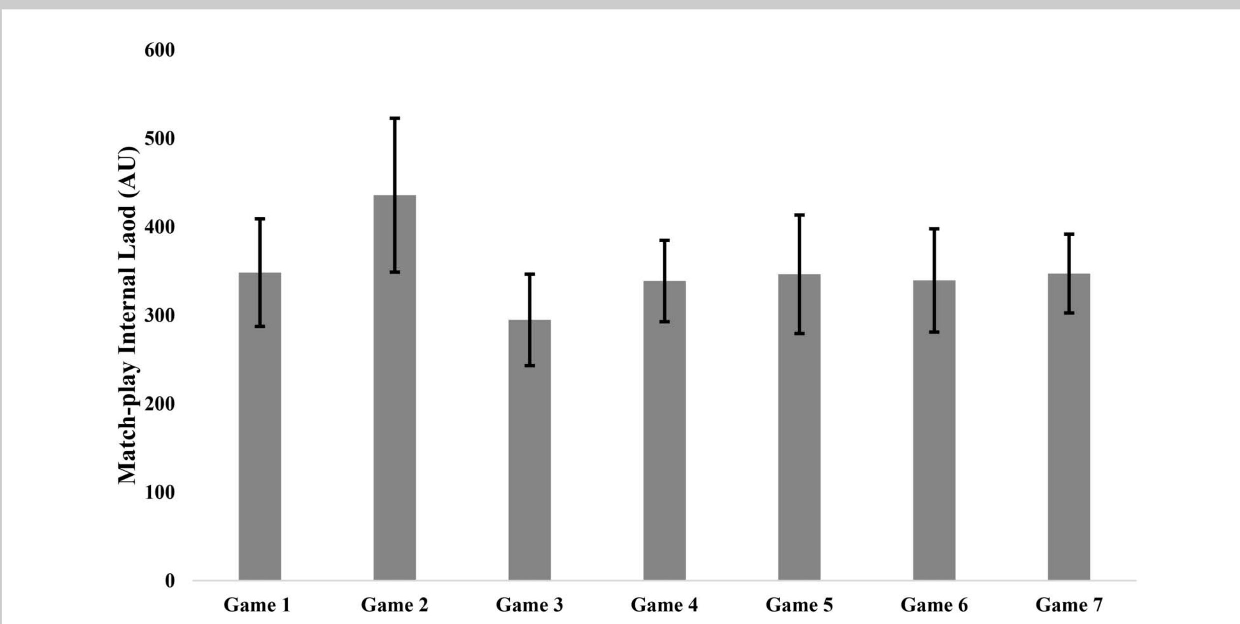

Figure 2. The changes in subjective load reported by players during a major international female field hockey tournament. Across match-play. All data presented by mean ± *SD*. AU = arbitrary unit.

