Introduction

1.1 Time Motion Analysis

Time motion analysis (TMA) records duration of match time spent in varying activities and is often referred to when quantifying work rate, work: rest ratios and contributions of energy systems in competitive environments. Data may be collected through audiotape, videotape or more recently, global positioning systems (Atkinson, 2007). Individual locomotor activities are classified into groups and can be further defined as high or low intensity. Classifications of player movements have been shown to vary significantly across studies, and are often the main cause for concern when discussing the limitations of investigations. In the present study, TMA is of particular interest regarding the physical demands of individual players. Understanding the level of intensity at which positions work assists research into the physiological responses of players for further development of training and assessment programmes. The current investigation aims to examine whether TMA varies among different playing positions, and assess its subsequent contributions to the physiological demands of the sport.

1.2 Heart Rate

Heart Rate (HR) has commonly been used as an indicator of the physiological demands of exercise within team sports. HR response to activity during submaximal exercise increases in direct proportion to exercise intensity until steady state; whereby work rate is maintained at a constant level and there is evidence of a plateau

in HR values. Further increases in exercise intensity induce an additional rise in HR until subjects continue to stabilise at another steady state. HR remains stationary at this point due to the ability of the circulatory system to function most efficiently at this specific level of intensity. It is argued that subjects with a higher level of physical fitness will work at the same intensity, but at a lower HR than less physically conditioned individuals, (Wilmore & Costill, 2004). Consequently, HR levels attained during exercise are often used as an indicator of heart efficiency; whereby lower HR values demonstrate a more efficient heart. Maximum exercise levels are reached when increases in individual HR discontinue and a plateau in values is met. This HR level is defined as the maximum heart rate (HR_{max}) and is the peak HR value achieved during maximal effort exercise.

Increased aerobic fitness and its subsequent adaptations on the cardiovascular system enable athletes to recover from high intensity activities at a faster rate than those less aerobically conditioned. Significantly developed recovery rates are due to the increase in left ventricular cavity size and consequently Stroke Volume, (SV), (Aubert et al., 2003; McArdle et al., 2006; Wilmore and Costill, 2004). These adaptations improve the blood pumping capability of the heart, thus providing increased levels of Oxygen (O_2) to the working muscles whilst requiring only a slight increase in HR. Aubert et al., (2003) confirmed these statements by suggesting that Heart Rate Variability during exercise is primarily dependent upon aerobic adaptations as well as genetic predisposition, environmental factors and skill levels. It is therefore observed that aerobically trained individuals are able to perform at a lower HR level than untrained populations at the same intensity. The present study aims to investigate whether HR values achieved in field hockey vary dependent on

player position. If significant differences are noted, it is then possible to ascertain whether aerobic familiarity in certain positions have an affect on HR responses to exercise.

1.3 Blood Lactate

The correlation between BLA and exercise intensity is similar to that of the HR-intensity relationship; increases in exercise intensity initiates a significant rise in lactate levels, this substrate has been found to be a key contributor to fatigue. Furthermore, it has been observed that active recovery from high intensity exercise increases the rate of lactate removal and is particularly useful during interval training (Dupont et al., 2004; McArdle et al., 2006).

Frequently during high intensity exercise the physiological demands exceed the rate at which the body is able to supply or utilise oxygen (O_2). An affect of this is the decrease in amount of hydrogen (H) removal from NADH which leads to a reduction in production of anaerobic energy. Removal of H facilitates oxidisation of 3-phosphoglyceraldehyde thus preventing the potential cessation of anaerobic glycolysis. Blood lactate (BLA) is formed as a substrate of this process when non-oxidised H combines with pyruvate and is catalysed by lactate dehydrogenase. Unless reversed back into glycolysis, the lactate formed within the muscle will be removed into the blood stream for buffering from the site of energy metabolism via diffusion.

Aerobic training has been observed to have a significant affect on BLA accumulation, primarily through prolonging the amount of time spent at increasing intensities prior to the onset of blood lactate accumulation (OBLA). Aerobic adaptations caused by training occur at central and peripheral levels and are defined by decreased level of lactate production and increased rate of lactate removal. During high intensity activities aerobically trained individuals have been witnessed to have a more favourable lactate threshold than untrained subjects. Consequently, a trained and untrained individual performing at identical exercise intensities may experience significant OBLA at different percentages of their aerobic power; namely the trained subject will reach their lactate threshold at a higher percentage of $\dot{V}O_{2max}$. The present study aims to establish variations across different positional roles in the sport of field hockey and expects lactate accumulation to be related to the aerobic familiarity of certain positions.

1.4 Fitness Testing

Fitness Tests (FT) in all sports are vital for providing coach, athlete and sport scientists with relevant information regarding the physiological demands of the activity and the necessary characteristics for success, (Australian Sports Commission, 2000). FT results quantify weaknesses and strengths in individual players as well as assisting the coach in monitoring the athlete's response to training. Considering this information, coaches are able to provide accurate feedback regarding future athlete development and are able to adapt training programmes to better suit the demands of the sport.

Atkinson's (2007) Great Britain Fitness Test (FT) is an assessment into the cardiovascular capabilities of elite level field hockey players. In particular it looks to evaluate player abilities in the four main components of; Speed Agility (SA), Speed Agility Endurance (SAE), Speed Endurance (SE) and Aerobic Endurance (AE). Assessment of cardiorespiratory fitness in subjects from invasion games is best administered in the field environment due to specificity of the task in addition to inexpensive equipment and practicalities of performing testing on large numbers of subjects simultaneously, (Barrrow, 1989). A key prerequisite to a successful fitness assessment is that it accurately represents the physiological demands of the sport in question. No studies have previously attempted to assess the relevance of this particular FT in comparison to the competitive environment; consequently the present study aims to establish whether Atkinson's (2007) FT accurately represents the physiological demands of a hockey match. Investigation into the specificity of the four individual components will then be assessed in order to evaluate which aspect is more closely related to field hockey performance.

