Activity profile and between-match variation in elite male field hockey

Caroline Sunderland[1] and Phillip L. Edwards[1,2]

[1]Sport, Health and Performance Enhancement (SHAPE) Research Centre, Department of Sports Science. Nottingham Trent University, School of Science and Technology, Nottingham, NG11 8NS, UK. [2]Boston College, MA 02467, USA.

Running head: Hockey match activity and variability

Corresponding author contact details:

Name: Caroline Sunderland, Ph.D.

Address: Sport, Health and Performance Enhancement (SHAPE) Research Centre,

Department of Sports Science.

Nottingham Trent University,

Nottingham,

NG11 8NS, UK.

Tel: 0115 8486379

Fax: 0115 8486636

E-mail: caroline.sunderland@ntu.ac.uk

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ABSTRACT

This study aimed to: 1) provide a position specific activity profile for elite male hockey players; 2) determine if the activity profile was altered by the introduction of the 'self-pass' rule and 3) provide information relating to match to match variability in elite male field hockey. The activity of 28 elite male field hockey players was analysed over 2 seasons totalling 395 player-match analyses using Global Positioning Satellite technology. Total distance, high speed running (>15.5 km.h^{-1}), sprinting (>20 km.h^{-1}) and mean speed were recorded. Players were categorised into 4 positions: full-back (FB); half-back (HB); midfield (M) and forward (F). Data were analysed using a 2 way ANOVA (season, position) and between-match coefficients of variation (CV). The time played differs with position (FB: 65.5±5.3, HB: 49.5±11.5, M: 45.9±7.1, F: 39.5±5.4 min; P<0.0005) and thus affected the activity profile. Total distance covered was greater for full backs (FB: 8001±447, HB: 6435±1399, M: 6415±908, F: 5844±762 m, p<0.001) and mean speed and percentage time spent high-speed running and sprinting was greater for forwards than all other positions (HSR: FB: 6.8±1.0, HB: 8.8±1.3, M: 10.7±1.2, F: 13.5±1.8 %, p<0.001). The activity profile did not differ with the introduction of the self-pass. Match to match variability (CV) ranged from 5.0% to 22.0% for total and sprint distance respectively. This is the first study to present an activity profile of elite men's field hockey and its associated variability and demonstrates that each position is unique and therefore training and recovery should be position specific.

Keywords: GPS, high-speed running, sports, high-intensity, repeated sprinting

INTRODUCTION

Research into field hockey has increased in recent years with the development of motion analysis software and global positioning systems (9, 15, 16, 18, 25, 26). International men's and women's players cover a total distance of 5800-7100 m and 5541 m respectively, of which ~350 m and 232 m are at high-speeds (>19 $km.h^{-1}$: (15, 18, 26); unpublished observations). At the National level, elite female players have been shown to cover 6000-6800 m (9, 25) of which 90% is at low intensity (standing, walking or jogging; (16)). Playing position effects the activity profile of players, with forwards covering a greater percentage of pitch time at high-speeds including sprinting than defenders (13, 15, 18). Further, during men's international tournament competition more high speed running (>15.0 $km.h^{-1}$) is completed than during national level tournaments (13). This research has provided an initial insight into the demands of field hockey which is fundamental for the development of specific training and prescription of appropriate recovery. The existing studies have provided coaches and sports scientists with the information required to develop more informed training programs as well as aiding in team selection and substitution strategies. However, the research into elite male hockey is limited by either small sample sizes (15), too little information about between match recovery time (15), or presents data from tournaments (26). Therefore research is required to investigate the activity profile of elite men's hockey with appropriate recovery between matches.

The International Hockey Federation (FIH) has an objective to enhance the 'flow of play' and therefore introduced the "self-pass" rule in May 2009 (8). The rule, which allows players to restart play from a free hit by passing the ball to themselves, was implemented to 'enable the game to flow more freely' with the officials instructed to avoid, where possible, 'unnecessary interruptions to the flow' of the game (8). It was suggested that this would increase the speed of the game and therefore require players to complete more high-speed activities and alter the activity profile of matches. To date, there is no research that has presented activity profiles of players by position since the advent of the 'self-pass' rule and whether substitution strategies have been altered because of the rule change.