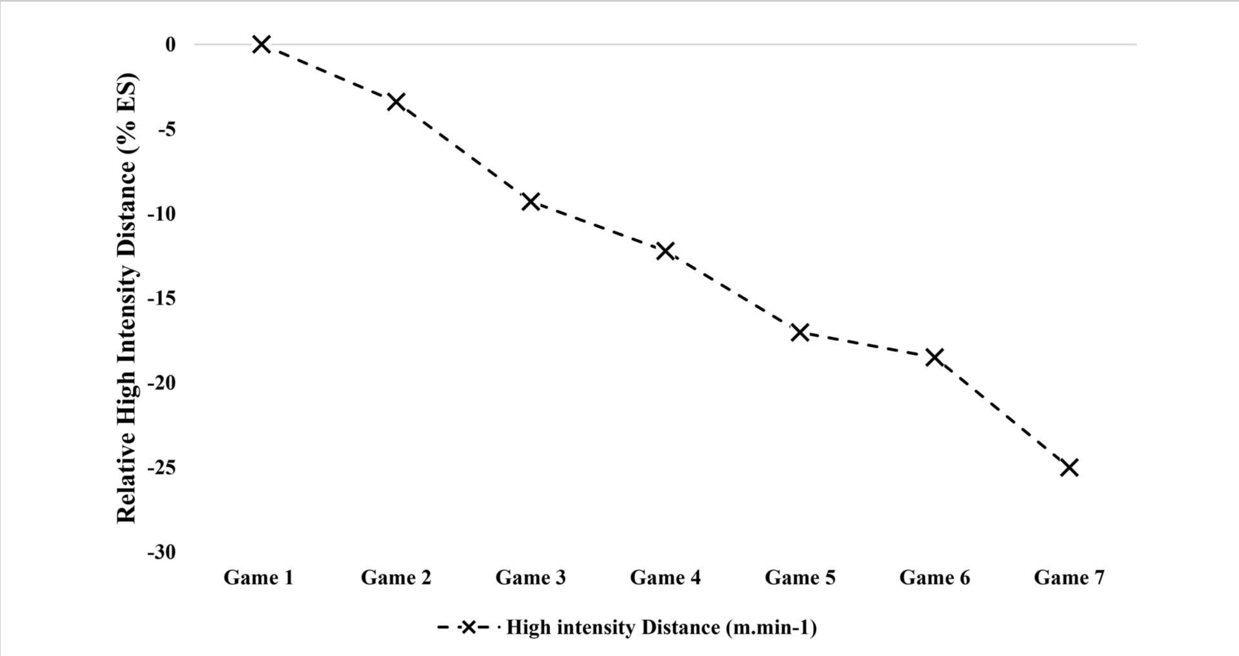

Figure 3. The changes to relative high-intensity distance (m·min^{-1}; ≥16 km·h^{-1}) across major international female field hockey tournament. All data presented by mean ± *SD*. ES = effect size.

period. Over the course of a 2-week congested period, specific running performance and perceptual wellness variables of interest were monitored daily. Players' running performance was monitored using GPS (10 Hz S5; Catapult Innovations). Players' perceptual wellness was monitored using their daily monitoring software (Kitman Labs, Joyce Court, Ireland). The results of the current study were recorded during World League 2, which took place in Johannesburg (South Africa) during the 2016–2017 season. Game data were included only if players were used in all 4 quarters and played a minimum of 7 minutes per quarter (4,36). All competitive matches took place between 14:00 and 20:00 PM Temperature during match-play ranged between 12 and 21°C. Before match-play, players were advised to abstain from any strenuous activity and were advised to maintain their normal prematch routine and diet with special emphasis being placed on the intake of fluids and carbohydrates.

Subjects

Sixteen elite international female field hockey outfield players (all mean ± *SD*, 23 ± 3 years; 162.6 ± 13 cm; and 66 ± 6 kg) participated in the current observational study. Players were selected from the current Irish senior national squad (*n* = 26) and were therefore deemed the best players within the full training squad. Before testing and after ethical approval, participants were provided with information, which informed them of the purpose, benefits, and procedures of the current study. Written informed consent and medical declaration were obtained from participants in line with the procedures set by Institute of Technology Tallaght research ethics committee.

Procedures

Measurement of External Load. To determine the physical demands, participants were required to wear an individual GPS unit (S5; Catapult Innovations) sampling at 10-Hz, containing a triaxial accelerometer in 7 games over a 15-day period. The GPS unit (mass: 67 g; 50 × 90 mm) was encased within the confines of a harness and worn by the athletes with the unit resting between the shoulder blades in the upper thoracic region. The coefficient of variation (CV%) of GPS units used during intermittent exercise has previously been reported as 1.6–5% for a range of running and speed measures (25). Given the use of rolling substitutes, the time each participant spent in match-play was noted as players' "time on feet." Therefore, if a player had a first rotation in Q1 of 3 minutes and a second rotation of 6 minutes, the total time for that specific Q was noted as 9 minutes. Players' time on feet was then calculated by adding all Q's time together. Players' time on feet was then used to determine players' relative distance during match-play (distance traveled/time on feet). The data were extracted from each unit and split using the unit software (Catapult Innovations). Data were then exported to Microsoft Excel (Microsoft, Redmond, USA) to allow for further analysis. Before the observational period, players' individual maximal velocity was assessed during a maximal velocity test. Dual timing gates were placed at 0, 10, 20, 30, and 40 m (Witty; Micro-gate, Bolzano, Italy). Players' velocity was measured to the nearest 0.01