Methodology

3.1 Subjects

Six undergraduate Sports Science students from the University of Wales Institute, Cardiff (UWIC) participated in the study on completion of informed consent (Appendix 1) and Par – Q forms, (Appendix 2). All subjects were members of University field hockey teams, and performed two training sessions and two matches a week up to and including the duration of the study. Ethical approval was received from the University Research Ethics Committee (UREC). Six subjects, (mean $\pm$ SD; Age 20.6 $\pm$ 1.19; Height 164.88 $\pm$ 5.89; weight 66.57 $\pm$ 6.88) were randomly selected from Defenders, Midfielders, and Forwards, two participants from each position. Anthropometric data on specific positions is as follows; Defenders, (N 2; Age 21.3 $\pm$ 0.21; Height 166.80 $\pm$ 7.50cm; weight 69.85 $\pm$ 11.38); Midfielders, (N 2; Age 21.4 $\pm$ 0.35; Height 163.80 $\pm$ 5.94; weight 63.55 $\pm$ 0.35); Forwards, (N 2; Age 19.1 $\pm$ 0.35; Height 164.05 $\pm$ 8.41; weight 66.30 $\pm$ 8.20).

3.2 Study Design

The study was conducted over a four month period. Match analysis was performed on three separate occasions; two subjects per match, and the fitness test on one occasion with all subjects tested in one session. Prior to the start subjects were informed that their Movement Patterns, Blood Lactate ($mmol \cdot l^{-1}$) and Heart Rate ($b \cdot min^{-1}$) would be taken during the first twenty minutes of the hockey match. All data collection occurred at the University of Wales Institute, Cardiff, on artificial turf.

The Great Britain fitness test (FT) was established by Pete Atkinson, Lead Strength and Conditioning Coach from the English Institute of Sport (EIS) and practitioner with England and Great Britain Field Hockey Teams. The test was formed to assess player abilities in Speed Agility, Speed Agility Endurance, Speed Endurance and Aerobic Endurance at an elite level. The nature of the assessment allowed the FT to be performed in a field test situation on artificial surfaces, enabling all home countries to undertake the assessment outside of a laboratory environment during squad training sessions.

3.3 Anthropometric Measurements

3.3.1 Body Mass

Body mass was obtained through use of scales (Seca, Germany) in a laboratory environment. Each subject was advised to remove shoes, any excess clothing and empty pockets prior to stepping onto the scales to achieve accurate body mass. One foot was placed onto the scales to prepare readings to be taken, subjects then mounted the scales facing forwards and remaining stationary while measurements were taken to the nearest tenth of a kilogram (kg).

3.3.2 Stature

Height was obtained through use of a stadiometer (Holtain Ltd, Crymych, Dyfed) from the floor to the top of the head. Subjects were again asked to remove footwear and face away from the equipment in a stationary position with heels together while measurements were taken to the nearest tenth of a centimetre (cm).

3.4 Great Britain Hockey Fitness Test Protocols

Subjects were divided into pairs; one performing the test, the other recording time taken to complete each component. Example data collection sheets are demonstrated in Appendix 3. The baseline acted as both the starting and finishing point for all subjects between each individual repetition of each component. All components began after a five second count down by the test co-ordinator and were initiated according to the rolling clock times provided. Measurements of these activities were time taken to complete each repetition (TT), measured using a Stop Watch (Seiko); BLA and continuous HR.

Speed Agility (SA) required subjects to perform one maximal sprint from the baseline out to a cone at five, ten and fifteen metres; between each marker they returned to the baseline before attempting the next length. Total distance covered in this test was 60 metres. One repetition at this activity began with the clock at zero seconds.

Three separate repetitions of Speed Agility Endurance (SAE) commenced at 30 seconds, 1min and 1.30mins on the rolling clock. Participants were required to perform identical procedures to that of the SA test with a rest between each sprint. Rest periods were determined by the amount of time taken to complete each repetition; the shorter amount of time taken to perform the task gave the subjects a longer rest period. The testing coordinator performed a five second count down to prepare subjects at the start of each run. Total distanced covered was 180 metres, (three 60m shuttles).

Protocols indicated a break in testing allowing significant subject recovery before initiation of the Speed Endurance (SE) phase at five minutes on the rolling clock. SE entailed four sprint shuttles from the baseline to the 25 yard line and 50 yard line respectively, equaling four 150 yard (600 yard) runs. Repetitions of each component began at 5mins, 6.30mins, 8mins and 9.30mins respectively.

The final component of the Great Britain Fitness Test began at 13 minutes on the rolling clock. Another short break prior to this exercise allowed subjects another recovery relative to the amount of time taken to complete the previous task. Demands of the Aerobic Endurance (AE) component consisted of a single 1000 yard run. Beginning at the base line subjects ran to each line and back twice, (25 yard line, 50 yard line, 75 yard line, 100 yards, 100 yards, 75 yard line, 50 yard line, 25 yard line). Subjects were asked to run to the lines of the pitch in a pyramid fashion, using the 25 yard line as their first and last shuttle to assist test coordinators to track how many lengths remained for each subject to run.

3.5 Match Analysis

Match analysis measurements included BLA collected at 7, 14 and 20, minutes; Time Motion Analysis (TMA) recorded for the entirety of the first twenty minutes of competition; and continual HR with readings taken every five seconds for the duration of analysis. Heart Rate Monitors (HRM) were attached to subjects ahead of warm up and removed at half time, so to limit player disruption.

3.6 Blood Lactate

FT BLA data was obtained on five occasions, namely upon completion of each component of the test. Subjects were required to remain upright and stationary during testing and samples were taken from the right index finger. Lactate values were noted and subjects were allowed to continue the test according to the rolling clock. BLA data was obtained on only four occasions during match analysis; at rest, 7 minutes, 14 minutes and 20 minutes. Subjects were substituted according to the FIH rules and remained out of play until BLA was taken and testers considered the site of sampling sanitary enough to return to play.