Recent research in soccer has demonstrated that in elite level soccer, match to match variability is high, with coefficient of variation values of 16.2% and 30.8% for high-speed running (19.8-25.2 km.h^{-1}) and total sprint distance (>25.2 km.h^{-1}) covered (12). This variation is in part due to factors such as playing position, tactics employed and technical requirements of the game (12). For coaches, sports scientists and researchers alike, data related to between-match variability is important for not only intervention based research or assessing the effectiveness of training but also if specific variables, such as high-speed running are used as a performance indicator (12). Field-hockey, though a high-intensity intermittent sport similar to soccer, has several differences in rules and thus tactics that may result in differences in between-match variability. The use of rolling substitutions and tactics employed results in substantial differences in time on the pitch for different playing positions and therefore activity profiles and pacing strategies (18). Forward players often play in short spells and spend a greater percentage of time at high-speeds, potentially reducing between match variability. Between match variability in elite field hockey may therefore differ from soccer and by playing position.

Time-motion analysis provides us information pertaining to the duration, frequency and distance covered in different motion categories. This information is essential as it can be used to estimate the contribution of each energy supply to match-play, provides a greater understanding of the specific demands imposed upon field hockey players and is necessary to develop appropriate field-hockey specific training and recovery programmes (16, 21). Therefore, aim of the present study was three-fold: 1) provide a position specific activity profile for elite male hockey players; 2) to determine if activity profile changed after the introduction of the 'self-pass' rule and 3) provide information relating to match to match variability in elite male field hockey. We hypothesised that the activity profile of players would differ with position, with forwards and midfield players completing more high-speed running than defenders.

METHODS

Experimental Approach to the Problem

The activity profile of 28 outfield players competing for a single club in the England Hockey League Premier Division in the 2008-2009 (n=23 matches, 161 cases) and 2009-2010 (n=20 matches, 234 cases) seasons was monitored. As determined by the league fixtures matches were separated by a minimum of 6 days except for 3 matches (1 in 2008-09; 2 in 2009-10) which were 1 day after the previous match, and incorporated a 2 month break over the Christmas period. Fifteen players were present during both seasons. Players were analysed according to their primary position for a given match with four positional groups identified: fullback (FB); halfback (HB); midfield (M) and forward (F). The decision was made to separate the defensive players into two groups due to the perceived differences in positional demands with the primary reason being the playing times for each position (mean playing time: FB = 68 min; HB = 53 min) which reflect the physiological demands of the positions.

Participants

Twenty-eight elite (n=20 international) level male field hockey players volunteered to participate in the study and provided their informed consent (age: 21.1±3.4 years; stature: 1.78±0.06 m; body mass: 73.8±8.2 kg; all mean±SD; Table 1). Institutional ethics committee approval for the study was provided. **Insert Table 1 near here.

Procedures

Player on-field activities were recorded by a single GPS unit per player, for the duration of the game (SPIElite 1 Hz, GPSports, Fyshwick, Australia). The GPS unit is integrated with a 100Hz accelerometer to improve speed and distance accuracy. The same unit was used for each player throughout and the system used has previously been validated specifically for field hockey match movements at latitudes employed in the present study (4) (mean difference ± 95% limits of agreement: 0.0 ± 0.9 km.h^{-1} and 2.5 ± 15.8 m), (17) including high-speed running and sprinting (linear distance percentage bias: 2.5% and non-linear distance percentage bias adjusted for lean: -4.3% (11); mean difference ± 95% limits of agreement: 0.2 ± 1.2 km.h^{-1}) (17). Time on the substitution bench was not analysed. The GPS units were positioned between the scapular planes at t2-t6 of the spinal column and secured in place with a custom-made vest. During the testing period 8±1 satellites were used for the position fix by the GPS units with a mean horizontal dilution of precision of 1.23±0.36. The mean±SD temperature was 11.2±5.2 ^{o}C. For the 2008-09 season, 8±1 satellites with a horizontal dilution of precision of 1.47±0.39 were used by the GPS and in the 2009-10 season, 8±1 satellites with a horizontal dilution of precision of 1.04 ±0.17 were used by the GPS to fix position. The mean temperatures were 11.8±4.6 ^{o}C and 10.8±5.7 ^{o}C for the 2008-09 and 2009-10 seasons respectively.