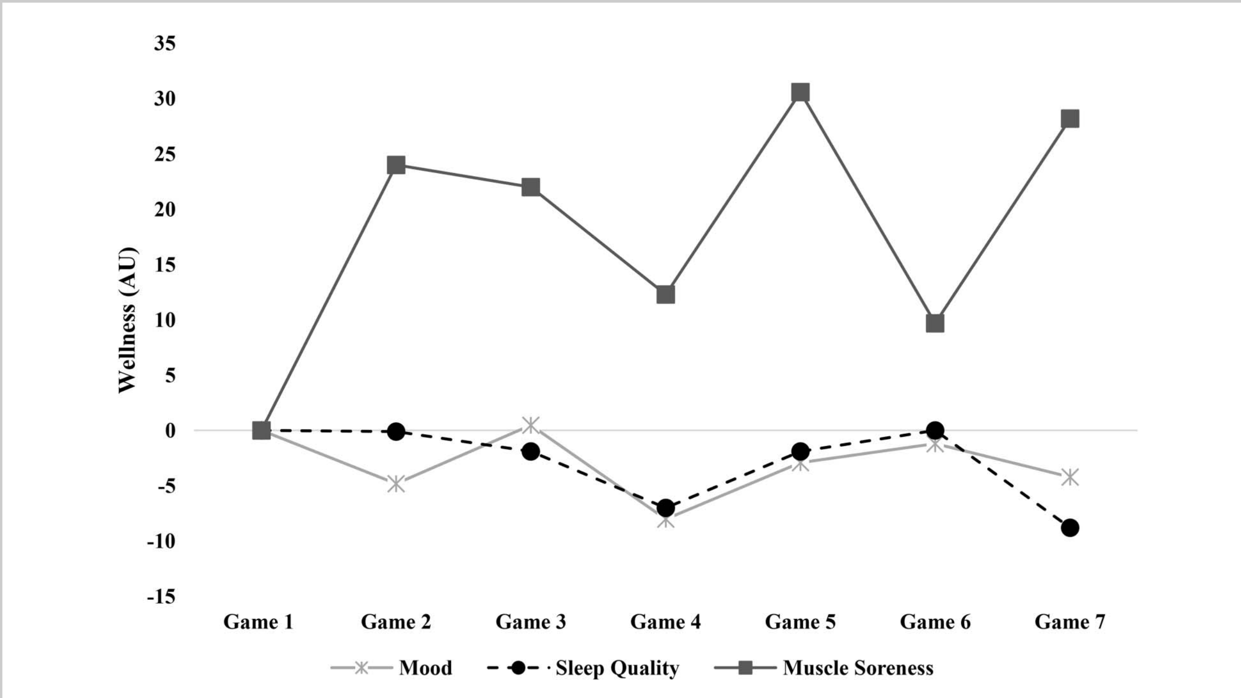

Figure 4. Daily changes in players' wellness using a psychometric questionnaire across a major international female field hockey tournament. All data presented by mean ± *SD*. AU = arbitrary unit.

seconds. The subjects' fastest time was obtained after 3 attempts. The velocity between the 30- and 40-m gates was used to measure their maximal velocity, which was then used to assess players' relative maximal velocity exposures during match-play (22). Running performance demands were classified based on distances covered across 5 speed zones adapted for elite female field hockey (19,26,27). Zone 1 (<7.9 $km \cdot h^{-1}$), zone 2 (8–10.9 $km \cdot h^{-1}$), zone 3 (11–15.9 $km \cdot h^{-1}$), zone 4 (>16 $km \cdot h^{-1}$), and zone 5 (>20 $km \cdot h^{-1}$). Other variables of interest included relative TD (RTD; $m \cdot min^{-1}$), relative HID (RHID; $m \cdot min^{-1}$; >16 $km \cdot h^{-1}$), maximal velocity ($km \cdot h^{-1}$), and percentage maximal velocity (%).

Measurements of Training Load and Wellness. The intensity of all match-plays was determined using the modified Borg CR-10 rate of perceived exertion (RPE) scale; each player provided a rating 60 minutes after the end of match-play (20). Each player's RPE was multiplied by time on feet during match-play, allowing for an individual arbitrary unit (AU) internal load score. Additional players completed a psychometric questionnaire, which was part of the squads daily monitoring and was used to assess players' well-being (9,20,33). The following 3 variables were measured using the questionnaire: (a) sleep quality, (b) muscle soreness, and (c) mood. The players were asked to rank all variables on a 10-point scale ranging from 1 (worst) to 10 (best). Muscle soreness was also measured on a 10-point scale; however, it was ranked ranging from 1 (a little) to 10 (a lot). All players were requested to complete their daily monitoring alone between the hours of 8 and 9 AM to avoid any external influence from other players or management staff (Figure 1).

Statistical Analyses

Data are presented as means ± *SD* and were log transformed to reduce bias because of nonuniformity of error and analyzed using the effect size (ES) statistic with 90% confidence intervals (CIs) and % change to determine the magnitude of effects. Thresholds for the magnitude of the observed change for each variable were determined as the within-participant *SD* in that variable × 0.2, 0.6, and 1.2 for a small, moderate, and large effect, respectively. Threshold probabilities for a meaningful effect based on the 90% CI were as follows: <0.5% most unlikely, 0.5–5% very unlikely, 5–25% unlikely, 25–75% possibly, 75–95% likely, 95–99.5% very likely, and >99.5% most likely using the Hopkins. Spreadsheets for analysis of controlled trials, with adjustment for a subject characteristic (12,34). Effects with 90% CI across a likely small positive or negative change were classified as unclear. All calculations were completed using a predesigned spreadsheet (11).