Blood samplers wore latex examination gloves (BCB Ltd, Cardiff, UK) at all times. The site of penetration was swabbed using anti-septic wipes (Sterets, Seaton Healthcare Group plc, UK) and were disposed of in a Biohazard bin (Sharpsafe, Frontie Medical, UK). The cleaned index finger was then punctured by a lancet (Softclix Pro, Roche Diagnostics, Sussex, UK) and blood collected onto the tip of the Lactate Pro (Model Biosen_C Sport, Ostfalen, Magdeburg) for sample assessment. Lactate Pro analysers counted down from one minute before displaying BLA scores. Subjects were provided with tissues to wipe excess blood from the sampling site and all disposable items were placed in the Biohazard bin.

3.7 Heart Rate

Heart Rate data was obtained continually every five seconds during both the FT and Match. Subjects were provided with a Polar Wrist Watch and Heart Rate Monitor (-) to strap around the chest at the bottom of the sternum in contact with the skin below any undergarments. A conductive gel was applied to the straps of the Heart Rate Monitors (HRM) to ensure accurate reading. During the testing procedures participants were instructed to stand away from each other so to avoid confusion of inter-subject HRM readings. Watches were synchronised to begin recording data simultaneously. During interruptions in play and for BLA sampling and on completion of FT components, testers checked each subject's HRM to confirm continued recording.

Data was downloaded onto Polar Precision Software (Polar Electro, Oy., Finland) in a controlled laboratory environment and copied into an Excel Spreadsheet (Microsoft Works, Microsoft) and the Statistical Package for Social Sciences, (SPSS Inc, Chicago, IL, USA) for further analysis.

3.8 Time Motion Analysis

Two video cameras were positioned at the half way point of the Astroturf approximately two metres from the sideline to allow equal views of the entire pitch. Tripods were used to ensure smooth player tracking. Camera operators were instructed to video the entire subject and their surrounding area, including nearby players and if appropriate, the ball in play to indicate intentions of movements.

Analysis of TMA data divided movements into the following categories, as defined by Spencer et al., (2004) and Lothian and Farrally, (1994), with intensity levels in parenthesis;

- *Standing:* Motionless. (Low)
- *Walking:* Motion, both feet in contact with the ground at the same time. (Low)
- *Jogging:* Motion, airborne phase, low knee lift. (Low)
- *Striding:* More vigorous than jogging, airborne phase, higher knee lift. (High)
- *Sprinting:* Maximal effort, higher knee lift and greater extension of lower leg. (High)
- *Hockey Related Activities:* Hitting, pushing, tackling, lunging, receiving, dribbling and other similar ball related movements. (High)

3.9 Reliability

Repeated use of Camera, BLA and HR equipment in numerous studies has indicated that - Video Cameras, Polar Heart Rate Monitors and Blood Lactate Analysis Equipment are reliable in monitoring movement patterns and testing individual HR and BLA in both laboratory and field testing environments.

Intra-test reliability of the analysis of movement patterns was performed through Pearson's correlation into test-retest reliability, with each subject's footage analysed twice. Testing indicated there is a significant positive relationship between both sets of analysis performed on each piece of footage, ($r = .958$, $df = 34$; $p < 0.001$).

Therefore test-retest reliability into the correlation between sets of analysis proves the testing procedure is reliable.

3.10 Statistical Analysis

Data was analysed using the Statistical Package for Social Sciences, (SPSS Inc, Chicago, IL, USA). Normal distribution was assessed using Kolmogrov-Smirnov test ($P > 0.05$) indicating normality across all data. A 3 x 3 (group x condition) ANOVA was used for analysis of HR and a 3 x 4 ANOVA used for BLA analysis in both Match and FT to indicate significant differences between positional dependent variables in each condition. A Bonferroni Post-Hoc test was performed to represent differences in means between individual positions with significance at the $P < 0.05$ level. Additionally, the Bonferroni test considered the possibility of a Type I error (rejecting a correct null hypothesis), by demonstrating 95% confidence intervals used to represent the value in the further population.

Results

4.1 Anthropometric Measurements

Prior to data collection, anthropometric measurements were obtained for each subject, results of which can be seen in Table 1.

Table 1. Mean ± SD Anthropometric measurements of subjects from each position.

Position	Age (Years)	Height (cm)	Mass (kg)
Defender	21.3 ± 0.21	166.80 ± 7.50	69.85 ± 11.38
Midfielder	21.4 ± 0.35	163.80 ± 5.94	63.55 ± 0.35
Forward	19.1 ± 0.35	164.05 ± 8.41	66.30 ± 8.20

4.2 Heart Rate

Tables 2 and 3 represent mean ± SD HR values achieved during each component of the FT and seven minute intervals of the match. Comparison of the two tables indicated the majority of match play was performed at the level of Aerobic Endurance (AE) due to similarities between HR values in this final component and match values from all positions. Tables 6 and 7 indicate overall HR in both FT and competitive conditions. 4 x 3 ANOVA results indicate significant differences between positions in the FT (Table 6) during the SAE, and AE components, ($P < 0.05$). However, significant HR differences were not observed between positions in the SA component, (mean differences; defender and midfielder, 0.3000; defender and forward, 16.7889; midfielder and forward, 17.0889) or between defenders and

forwards (mean difference 5.7556) in the SE component, ($P > 0.05$). Match HR (Table 7) values indicate significant differences ($P < 0.05$) across all positions between seven to twenty minutes of competitive play. However, the first seven minutes of the match, indicate no significant difference ($P > 0.05$) in HR values between forwards and defenders (mean difference 1.3205).

Table 2. Mean ± SD HR ($b \cdot min^{-1}$) of individual FT components.

FT Position	SA	SAE	SE	AE
D	109 ± 19.80	111.5 ± 12.02	158 ± 9.90	167.5 ± 10.61
M	109 ± 19.80	170.5 ± 9.19	171.5 ± 12.02	182.5 ± 7.78
F	90.5 ± 21.92	114.5 ± 26.16	164.5 ± 12.02	171 ± 11.31

Table 3. Mean ± SD HR ($b \cdot min^{-1}$) of seven minute match intervals.