All matches took place on artificial turf field hockey pitches (91.4 x 55.0 m) and were 70 minutes (2 x 35 min halves). Player activity categories were classified as high-speed running (>15.5 km·h^{-1}) and sprinting (>20 km·h^{-1} for at least 1 s; (7)). Total distance, time and number of sprints were recorded and mean speed, mean sprint number and sprint distance were calculated. Total distance and total high speed running distance are presented for the time on the pitch and the % time reflects the percentage time spent in that activity category in comparison with total time on the pitch.

Statistical analyses

Histograms and Kolmogorov-Smirnov were used to confirm normality of distribution. Mean data for each player in a specific playing position for each season was used for the statistical analyses for activity profile and are presented. A 2 way ANOVA (season, position) was employed to assess whether there were any differences between season and/or position for distances, percentage time, sprint number and CV. Data were checked for homogeneity of variance using the Levene's test and post-hoc Bonferroni analyses were completed following significant main effects or interactions. The effect size (Cohen's *d*) of all significant differences were calculated using trial pairings and interpreted using the following thresholds: <0.2 = trivial effect; 0.2–0.49 = small effect; 0.5–0.8 = moderate effect and >0.8 = large effect (5). Between-match coefficients of variation (CV) were calculated for each variable by season by dividing the standard deviation of repeated match performance data by the corresponding mean value for each player and multiplying by 100. For the between-match variability, distance variables were normalised to the mean time on the pitch for each position for each season. Data were presented as the mean ± SD and significance was accepted at the P≤0.05 level. In text season data is presented in chronological order, 2008-09 then 2009-10 throughout.

RESULTS

The number of substitutions made per match was higher in the 2009-2010 season than the 2008-2009 season (*p=0.001*; 2008-2009: 39±6; 2009-2010: 49±9). This ranged from 31 to 48 in 2008-2009 to 30 to 62 in 2009-2010. The time played did not differ between seasons (2008-2009: 45.2±10.9 min; 2009-2010: 48.6±10.9 min; season effect *p=0.16*, interaction *p=0.69*) but was different between positions (position effect *p<0.001,*) with fullbacks playing for a greater duration than all other positions (*post-hoc*: *p<0.005;* HB: *d=1.72,* M: *d=3.09*, F: *d=5.05*) and halfbacks playing for more time than forwards (*post-hoc*: *p<0.001 d=1.26;* FB: 65.5±5.3, HB: 49.5±11.5, M: 45.9±7.1, F: 39.5±5.4 min).

Total match distances covered were similar between the 2008-2009 and 2009-2010 seasons (6237±1186, 6594±1074 m; season effect *p=0.28*, *d=0.32*) and this was unaffected by position (interaction *p=0.70*). Between positional groups, the fullbacks were found to cover more distance than the other positions (position effect *p<0.001, post-hoc*: HB *p=0.02 d=1.42*, M *p=0.01 d=2.05*, F *p<0.001 d=3.2*; Table 2).

Mean speed, as a reflection of distance covered normalised for time played, was not significantly different between seasons (8.40±0.71, 8.30±0.90 $km \cdot h^{-1}$; season effect *p=0.3*, interaction *p=0.41*). The forwards ran at a higher mean speed than all other positions (position effect *p<0.001, post-hoc*: FB and HB *p<0.001 d=3.33 and 2.28*, M *p<0.01 d=1.27*; Table 2) and the midfield players ran at a higher mean speed than fullbacks and halfbacks (position effect *p<0.001, post-hoc*: FB *p<0.001 d=3.33*, HB *p<0.05 d=1.61*; Table 2).

**Insert Table 2 near here.

High-speed running distance was similar between seasons (season effect *p=0.49,* interaction *p=0.78*) but differed by position with the forwards covering more distance than the halfbacks (position effect *p=0.02 d=1.07*, *post-hoc*: *p=0.03;* Table 3). Season did not affect percentage of time spent high-speed running (season effect *p=0.79,* interaction *p=0.81*), with substantial differences between position (position effect *p=0.02;* Table 3). Forwards spent more percentage of game time high-speed running than all other positions (*post-hoc*: $p<0.001$ FB: *d=4.29,* HB: *d=2.98*, M: *d=1.85*) and midfield players spent more game time high-speed running than fullbacks and halfbacks (*post-hoc*: $p<0.05$, FB: *d=3.6*, HB: *d=1.58*).