Results

Activity Profiles

Compared with game 1 (45.0 ± 7.7 minutes), time on feet increased in game 2 (49.7 ± 9.5 minutes; 9.41% ES; 0.39 ±

Table 2. The difference in global activity profiles and wellness scores compared with game 1 for each game during a major international female field hockey tournament.*†

	ES game 1–2 (95% CI)	ES game 1–3 (95% CI)	ES game 1–4 (95% CI)	ES game 1–5 (95% CI)	ES game 1–6 (95% CI)	ES game 1–7 (95% CI)
Running performance						
Total distance (m)	7.7 (−0.39 ± 0.26) *Likely*	−2.0 (−0.12 ± 0.27) *Possibly*	−1.4 (−0.11 ± 0.06) *Possibly*	−1.0 (−0.07 ± 0.72) *Unclear*	0 (−0.0 ± 0.65) *Unclear*	1.1 (0.08 ± 0.57) *Unlikely*
Total distance (m·min^{-1})	−2.2 (−0.20 ± 0.32) *Possibly*	−0.5 (−0.05 ± 0.08) *Possibly*	−0.2 (−0.02 ± 0.65) *Unclear*	−0.5 (−0.06 ± 0.6) *Unclear*	−0.7 (−0.74 ± 0.63) *Likely*	−9.5 (−0.95 ± 0.63) *Very Likely*
High-intensity distance (m·min^{-1})	−3.4 (−0.09 ± 0.63) *Unclear*	−9.2 (−0.24 ± 0.39) *Likely*	−12.2 (−0.37 ± 0.27) *Possibly*	−17.0 (−5.60 ± 0.63) *Likely*	−18.5 (−0.61 ± 0.2) *Likely*	−25.0 (−0.63 ± 0.13) *Very Likely*
Wellness						
Load (AU)	23.0 (0.83 ± 0.18) *Very Likely*	−16.7 (−0.84 ± 0.19) very *Likely*	−1.1 (−0.06 ± 0.71) *Unclear*	−0.0 (−0.01 ± 0.64) *Unclear*	−1.9 (−0.09 ± 0.74) unclear	0.7 (0.04 ± 0.01) *Possibly*
Muscle soreness (AU)	24.0 (0.92 ± 0.13) *Likely*	22.0 (0.47 ± 0.19) *Likely*	12.3 (0.29 ± 0.36) *Possibly*	30.6 (0.75 ± 0.25) *Very Likely*	9.7 (0.22 ± 0.12) *Possibly*	28.2 (0.71 ± 0.15) *Likely*
Sleep quality (AU)	−0.1 (−0.01 ± 0.66) *Unclear*	−1.9 (−0.20 ± 0.45) *Possibly*	−7.0 (−0.59 ± 0.06) *Likely*	−1.9 (−0.20 ± 0.45) *Possibly*	*No Change*	−8.8 (−0.77 ± 0.12) *Likely*

*ES = effect size; CI = confidence interval; AU = arbitrary unit.

†All data are presented as mean ± *SD*. High-intensity distance (m·min^{-1}) corresponds to any movement >16 km·h^{-1} relative to the time the player spent on feet. CI signifies the confidence interval with ES representing effect size. Threshold probabilities for a meaningful effect based on the 90% CI were set.

0.2; *likely*) followed by a decrease in games 3 (44.3 ± 7.0 minutes; −1.69% ES; 0.08 ± 0.10; *possibly*), 4 (43.2 ± 3.9 minutes; −1.82% ES; −0.11 ± 0.12; possibly), and 5 (43.6 ± 4.9 minutes; −1.05% ES; −0.06 ± 0.03; *unclear*), compared with games 6 (47.2 ± 5.8 minutes; 6.7% ES; 0.36 ± 0.21; likely) and 7 (48.2 ± 4.8 minutes; 8.86% ES; 0.55 ± 0.63; likely), where time on feet increased. Players covered an average TD of 5,147 ± 628 m. When compared with game 1 (5,135 ± 646 m), TD increased during game 2 (5,566 ± 920 m; 7.7% ES; 0.39 ± 0.26; *likely*) but decreased for each game thereafter (Table 1) In addition, players had an average RTD of 113.0 ± 8.9 $m \cdot min^{-1}$. Players' RTD continually decreased after game 1 (115.8 ± 11.5 $m \cdot min^{-1}$) (Table 1) with the biggest decrement in performance being observed in game 7 (106.1 ± 9.8 $m \cdot min^{-1}$; −9.47% ES; −0.95 ± 0.63; *very likely*). Similar results were observed for RHID. High-intensity activity (Figure 2) decreased significantly during game 4 (16.3 ± 4.9 $m \cdot min^{-1}$; −12.21% ES; −0.37 ± 0.27; *possible*), game 5 (14.9 ± 4.1 $m \cdot min^{-1}$; −17.02% ES; −0.6 ± 0.63; *likely*), game 6 (14.9 ± 4.4 $m \cdot min^{-1}$; −18.5% ES; −0.62 ± 0.2; *likely*), and game 7 (15.0 ± 5.8 $m \cdot min^{-1}$; −25.0% ES; −0.63 ± 0.13; *likely*). Players' average max velocity was 24.1 ± 1.3 $km \cdot h^{-1}$. When compared with game 1 (23.8 ± 1.5 $km \cdot h^{-1}$), max velocity increased during games 2 (25.1 ± 1.2 $km \cdot h^{-1}$; 5.89% ES; 0.39 ± 0.93; *likely*) and 3 (24.7 ± 1.8 $km \cdot h^{-1}$; 3.4% ES; 0.4 ± 0.13; *likely*). Players' relative max velocity (89 ± 6%) also increased in games 2 (93.4 ± 4%; 5.9% ES; 0.9 ± 0.1; *likely*) and 3 (92 ± 8%; 3.4% ES; 0.4 ± 0.11; *likely*) when compared with game 1 (88 ± 6%).