Match Position	7 min	14 min	20 min
D	167.5 ± 13.44	168 ± 14.14	168 ± 2.83
M	174.5 ± 0.71	185.5 ± 3.54	184.5 ± 0.71
F	168 ± 11.31	178 ± 8.49	178 ± 4.24

Figure 1 represents HR values across all three positions during the FT. Increases and decreases in individual HR was dependent on which of the four components performed. A significant increase in HR levels from the commencement of testing indicates the physiological response for the SA and SAE activities during the first five minutes of activity; the four repetitions of SE are manifested across all three positions with four similar peaks in HR between approximately five and eleven minutes; finally AE is represented by the gradual increase to plateau in HR values

from thirteen minutes. All significant increases or decreases in HR are correlated with FT rolling clock protocols.

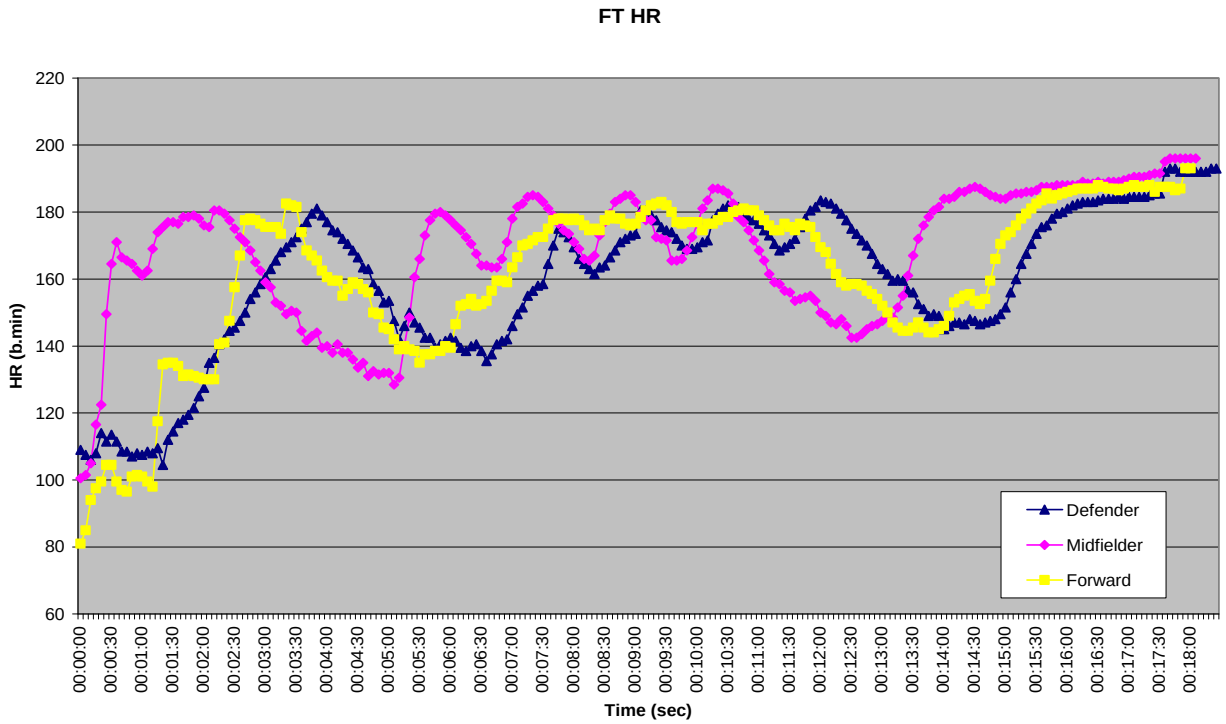

Figure 1. HR of player positions during FT.

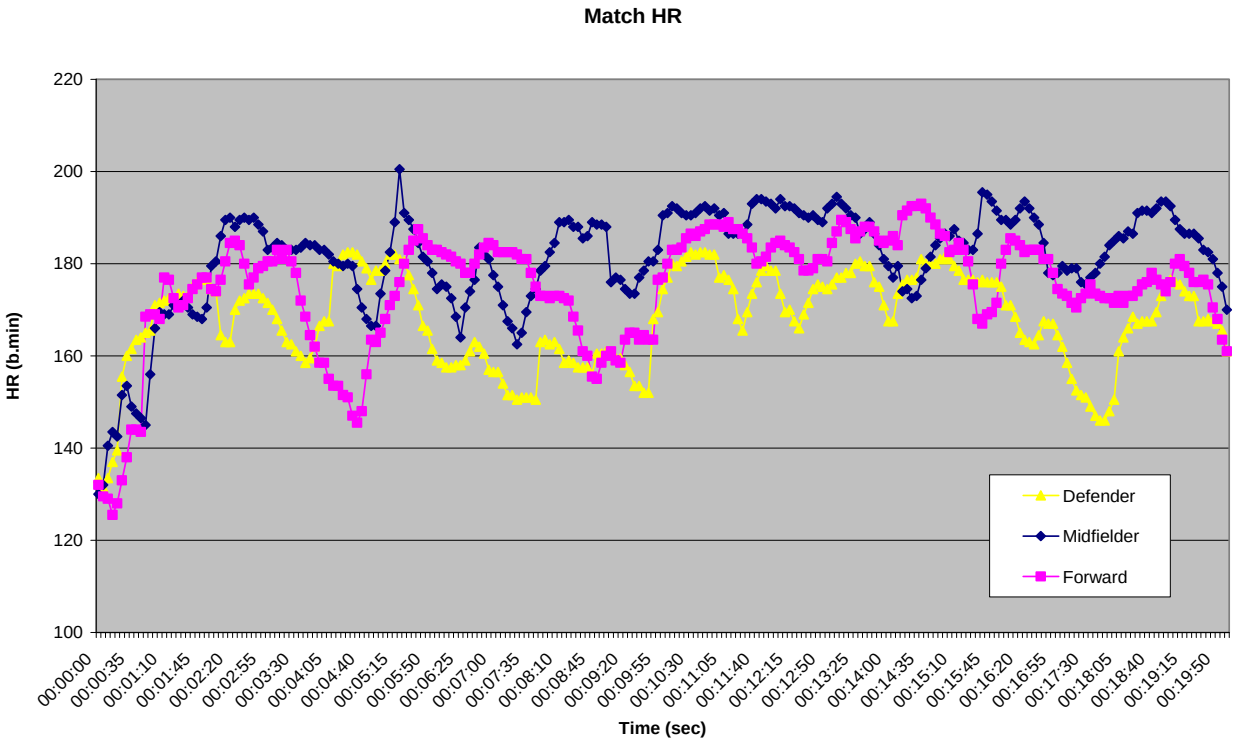

Figure 2. HR of player positions during competition.