The total distance covered sprinting was not different between the 2008-09 and 2009-10 seasons and did not differ with playing position (season effect *p=0.88,* position effect *p=0.12,* interaction *p=0.86*; Table 3). The percentage of time spent sprinting was similar between seasons (3.0±0.9, 2.8±0.7 %; season effect *p=0.32*, interaction *p=0.98*), but differed with playing position (position effect $p<0.001$). The percentage of time sprinting by forwards was greater than all other positions (position effect $p<0.001$, *post-hoc:* $p<0.001$, FB: *d=2.98*, HB; *d=1.91* and M: *d=1.33*; Table 3) and the midfield players spent more time sprinting than fullbacks (position effect $p<0.001$, *post-hoc*: FB $p<0.01$, *d=2.59*; Table 3).

**Insert Table 3 near here.

The match to match variability for the two seasons is presented in Table 4. Match to match variability ranged from 5.0% for normalised total distance to 22.0% for normalised sprint distance. There was no difference between season or with position for the match to match variability for normalised total or sprint distance, mean speed, percentage time sprinting or sprint distance (Table 4). Both normalised high-speed running distance and percentage time spent high-speed running were not different between season ($p \geq 0.24$) or with position ($p \geq 0.11$) but did show a significant interaction ($p=0.02$; Table 4). A greater match to match variability was shown for the fullbacks for the 2009-10 season than the midfield players for the 2008-09 season (*post-hoc* $p<0.05$).

**Insert Table 4 near here.

DISCUSSION

The present study describes the activity profile of elite men's field hockey across 2 seasons and is the first to report match to match variability and whether the introduction of the self-pass rule has affected the activity profile. The time played varies considerably with position and thus affected the activity profile. Total distance covered is greater for full backs and mean speed and percentage time spent high-speed running and sprinting was greater for forwards than all other positions. Match to match variability (CV) ranged from 5.0% to 22.0% for normalised total distance and sprint distance respectively. The introduction of the self-pass rule did not alter the activity profile or the between-match variability.

The present study demonstrates that the activity profile and implicitly the physical demands placed upon players differ considerably with playing position. The mean speed increases from full backs and half backs to midfield and increases again for forwards, a finding that is in agreement with other recent research into the physical requirements of positions in elite men's field hockey (13, 15). Forwards cover more distance high-speed running than halfbacks and spend a greater percentage of match time high-speed running and sprinting and complete more sprints per minute than all other positions. Midfield players run at high speeds more than fullbacks and halfbacks, also sprinting more than fullbacks as a percentage of total playing time. These findings are in agreement with the only other research presenting data from the highest National level (Australia), where midfield players were observed to cover more high-speed running than defenders (13). Clearly the physical requirements of each position are unique.

The difference in time played by position, as a result of the different tactics and thus substitution strategies employed by playing position is the key explanation for the differences in activity profile between playing positions. In agreement with previous research in elite women's hockey, fullbacks have 0-1 substitutions per half, half-backs 1-2, midfield 1-3 and forwards 2-4 per half, (18) resulting in up to 62 substitutions per match.

Direct comparisons with previous research examining the demands of elite hockey are problematic due to different methodologies and/or speed zones being employed. However, the percentage time spent engaged in high-speed running was much higher (10.8%) compared to that previously reported (6.2, (22) and 5.6%, (23)). From the present study and recent research, (15) it is evident that the style of field hockey played (technically and tactically) in the last decade, is played at higher speeds and incorporates more repeated sprinting than previously (3, 10, 13, 14, 19).

This is the first study to explore the activity profile and physical changes caused by the implementation of the 'self-pass' rule in field hockey. Given the nature of the 'self-pass' rule and its stated aims (to improve the 'flow' of the game and to increase the ball-in-play time) it could be assumed that the physical demands on players competing at an elite-level would have increased. However, the results of this study show that, for the squad analysed, the introduction of the 'self-pass' has had no impact on overall high-speed running completed during a match. In fact, what is startling is the similarity between the two seasons for all variables assessed. The increase in the number of substitutions made after the introduction of the 'self-pass' rule may well have contributed to this by ensuring players were maintaining their high-speed activity. It therefore may be reasonable to suggest that the team analysed were already competing at the 'ceiling' of the physiological ability prior to the rule change and therefore the 'self-pass' had little impact on their style of play. As such, it should be noted that the results attained, are specific to the team tested and further analysis of different player groups would provide greater insight into the changes. In addition, the variation between matches described below, may also partially explain the lack of any differences reported, as small changes (below the CV presented for match variation) may not be detected.