Changes in Load and Wellness

Players reported to have an average match-play load of 350 ± 58 AU. Compared with game 1 (348 ± 61 AU), internal load increased during game 2 (436 ± 85 AU; 23% ES; 0.83 ± 0.18; *very likely*) with players reporting a decrease in load during game 3 (295 ± 52 AU; −16.7% ES; −0.84 ± 0.19; *very likely*). The reported load during games 4 (339 ± 42 AU; −1.1% ES; −0.06 ± 0.71; *unclear*), 5 (346 ± 67 AU; −0.3% ES; −0.01 ± 0.64; unclear) 6 (339 ± 58 AU; −1.9% ES; −0.09 ± 0.74; *unclear*), and 7 (347 ± 45 AU; −0.7% ES; −0.04 ± 0.01; *unclear*) was similar to that reported in game 1 (Figure 2). Compared with game 1 (8.0 ± 1.1 AU), players' mood decreased on the days of games 2 (7.5 ± 1.1 AU; −4.8% ES; −0.31 ± 0.65; *possibly*), 4 (7.2 ± 1.6 AU; −8% ES; −0.9 ± 0.25; *likely*), 5 (7.8 ± 1.1 AU; −2.9% ES; −0.18 ± 0.33; *possibly*), and 7 (7.6 ± 0.8 AU; −4.2% ES; −0.32 ± 0.33; *possibly*) (Figure 3). In addition, compared with game 1 (8.2 ± 0.8 AU), players' quality of sleep continued to drop during this highly congested period (Figure 4). Players reported the highest drop in sleep quality on the day of games 4 (7.8 ± 1.0 AU; −7% ES; −0.59 ± 0.06; *likely*) and 7 (7.6 ± 1.0 AU; −8.8% ES; −0.77 ± 0.12; *likely*). However, returned to normal on the day of game 6 (8.2 ± 0.7 AU; 0% ES). Similar trends were reported for muscles soreness. Compared with game 1 (2.8 ± 1.1 AU), players' muscles soreness continually increased (Table 2) throughout the tournament. Players reported the highest muscle soreness on the days of games 5 (3.8 ± 1.0 AU; 30.6% ES; 0.75 ± 0.25; *very likely*) and 7 (3.6 ± 0.9 AU; 28.2% ES; 0.71 ± 0.15; *likely*) with a drop in soreness being reported on the day of game 6 (3.3 ± 1.2 AU; 9.7% ES; −0.22 ± 0.12; *possibly*) (Figure 4).

Discussion

The primary aim of the current observational study was to determine the variation in players' activity profiles during a major international female field hockey tournament. In addition, we aimed to quantify players' well-being while determining whether an association is present between the changes in players' wellness measures and their activity profile during match-play. The main findings of the current study were that players RHID ($m \cdot min^{-1}$) reduced during tournament despite the number of rest days. Furthermore, substantial differences in running performance were observed when changes in players' psychometric questionnaire were reported. To authors' knowledge, the current observational study is one of the first to observe these decreases in elite female field hockey players' running performance when changes in players' psychometric questionnaire scores were reported.