Match Heart Rate values are represented in Figure 2. Fluctuations in HR for the duration of analysis indicate a variety of demands on subjects whereby constantly changing activities are represented by high HR values and recovery phases at low HR level. Midfielders appear to constantly perform at a higher HR level than forwards, with Defenders working at the lowest HR level of all positions.

4.3 Blood Lactate

Tables 4 and 5 indicate BLA results from the components of the FT and Match intervals respectively. No significant differences ($P > 0.05$) were observed between positions during all four components of the FT and at rest, (Table 8). Similarly, Table 9 indicates BLA values from the match environment where no significant differences ($P > 0.05$) have been observed between player positions throughout the duration of analysis.

Table 4. Mean ± SD BLA ($mmol \cdot l^{-1}$) of individual FT components.

FT Position	Rest	SA	SAE	SE	AE
D	1.2 ± 0.64	1.8 ± 0.14	8.8 ± 5.94	10.8 ± 2.69	12.0 ± 1.20
M	2.1± 0.21	3.0 ± 1.60	9.5 ± 0.80	10.7 ± 0.80	12.6 ± 1.80
F	1.2 ± 0.21	1.4 ± 0.00*	10.4 ± 0.00*	13.10 ± 0.00*	13.10 ± 0.00*

* Denotes misplaced BLA result.

Table 5. Mean Match BLA ($mmol \cdot l^{-1}$) at seven minute intervals.

Match Position	Rest	7 min	14 min	20 min
D	1.3 ± 0.21	4.9 ± 1.34	8.6 ± 0.28	6.8 ± 3.54
M	1.5 ± 0.28	7.1 ± 2.33	8.1 ± 1.20	8.7 ± 0.42
F	2.8 ± 1.34	5.4 ± 0	8.0 ± 0.49	9.7 ± 0.42

Table 6. FT Mean Heart Rate ($b \cdot min^{-1}$) comparisons between positions (with 95% confidence intervals)

Dependent Variable	Position (I)	Position (J)	Mean Difference	P Value	Lower 95% CI	Upper 95% CI
Speed Agility	Defender	Midfielder	0.3000	1.000	-19.90607341	19.30607341
		Forward	16.7889	0.128	-3.354436691	36.93221447
	Midfielder	Defender	0.3000	1.000	-19.30607341	19.90607341
		Forward	17.0889	0.118	-3.054436691	37.23221447
	Forward	Defender	16.7889	0.128	-36.93221447	3.354436691
		Midfielder	17.0889	0.118	-37.23221447	3.054436691
Speed Agility Endurance	Defender	Midfielder	56.0000 *	0.000	-60.80671023	-51.19328977
		Forward	6.2111 *	0.010	1.272685802	11.14953642
	Midfielder	Defender	56.0000 *	0.000	51.19328977	60.80671023
		Forward	62.2111 *	0.000	57.2726858	67.14953642
	Forward	Defender	6.2111 *	0.010	-11.14953642	-1.272685802
		Midfielder	62.2111 *	0.000	-67.14953642	-57.2726858
Speed Endurance	Defender	Midfielder	16.5000 *	0.027	-31.49502317	-1.504976827
		Forward	5.7556	1.000	-9.650366249	21.16147736
	Midfielder	Defender	16.5000 *	0.027	1.504976827	31.49502317
		Forward	22.2556 *	0.003	6.849633751	37.66147736
	Forward	Defender	5.7556	1.000	-21.16147736	9.650366249
		Midfielder	22.2556 *	0.003	-37.66147736	-6.849633751
Aerobic Endurance	Defender	Midfielder	14.3000 *	0.000	-21.32625693	-7.273743075
		Forward	13.0333 *	0.000	5.81454057	20.2521261
	Midfielder	Defender	14.3000 *	0.000	7.273743075	21.32625693
		Forward	27.3333 *	0.000	20.11454057	34.5521261
	Forward	Defender	13.0333 *	0.000	-20.2521261	-5.81454057
		Midfielder	27.3333 *	0.000	-34.5521261	-20.11454057

* Denotes Significance at $P < 0.05$

Table 7. Match Mean Heart Rate ($b \cdot min^{-1}$) Comparisons between Positions (with 95% confidence intervals)

Dependent Variable	Position (I)	Position (J)	Mean Difference	P Value	Lower 95% CI	Upper 95% CI
T7	Defender	Midfielder	7.2899 *	0.002	-12.4071	-2.1728
		Forward	1.3205	1.000	-6.5438	3.9028
	Midfielder	Defender	7.2899 *	0.002	2.1728	12.4071
		Forward	5.9694 *	0.019	0.7314	11.2074
	Forward	Defender	1.3205	1.000	-3.9028	6.5438
		Midfielder	5.9694 *	0.019	-11.2074	-0.7314
T14	Defender	Midfielder	17.3527 *	0.000	-21.0921	-13.6133
		Forward	9.8626 *	0.000	-13.6795	-6.0456
	Midfielder	Defender	17.3527 *	0.000	13.6133	21.0921
		Forward	7.4901 *	0.000	3.6624	11.3179
	Forward	Defender	9.8626 *	0.000	6.0456	13.6795
		Midfielder	7.4901 *	0.000	-11.3179	-3.6624
T20	Defender	Midfielder	16.3235 *	0.000	-19.3788	-13.2681
		Forward	10.3974 *	0.000	-13.5161	-7.2787
	Midfielder	Defender	16.3235 *	0.000	13.2681	19.3788
		Forward	5.9260 *	0.000	2.7985	9.0535
	Forward	Defender	10.3974 *	0.000	7.2787	13.5161
		Midfielder	5.9260 *	0.000	-9.0535	-2.7985

* Denotes Significance at $P < 0.05$.