Between match variation ranged from 5 to 22% for normalised total and sprint distance respectively and was unaffected by season or playing position. The lack of an effect of playing position on between match variation should be considered with caution due to the small number of players in each position. However, unlike soccer where large datasets are available for research use, this is not the case for field hockey as elite and international teams will not share data with competitors. For mean speed, variation was 5%, for high-speed running the CV was 13%, with only sprint variables exceeding a CV of 15% (17.6-22%). For a high-speed running distance of 1400m during a match, you would therefore expect variation of 182 m per match, a change in distance in excess of this, could therefore be a result of changes in training status or other interventions (1). The between match variation presented is less than that reported for soccer using a very large sample size across several teams, (11) but similar to that reported for a single team (20). It would seem prudent to suggest that the between match variation within one team, who use consistent tactics, is going to be less than across teams who regularly change tactics. Further, in field hockey, the use of rolling substitutions means that players compete for much less time than soccer players, maintaining a higher intensity, resulting in less variability between performances. From this and previous studies (12, 20), it is imperative that between match variation is determined by sports scientists if meaningful differences in performance following an intervention, are to be established (1, 24).

Some authors have argued that 1 Hz GPS is not sufficiently accurate to evaluate individual sprint distances and repeated sprints and so its use in the present study could be seen as a potential limitation (2). However, the key outcome variables in this study were total distance and total high-speed running distance or percentage of match time in specific speed categories, and even those who have criticized the use of 1 Hz GPS agree that it is accurate for measuring total distance over the match. Furthermore, the validity of the specific GPS units employed in this study in relation to team sport movements has demonstrated: over a 200m course linear percentage bias was 2.5% and non-linear percentage bias adjusted for lean was -4.3% (11); for a 128.5m course bias was -1.87% (6); and specifically for hockey specific movements and distances bias was 0.04% for total match distance (6818m) and 0.4% for cruising (52.3m) and sprinting (26.0m) (17). Therefore, for the data presented in this study the 1Hz GPS employed was sufficiently precise to examine the variables investigated.

The results of the present study provide an in depth analysis of the activity profile of elite men’s hockey and adds to the existing literature from tournaments (13, 26). Our results demonstrate that the activity profile of the playing positions differs considerably and should be considered in player preparation. The introduction of the ‘self-pass’ rule has not altered this activity profile. Between-match variation, specific to a performance variable (12), should be considered by sports scientists when making inferences about performance changes and interventions in elite hockey. The use of rolling substitutions, differences in tactics employed, player selection and availability in other elite teams, may affect the between-match variation and activity profile.

Practical Applications

The activity profile for elite men’s field hockey is position specific and thus training schedules, sessions and recovery should be tailored by position, taking into account the needs of each individual. When assessing changes in running performance between matches the coefficient of variations presented for variables such as total distance and high speed running distance should be considered by the trainer or sports scientist. Further, where appropriate, coefficient of variations should be calculated by sports scientists for their specific team if running performance is a performance measure that is regularly evaluated. Finally, as field hockey rules change, assessments should be made upon their impact on the activity profile of the players to allow adaptations to training programmes and recovery protocols to be made.

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Table 1. Participant information (FB = Full Back; HB = Half Back; M = Midfield; F = Forward).

Season	Matches Analysed	Total cases	Participants			Position			
			Total	Junior International	Senior International	FB	HB	M	F
2008-2009	13	161	23	18	2	3	6	7	10
2009-2010	17	234	20	14	6	3	5	8	8

Table 2. Mean±SD total distance covered (season effect *p=0.28;* position effect *p<0.001)* and mean speed (season effect *p=0.3;* position effect *p<0.001*).