The application of RPE has been shown to be a practical and valid noninvasive measurement to gauge player load in team sports (8,15,20,29). During this congested period, players had an average session load of 350 ± 58 AU. Our results show that significant daily variations in training load during the tournament, with differences observed between game 2 and game 3. When compared with game 1, game 2 saw a significant percentage increase, whereas game 3 saw a significant percentage decrease. During these highly congested periods, it is important to note that players are likely to have variance in load also known as "spikes" (20,33). Even these subtle "spikes" in load have previously been linked increased injury risk in team sport athletes (13,22,23,37). Previous literature has suggested that coaches should program for these in-season periods by gradually exposing the athletes to these fluctuating loads before the tournament (6). Therefore, it is recommended that coaching staff gradually expose athletes to these change in loads by mimicking the demands of a tournament during specific training blocks.

Recently, the match-play demands of elite female field hockey across quarters have been reported (26). On average, players will cover a TD of 4,847 ± 583 m (127.6 ± 15.3 $m \cdot min^{-1}$) with 580 ± 147 m (15.3 ± 3.9 $m \cdot min^{-1}$) at high intensity (m; >16 $km \cdot h^{-1}$). During this congested period, players covered an average TD of 5,147 ± 628 m (113.0 ± 8.9 $m \cdot min^{-1}$) with 753 ± 33 m (16.4 ± 5.3 $m \cdot min^{-1}$) at high intensity. Overall, players' TD stayed relatively consistent over the course of this high-intensity period with the highest difference being reported between game 1 and 2. However, players' RTD did not, when compared with game 1 players' RTD continued to decrease during all games regardless of the number of recovery days in-between.

Despite the 3-day recovery between games 3 and 4, players' RTD decreased when compared with game 1. The highest decrements in RTD were observed during games 6 and 7. However, as these are play-off games, it is possible that there is evidence of pacing to cope with match-play demands (5,36). When compared with game 1, players' RHID saw the highest decrement during games 5 and 7. A recent review by Waldron and Highton (36) stated that fatigue is unidirectional and that it leads to the eventual reduction in performance when compared with baseline values. Therefore, it can be interpreted that the results of the current observational study suggest that players are accumulating fatigue rather than engaging in pacing strategies.

Psychological monitoring has been reported as an effective way of assessing responses to a training dose (9,10,20,32). Although this noninvasive method of monitoring has been shown as advantageous in other team cohorts, it is still unclear how useful it is in elite female field hockey. The results of the current study observed a decrease in mood and sleep quality in conjunction with increased muscle soreness. Players reported the highest decrement in sleep quality in the morning of games 4 and 7. Interestingly, these were the days that were of vast importance. A win in game 4 would secure an easier draw in the quarter finals, and a win in game 7 would ensure the team World Cup qualification after other continental tournaments. In addition, players reported the highest drop in sleep quality in the morning of game 7. When compared with game 1, players reported the lowest mood in the morning of game 4. As expected, players' muscle soreness progressively increased across the 15 days. Players reported the highest scores on the days of games 5 and 7. Despite the 2-day recovery after game 4, players reported the highest score in muscle soreness echoing the importance of recovery and additional sleep enhancement strategies during a major international female field hockey tournament (32). Although these results may be simplistic in nature, the findings support the need for coaches to acknowledge the importance of daily perceptual questionnaires and their uses on guiding best practice (17,20,32). In addition, coaching staff need to consider the gradual increase in muscle soreness and the effect it may have on players ability to maintain match-play demands.

Previously, the ability to perform more high-speed running during match-play has been correlated to an increase in performance (2,21). To the authors' knowledge, this is one of the first observational studies reporting a decrease in female athletes' daily wellness measures, which resulted in their high-intensity running performance being affected. Overall, players reported the highest score for muscle soreness in the morning of game 5. In response to this increased muscle soreness, we observed that RHID decreased the most when compared with the first day of the tournament. Similar results were observed when players' sleep quality was considered. In addition to reporting a high muscle soreness, players reported the lowest score for sleep quality in the morning of game 7. After this decline in sleep quality and an increase in muscle soreness, players' running performance was significantly affected. Players' RTD and RHID decreased the most during game 7 when compared with game 1. The results of the current observational study need to be interpreted within the context of the study limitations. Alike many other studies examining team sports, we present a data from a tournament that represents a case study of 1 elite female hockey team. While we report measurements of running performance and subjective well-being, we did not assess the biochemical and objective muscular measurements to quantify fatigue. Although it would be ideal to measure direct biological and biochemical markers such as creatine kinase (1,3), the capacity to maintain a highly level of testing within this environment makes this hard to achieve.