Table 8. FT Mean BLA ($mmol \cdot l^{-1}$) comparisons between Positions (with 95% confidence intervals)

Dependent Variable	(I) Position	(J) Position	Mean Difference (I-J)	P Value	Lower 95% CI	Upper 95% CI
Rest	Defender	Midfielder	-0.8	0.357	-2.595431159	0.995431159
		Forward	-0.05	1.000	-1.845431159	1.745431159
	Midfielder	Defender	0.8	0.357	-0.995431159	2.595431159
		Forward	0.75	0.407	-1.045431159	2.545431159
	Forward	Defender	0.05	1.000	-1.745431159	1.845431159
		Midfielder	-0.75	0.407	-2.545431159	1.045431159
SA	Defender	Midfielder	-1.2	0.826	-5.579976121	3.179976121
		Forward	0.4	1.000	-3.979976121	4.779976121
	Midfielder	Defender	1.2	0.826	-3.179976121	5.579976121
		Forward	1.6	0.522	-2.779976121	5.979976121
	Forward	Defender	-0.4	1.000	-4.779976121	3.979976121
		Midfielder	-1.6	0.522	-5.979976121	2.779976121
SAE	Defender	Midfielder	-0.75	1.000	-17.54706121	16.04706121
		Forward	-1.6	1.000	-18.39706121	15.19706121
	Midfielder	Defender	0.75	1.000	-16.04706121	17.54706121
		Forward	-0.85	1.000	-17.64706121	15.94706121
	Forward	Defender	1.6	1.000	-15.19706121	18.39706121
		Midfielder	0.85	1.000	-15.94706121	17.64706121
SE	Defender	Midfielder	0.1	1.000	-7.801091311	8.001091311
		Forward	-2.3	0.757	-10.20109131	5.601091311
	Midfielder	Defender	-0.1	1.000	-8.001091311	7.801091311
		Forward	-2.4	0.710	-10.30109131	5.501091311
	Forward	Defender	2.3	0.757	-5.601091311	10.20109131
		Midfielder	2.4	0.710	-5.501091311	10.30109131
AE	Defender	Midfielder	-0.55	1.000	-6.709216762	5.609216762
		Forward	-1.05	1.000	-7.209216762	5.109216762
	Midfielder	Defender	0.55	1.000	-5.609216762	6.709216762
		Forward	-0.5	1.000	-6.659216762	5.659216762
	Forward	Defender	1.05	1.000	-5.109216762	7.209216762
		Midfielder	0.5	1.000	-5.659216762	6.659216762

* Denotes significance at $P < 0.05$

Table 9. Match Mean BLA ($mmol \cdot l^{-1}$) comparisons between Positions (with 95% confidence intervals)

Dependent Variable	Position (I)	Position (J)	Mean Difference	P Value	Lower 95% CI	Upper 95% CI
Rest	Defender	Midfielder	0.2500	1.000	-4.1454	3.6454
		Forward	1.5000	0.475	-5.3954	2.3954
	Midfielder	Defender	0.2500	1.000	-3.6454	4.1454
		Forward	1.2500	0.651	-5.1454	2.6454
	Forward	Defender	1.5000	0.475	-2.3964	5.3954
		Midfielder	1.2500	0.651	-2.6454	5.1454
T7	Defender	Midfielder	2.2000	0.756	-9.7500	5.3500
		Forward	0.5500	1.000	-8.1000	7.0000
	Midfielder	Defender	2.2000	0.756	-5.3500	9.7500
		Forward	1.6500	1.000	-5.9000	9.2000
	Forward	Defender	0.5500	1.000	-7.0000	8.1000
		Midfielder	1.6500	1.000	-9.2000	5.9000
T14	Defender	Midfielder	0.5500	1.000	-3.1805	4.2805
		Forward	0.6500	1.000	-3.0805	4.3805
	Midfielder	Defender	0.5500	1.000	-4.2805	3.1805
		Forward	0.1000	1.000	-3.6305	3.8305
	Forward	Defender	0.6500	1.000	-4.3805	3.0805
		Midfielder	0.1000	1.000	-3.8305	3.6305
T20	Defender	Midfielder	1.9000	1.000	-11.9554	8.1554
		Forward	2.9000	0.767	-12.9554	7.1554
	Midfielder	Defender	1.9000	1.000	-8.1554	11.9554
		Forward	1.0000	1.000	-11.0554	9.0554
	Forward	Defender	2.900	0.767	-7.1554	12.9554
		Midfielder	1.0000	1.000	-9.0554	11.0554

* Denotes significance at $P < 0.05$.

4.4 Time Motion Analysis

Time motion analysis (TMA) data indicated in Figure 3 shows percentage of game time spent by each position performing each motion category. All three positions spent the largest amount of time performing the low intensity activity of walking, however Midfielders spent considerably longer performing high intensity, hockey related activities and other similar intensity movements such as striding or sprinting than other positions.