Position	Match Distance (m)		Mean Speed (km·h^{-1})	
	2008-09	2009-10	2008-09	2009-10
Full Back*	7780±381	8223±456	7.51±0.12	6.80±0.57
Half Back	6421±1726	6452±1081	7.79±0.53	7.88±0.37
Midfield‡	6019±903	6811±778	8.43±0.39	8.39±0.29
Forward†	5816±793	5881±774	9.02±0.45	9.03±0.79

*p<0.05 Fullback distance greater than halfback (*d=1.42*), midfield (*d=2.05*) and forward (*d=3.2*).

†p<0.01 Forward higher mean speed than fullback (*d=3.33*), halfback (*d=2.28*) and midfield (*d=1.27)*

‡p<0.05 Midfield higher mean speed than fullback (*d=3.33*) and halfback (*d=1.61*)

Table 3. Mean±SD total high-speed running (HSR; season effect *p=0.49;* position effect *p=0.02)* and sprinting distance (season effect *p=0.88;* position effect *p=0.12)* and percentage time spent high-speed running (season effect *p=0.79;* position effect *p<0.001)* and sprinting (season effect *p=0.32;* position effect *p<0.001*).

Position	HSR Distance (m)		% time HSR		Sprint Distance (m)		% time sprinting	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Fullback	1351±267	1364±82	7.0±1.2	6.6±1.0	438±59	418±49	1.9±0.2	1.7±0.3
Halfback	1295±448	1364±248	8.6±1.7	9.1±0.8	442±172	422±93	2.5±0.7	2.3±0.3
Midfield‡#	1408±154	1589±212	10.7±1.3	10.7±1.2	443±52	483±78	2.9±0.6	2.8±0.3
Forward*†	1656±270	1635±314	13.7±2.0	13.2±1.5	535±137	513±127	3.7±0.8	3.4±0.6

**p*=0.03 Forward greater high-speed running distance than halfback (*d=1.07*)

†*p*<0.001 Forward greater percentage of time spent high-speed running and sprinting than fullback (*d=4.29* and *2.98*), halfback (*d=2.98* and *1.91*) and midfield (*d=1.85* and *1.33* respectively).

#*p*<0.05 Midfield greater percentage of time spent high-speed running than fullback (*d=3.6*) and halfback (*d=1.58)*.

‡*p*<0.001 Midfield greater percentage of time spent sprinting than fullback (*d=2.59*)

Table 4. Overall between match variation and influence of season and playing position on between-match variation (% CV).

Activity	2008-2009 CV (%)					2009-2010 CV (%)				
	All	Fullback	Halfback	Midfield	Forward	All	Fullback	Halfback	Midfield	Forward
Normalised total distance	5.0±2.6	3.1±2.4	6.5±3.5	4.2±1.7	5.5±2.0	5.3±1.3	6.3±1.5	6.1±1.1	4.8±1.3	4.9±1.0
Mean speed	5.3±2.6	3.1±2.4	6.7±3.5	4.4±1.6	5.9±1.9	5.3±1.3	6.3±1.5	6.1±1.1	4.8±1.3	4.9±1.0
Normalised HSR distance	13.0±9.5	11.3±7.4	19.4±16.0	9.3±2.8*	11.3±2.5	13.7±5.4	23.8±3.9	11.8±2.4	15.2±4.0	10.8±3.2
Percentage time HSR	12.9±9.0	11.2±7.5	18.9±15.2	9.3±2.2*	11.4±2.2	13.8±5.6	23.9±3.7	12.0±3.3	14.8±3.3	10.0±2.9
Normalised sprint distance	20.9±11.0	21.9±7.4	24.6±19.8	20.3±5.6	17.2±3.2	22.0±7.6	25.9±7.1	18.1±3.3	23.3±8.9	21.8±8.6
Percentage time sprinting	20.2±8.9	22.5±6.3	22.7±15.4	19.7±5.6	17.1±2.8	21.2±7.4	26.1±6.3	17.3±3.6	22.3±8.7	20.9±8.2
Normalised sprint number	17.6±5.2	18.5±7.2	19.6±4.8	15.4±6.2	17.4±3.7	18.0±6.3	23.7±8.3	18.2±5.4	18.2±7.2	15.5±4.7

*Interaction p=0.02, *post hoc* p<0.05 2008-09 midfield lower than 2009-10 fullback.

HSR: high-speed running