To the authors' knowledge, the current observational study is the first to report players' wellness and the effect it has on their running performance during a major international female field hockey tournament. Until now, the demands faced by elite female field hockey players during a major international female field hockey tournament are unknown. During these congested periods, players reported an average internal load of 350 ± 58 AU with daily variations being observed. Despite the amount of recovery days between games, players' RTD and RHID continued to decrease over the 2-week period. In addition, the results of the current observation suggest that substantial changes in players' well-being are associated with reductions in running performance. Finally, despite the 3-day recovery between game 3 and 4, players' running performance never returned to baseline. Therefore, we suggest that the organizers of these congested periods reduce the number of games during the pool stages and allow for 3- to 4-day recovery between the pool and qualification games, in turn, giving teams the best possible chance to achieve their highest potential.

Practical Applications

During these high-intensity periods, it is likely that players will only have a minimum of 1 day to recover between matches, with many of these recovery days subsequent to playing 2 or 3 games on 3 consecutive days. Coaching staff should ensure careful management of players' playing time and recovery. Therefore, we suggest coaches implement specific individualized rotational strategies that allow for specific recovery time during match-play that aids the holistic recovery of players during these periods. In addition to actively engaging in re-warm-up strategies between rotations and at half time, coaching staff should monitor players' individual high-speed distance on a day-to-day basis to monitor the effects of potential fatigue. In addition, we suggest that coaching staff engage in specific sleep-based recovery strategies such as timed naps to increase players' sleep quality during these highly congested periods.

Acknowledgments

The authors thank all the players who participated in the current observational study. No external sources of funding were provided for this study, and the authors have no conflicts of interest to declare.