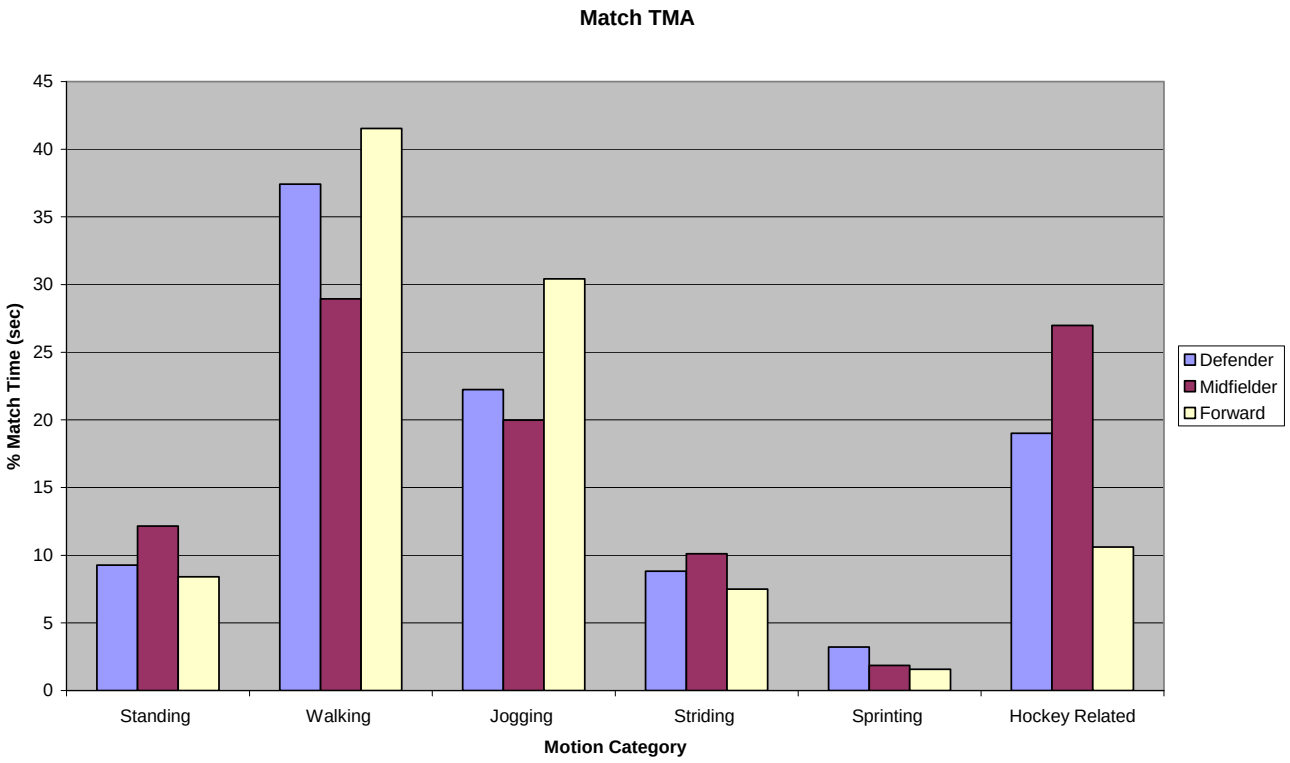

Figure 3. Duration (%) of match time spent in each motion category by each position in competition.

Table 10 indicates the percentage differences between positions regarding the amount of time spent performing different activities. The greatest percentage difference (16.39%)

is noticeable between Midfielders and Forwards concerning the percentage of time spent performing hockey related activities; the duration of these actions vary considerably across all three positions, with Defenders spending 8.41% more of match time than Forwards and 7.98% more time than Midfielders performing hockey related movements. The smallest difference occurred regarding the time spent sprinting between Midfielders and Forwards (0.29%). Other significant differences occur in walking between Midfielders and Forwards, with the latter spending 12.60% more match time walking than Midfielders; Midfielder and Forward jogging percentages also indicate Forwards spent 10.44% more time jogging than Midfielders (Table 11).

Table 10. Positional differences in duration (%) of movement patterns in competition

Movement	Position (I)	Time (%)	Position (J)	Time (%)	Difference (%)
Standing	Defender	9.27	Forward	8.40	0.87
			Midfielder	12.15	2.88
	Midfielder	12.15	Forward	8.40	3.75
Walking	Defender	37.43	Forward	41.54	4.11
			Midfielder	28.94	8.49
	Midfielder	28.94	Forward	41.54	12.60
Jogging	Defender	22.25	Forward	30.42	8.17
			Midfielder	19.98	2.27
	Midfielder	19.98	Forward	30.42	10.44
Striding	Defender	8.83	Forward	7.49	1.34
			Midfielder	10.10	1.27
	Midfielder	10.10	Forward	7.49	2.61
Sprinting	Defender	3.22	Forward	1.57	1.65
			Midfielder	1.86	1.36
	Midfielder	1.86	Forward	1.57	0.29 **
Hockey Related	Defender	19.01	Forward	10.60	8.41
			Midfielder	26.99	7.98
	Midfielder	26.99	Forward	10.60	16.39 *

* Denotes the largest percentage difference between positions

** Denotes the smallest percentage difference between positions

Table 11. Mean $\pm$ SD frequency of motion categories and changes in activity (s)

Motion Categories	Defenders	Midfielders	Forwards
Standing (Low)	23 $\pm$ 9.90	29.5 $\pm$ 5.66	19.5 $\pm$ 2.12
Walking (Low)	93 $\pm$ 13.44	70.25 $\pm$ 1.06	98.25 $\pm$ 25.81
Jogging (Low)	55.5 $\pm$ 24.75	48.5 $\pm$ 6.36	71.75 $\pm$ 17.32
Striding (High)	22 $\pm$ 5.66	24.5 $\pm$ 4.95	18 $\pm$ 7.07
Sprinting (High)	8 $\pm$ 0.71	4.5 $\pm$ 2.12	3.5 $\pm$ 0.71
Hockey Related (High)	47.25 $\pm$ 3.18	65.5 $\pm$ 2.83	24.75 $\pm$ 3.89
Change in Activity (s)	8.04 $\pm$ 0.10	8.24 $\pm$ 0.04	8.73 $\pm$ 2.06

6.1 Conclusion

Physiological demands of positional roles vary significantly in women's field hockey. HR levels differed depending on levels of exercise intensity defined through observation of TMA. Present findings indicated that Midfield players possess the highest mean HR during analysis. BLA accumulation across Defenders, Midfielders and Forwards indicated no significant differences in the amount of high intensity anaerobic exercise undertaken in a competitive environment. Duration (%) of match time spent performing high or low intensity activities were dependent on player positions and their individual roles during a match; Midfield positions were observed to perform the largest amount of time at high intensity exercise while Forwards remained at low intensity the most. HR comparisons between the FT and competition demonstrated the match environment evoked the highest HR values from all positions whereas BLA accumulation was greater during fitness assessment.