References

1. Andersson, H, Raastad, T, Nilsson, J, Paulsen, G, Garthe, I, and Kadi, F. Neuromuscular fatigue and recovery in elite female soccer: Effects of active recovery. *Med Sci Sports Exerc* 40: 372–380, 2008.
2. Andersson, H, Randers, M, Heiner-Moller, A, Krustrup, P, and Mohr, M. Elite female soccer players perform more high-intensity running when playing in international games when compared with domestic league games. *J Strength Cond Res* 24: 912–919, 2010.
3. Baird, M, Graham, S, Baker, J, and Bickerstaff, G. Creatine-kinase and exercise related muscle damage implications for muscle performance and recovery. *J Nutr Metab* 2012: 960363, 2012.
4. Black, G, Gabbett, T, Johnston, R, Naughton, M, and Dawson, B. The influence of rotations on match running performance in female Australian football midfielders. *Int J Sport Nutr Exerc Metab* 32: 1–44, 2011.
5. Black, G, Gabbett, T, Naughton, G, Cole, M, Johnston, R, and Dawson, B. The influence of contextual factors on running performance in female Australian Football match-play. *J Strength Cond Res*, 2017. Epub ahead of print.
6. Blanch, P and Gabbett, T. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *Br J Sports Med* 50: 471–475, 2016.
7. Bridge, C, Jones, M, and Drust, B. Physiological responses and perceived exertion during international taekwondo competition. *Int J Sports Physiol Perform* 4: 485–493, 2009.
8. Buchheit, M, Racinais, S, Bilsborough, J, Bourdon, P, Voss, S, Hocking, J, et al. Monitoring fitness, fatigue and running performance during a pre-season training camp in elite football players. *J Sci Med Sport* 16: 550–555, 2013.
9. Gallo, T, Cormack, S, Gabbett, T, and Lorenzen, C. Pre-training perceived wellness impacts training output in Australian football players. *J Sports Sci* 34: 1445–1451, 2016.
10. Gastin, P, Meyer, D, and Robinson, D. Efficacy of subjective ratings of wellness in monitoring adaptive responses to training and competition in elite Australian football. *J Strength Cond Res* 27: 2518–2526, 2013.
11. Hopkins, W, Marshall, S, Batterham, A, and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41: 3–12, 2009.
12. Hopkins, W. Spread sheet for analysis of controlled trails, crossovers and time series. *Sportscience* 21: 1–4, 2017.
13. Hulin, B, Gabbett, T, Lawson, D, Caputi, P, and Sampson, J. The acute:chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med* 50: 231–236, 2016.
14. Ihsan, M, Tan, F, Sahrom, S, Choo, H, Chia, M, and Aziz, A. Pre-game perceived wellness highly associates with match running performances during an international field hockey tournament. *Eur J Sport Sci* 17: 593–602, 2017.
15. Impellizzeri, F, Rampinini, E, Coutts, A, Sassi, A, and Marcora, S. Use of RPE-based training load in soccer. *Med Sci Sport Exerc* 36: 1042–1047, 2004.
16. Jennings, D, Cormack, S, Coutts, A, and Aughey, R. Global position system analysis of an international field hockey tournament. *Int J Sports Physiol Perform* 7: 224–231, 2012.
17. Johnston, R, Gibson, N, Twist, C, Gabbett, T, MacNay, S, and MacFarlane, N. Physiological responses to an intensified period of rugby league competition. *J Strength Cond Res* 27: 643–654, 2013.
18. Lupo, C, Capranica, L, and Tessitore, A. The validity of the session-RPE method for quantifying training load in water polo. *Int J Sports Physiol Perform* 9: 656–660, 2014.
19. Macutkiewicz, D and Sunderland, C. The use of GPS to evaluate activity profiles of elite women hockey players during match-play. *J Sports Sci* 29: 967–973, 2011.
20. Malone, S, Hughes, B, Roe, M, Collins, K, and Buchheit, M. Monitoring players fitness, fatigue status and running performance during an in-season training camp in elite Gaelic football. *Sci Med Footb* 16: 550–555, 2017.
21. Malone, S, Owen, A, Mendes, B, Hughes, B, Collins, K, and Gabbett, T. High-speed running and sprinting as an injury risk factor in soccer: Can well-developed physical qualities reduce the risk? *J Sci Med Sport* 21: 257–262, 2017.
22. Malone, S, Roe, M, Doran, D, Gabbett, T, and Collins, K. High chronic training loads and exposure to bouts of maximal velocity running reduce injury risk in elite Gaelic football. *J Sci Med Sport* 20: 250–254, 2017.
23. Malone, S, Roe, M, Doran, D, Gabbett, T, and Collins, K. Protection against spikes in workload with aerobic fitness and playing experience: The role of the acute: Chronic workload ratio on injury risk in elite Gaelic football. *Int J Sports Physiol Perform* 12: 393–401, 2017.
24. Malone, S, Solan, B, Collins, K, and Doran, D. The positional match running performance of elite Gaelic football. *J Strength Cond Res* 30: 2292–2298, 2016.
25. McFarlane, S, Tannath, S, and Kelly, V. The validity and reliability of global positioning systems in team sport: A brief review. *J Strength Cond Res* 30: 1470–1490, 2016.
26. McGuinness, A, Malone, S, Hughes, B, and Collins, K. The physical activity and physiological profiles of elite international female field hockey players across the quarters of competitive match-play. *J Strength Cond Res Cond Res*, 2018. Epub ahead of print.
27. McGuinness, A, Malone, S, Petrakos, G, and Collins, K. The physical and physiological demands of elite international female field hockey players during competitive match-play. *J Strength Cond Res*, 2017. Epub ahead of print.
28. McMahon, G. and Kennedy, R. Changes in player activity profiles following the 2015 FIH rule changes in elite women's hockey. *J Strenght Cond Res*. 2017: 1–24. Epub ahead of print.
29. Menaspà, M, Menaspà, P, Clark, S, and Fanchini, M. Validity of the online athlete management system to assess training load. *Int J Sports Physiol Perform* 32: 1–17, 2017. Epub ahead of print.
30. Mohr, M, Krustrup, P, Andersson, H, Kirkendal, D, and Bangsbo, J. Match activities of elite women soccer players at different performance levels. *J Strength Cond Res* 22: 341–349, 2008.
31. Spencer, M, Rechichi, C, Lawrence, S, Dawson, B, Bishop, D, and Goodman, C. Time-motion analysis of elite field hockey during several games in succession: A tournament scenario. *J Sci Med Sport* 8: 382–391, 2005.
32. Thornton, H, Duthie, G, Pitchford, N, Delaney, J, Benton, D, and Dascombe, B. Effect of a two-week high intensity training camp on sleep activity of professional rugby league athletes. *Int J Sports Physiol Perform* 12: 928–933, 2017.
33. Thorpe, R, Strudwirck, A, Buchheit, M, Atkinson, G, and Drust, B. Monitoring fatigue during the in-season competitive phase in elite soccer players. *Int J Sports Physiol Perform* 10: 958–964, 2015.
34. Twist, C, Highton, J, Daniels, M, Mill, N, and Close, G. Player responses to match and training demands during an intensified fixture schedule in professional rugby league: A case study. *Int J Sports Physiol Perform* 12: 1093–1099, 2017.
35. Vescovi, J and Frayne, D. Motion characteristics of Division I college field hockey: Female Athletes in Motion study. *Int J Sports Physiol Perform* 10: 476–481, 2015.
36. Waldron, M, Highton, J, Daniels, M, and Twist, C. Preliminary evidence of transient fatigue and pacing during interchanges in rugby league. *Int J Sports Physiol Perform* 8: 157–164, 2013.
37. Windt, J and Gabbett, T. How do training and competition workloads relate to injury? The workload-injury aetiology model. *Br J Sports Med* 51: 1–9, 2016.