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Appendix 1

Informed Consent Form

(Tester Copy)

Name:	Position (D/M/F):
Sex:	Tester:
Date of Birth:	Date of Test:
Sport:	Date of Match:

The purpose of this investigation is to evaluate the appropriateness of the Great Britain Hockey Fitness Test in relation to the physiological demands of a match in Women's Field Hockey.

Subjects will be required to undertake this fitness test and compete in a match environment. On both occasions Heart Rate data will be collected continually through use of Heart Rate Monitors. Blood Lactate samples will be obtained at rest before both sessions, on conclusion of the match and after each component of the fitness test.

The fitness test is administered to assess individual capabilities in the following areas; speed agility, speed agility endurance, speed endurance and aerobic endurance. The estimated total testing time is twenty minutes.

It is important that participants perform the test at an intensity similar to that at which they participate in matches. Ideally subjects should aim for maximum exertion across the four tests; consequently they may experience mild discomfort, however should pay attention to the enclosed instructions in order to minimise this affect as much as possible.

Subjects have the right to withdraw at any time during the testing procedures. Should you wish to make a complaint please do not hesitate to contact me at the above details. Confidentiality will be observed at all times during the test and data will be stored in accordance to the 1984 Data Protection Act.

I _____ fully understand the demands of this assessment and do so of my own free will. Any questions I have regarding the procedures have been answered to my full satisfaction.

Signed (Subject): _____ Date: _____

Signed (Tester): _____ Date: _____

Pre-Test Guidelines

The following information has been provided to ensure subjects are able to complete the test to the best of their ability whilst avoiding any discomfort. It is not obligatory for participants to follow these guidelines however it is recommended in order to ensure subject safety during the testing and assisting in obtaining as accurate results as possible.

- It is recommended subjects wear loose-fitting, comfortable clothes similar to that worn in a match environment.
- Subjects should avoid consumption of large meals, alcohol, caffeine for at least three hours before the test is due to start. Alternatively a light carbohydrate snack some two hours prior to testing is recommended.
- It is also suggested that in the twenty four hours prior to testing, subjects maintain a healthy fluid intake to avoid dehydration.
- As far as possible, aim to avoid any strenuous exercise on the day of testing.

Field Testing Conditions and Considerations

- Testing in the Wet
    - Subjects are reminded to bring a change of clothing.
    - In order to accurately recreate a match environment, testing will only be postponed in extreme weather conditions such as snow, ice or waterlogged surfaces.

- Testing in the Heat
    - Subjects should bring plenty of fluids to consume post-test in order to restore any fluids lost during exercise.

Appendix 2

Pre-test Medical Questionnaire

Please complete the following questionnaire, should you have any queries do not hesitate to contact me at the above details. All information obtained will be treated as confidential in accordance with the Data Protection Act of 1984.

Please Tick the most appropriate answer;

- How would you describe your present level of activity?
    - Sedentary
    - Moderately Active
    - Active
    - Highly Active
- How would you describe your current level of fitness?
    - Unfit
    - Healthy
    - Moderately Fit
    - Highly Trained
- Smoking Habits
    - Non-Smoker
    - Previous Smoker
    - Occasional Smoker
    - Regular Smoker
        - Number per day: ____

- Alcohol Consumption
    - Non-Drinker
    - Occasional Drinker
    - Regular Drinker
    - >1 Drink a Day

- Have you consulted your doctor or sought medical advice in the past six months?
    - Yes
    - No
    - If yes please state reasons: _____
- Are you currently on medication?
    - Yes
    - No
    - If yes please give details: _____
- Do you currently, or have you previously, suffered from any of the following;
    - Diabetes
    - Asthma
    - Bronchitis
    - Heart Complaints
    - Other: _____
- Is there a history of heart disease in your family?
    - Yes
    - No
- To your knowledge, are there any reasons (e.g. Injury.) why you would not be able to successfully complete the tests that have been outlined to you?
    - Yes
    - No
    - If yes please state reasons:_____

Signed (Subject): _____ Date: _____

Signed (Tester): _____ Date: _____

Appendix 3

FIELD HOCKEY FITNESS TEST

Fitness Testing Protocols

1 – Combined test (*Speed-agility; speed-agility endurance; speed-endurance; aerobic endurance*)

Combined test protocol

- Work in pairs – resting person records times
- Testing co-ordinator on 'rolling clock'

Equipment needed:

- Cones for speed-agility testing (30 if testing 20 players)
- Measuring tape

NAME:				
COMPONENT	**ROLLING CLOCK START TIME**	**TEST**	**TIME**	**BLA**
SPEED AGILITY	0 MINS	5-10-15M SHUTTLE	1.	1.
SPEED AGILITY ENDURANCE	30 SEC	5-10-15 SHUTTLE	1.	2.
	1 MIN	5-10-15 SHUTTLE	2.	
	1 MIN 30	5-10-15 SHUTTLE	3.	
SPEED ENDURANCE	5 MIN	25-50 SPRINT SHUTTLE	1.	3.
	6 MIN 30	25-50 SPRINT SHUTTLE	2.	
	8 MIN	25-50 SPRINT SHUTTLE	3.	
	9 MIN 30	25-50 SPRINT SHUTTLE	4.	
AEROBIC ENDURANCE	13 MIN	1000 YD DOGGY	1.	4.
		(Out and back to all lines) x 2		

Expected total testing time: Approx 17 minutes (for the pair 40 minutes – which allows for a transition between being tested to becoming recording partner of 5 minutes)