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DOES AEROBIC FITNESS OR REPEATED SPRINT ABILITY FITNESS INFLUENCE CONTRIBUTION TO PLAY, IN FEMALE UNIVERSITY HOCKEY PLAYERS? ARE THE FITNESS TESTS USED VALID METHODS OF ASSESSMENT?

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Abstract:

The aim of the study was to examine whether aerobic fitness or repeated sprint ability was related to match performance. During the competitive season, twelve UWIC university hockey players, from within the three squads, completed a multi-stage fitness test and two trials of a repeated sprint ability test (10 x 40m on 40 s). These tests are used in hockey, but whether these aspects of fitness relate to match performance is unclear. Match performance was then quantified during fixtures, in real time using the Power system (P.O'Donoghue). Each participant was analysed for a 35 minute duration, of which they were involved on the pitch. The selected measures considered most representative of either test or match performance, were performance level and shuttles achieved for the multi-stage fitness test, average and maximum sprint times (s) plus fatigue index (%) for the repeated sprint tests and percentage of time spent at either low of high intensity to represent match performance.

The results indicated only statistically non-significant correlations between the test results and match-related performance. The correlations between the multi-stage fitness test performance and the % of time spent at low and high intensity were ($P = 0.527$). The correlations between the results of the repeated sprint tests and the % of time spent at low and high intensity were, for average sprint time (s) ($P = 0.208$), for maximum sprint time (s) ($P = 0.80$) and for fatigue % ($P = 0.602$). There were also only statistically non-significant correlations between the level of performance achieved in the multi-stage fitness test and the results from the repeated sprint tests. The correlations between the multi-stage fitness test performance and average sprint time, maximum sprint time and fatigue % were ($P = 0.570$, $P = 0.421$, $P = 0.419$) respectively. In conclusion, this investigation provides no support to the validity of the multi-stage fitness test or repeated sprint test in relation to match performance in female university hockey players.

CHAPTER I

INTRODUCTION

Aim of Research

Field hockey is a team invasion game, with two teams each consisting of 11 players. It is characterised like other team games, such as football and rugby, by an intermittent activity profile (Duthie *et al.,* 2005; Mitchell-Taverner, 2005). Players are therefore required to have an expansive range of abilities and skills, and be capable of maintaining both of these, whilst performing constantly changing movement patterns, throughout a 70 minute match duration (Reilly & Borrie, 1992; Mitchell-Taverner, 2005). Players are required to produce-reproduce maximal sprints of short durations (1-7s), followed by short recovery periods, over the extended 70 minutes which imposes substantial physiological demands (Bishop *et al.,* 2001, 2003). Although physical size is unrelated to success in hockey, a successful player does need quick and skilful execution of technique (Anders, 1999), confirming the need for both aerobic and anaerobic fitness.

The game itself has undergone major modifications in recent years; the transfer from grass to artificial turf has changed the pace, style and to some extent the technical execution of some skills (Reilly & Borrie, 1992; Spencer *et al.* 2004). There have also been two fundamental rule changes, the removal of offside and the allowance of unlimited rolling substitutions (Spencer *et al.* 2004). These changes have significantly altered the physiological demands of the game, with greater total distances being covered and higher intensities being maintained (Spencer *et al.* 2004; Coutts, 2005). As a result of this, at present there is a gap in the knowledge with relation to the physiological demands of the current game. This also

emphasises the need to establish whether fitness tests used within hockey, such as the multi-stage fitness test (MSFT) and variations of repeated sprint tests (RSTs), give valid indications of potential match performance (Lothian & Farrally, 1994; Spencer *et al.,* 2005).

The quality and validity of the assessment procedures used to assess physiological performance indicators need to be considered. Two fundamental fitness prerequisites essential for a player are repeated sprint ability (RSA) and aerobic fitness (Reilly & Thomas, 1976; Reilly & Borrie, 1992; Dawson *et al.,* 1993). Examination of the assessment tests for these variables is critical in determining whether or not the tests are valid indicators of match performance. Whether the fitness aspects being measured relate to match performance is at present uncertain.

If the tests are found to be valid, then the results can be useful within hockey to assess an individual in terms of their performance. This will allow us to identify players' strengths and weaknesses, which can then be used within goal setting, aid the selection process, to monitor progression/regression and to monitor the effectiveness of implementing a specific training programme (Marrow *et al.,* 2005). If the tests are found to be invalid, or the aspects of fitness not relate to match performance, then this demonstrates the need for further test development/alteration or the construction of alterative tests. It also prevents invalid results being used and applied, which could be highly detrimental.

RSA is defined as the ability to perform repeated sprints with minimal recovery between the end of one sprint and the beginning of the next (Spencer *et al.,* 2005). Many, such as Bishop and others (2001, 2003), and Spencer and co workers (2004), now consider RSA an integral fitness prerequisite of team sport performance. It is apparent that the anaerobic ATP production required to enable repeated sprint activity to occur, is provided by contributions from the PCr degradation, anaerobic glycolysis and aerobic system (Wilmore & Costill, 2004; McArdle *et al.,* 2006). Each systems contribution is determined and altered in accordance with the duration, frequency and recovery time between sprints.

The ATP-PCr system is the predominant energy pathway utilised when performing high-intensity / short-duration activities (Wilmore & Costill, 2004). It is therefore important that hockey players have an efficient ATP-PCr system. The fact that PCr stores are only partially depleted during repeated sprint bouts indicates the importance of anaerobic glycolysis as an energy pathway used by hockey players. The rate of PCr degradation also appears to be directly related to training status, although this has not yet been researched in team sport participants (Bishop *et al.,* 2003; Wilmore & Costill, 2004). The performance of subsequent sprints uses an increased contribution from the aerobic system and this reliance increases as the frequency of the sprinting intensifies (Spencer, *et al.,* 2005).

RSA and its testing are still relatively new concepts, and subsequently there is limited research that has examined the reliability and validity of RSA as a performance indicator in terms of its relation to match performance, or critiqued the procedural assessment methods.

Maximal oxygen uptake ($\dot{V}O_{2max}$) is suggested by Shephard, (1994) to be a universal measure of aerobic fitness. $\dot{V}O_{2max}$ is defined as "the global outcome of the rate at which the body can extract oxygen from the atmosphere via the cardiopulmonary system, transport it via the cardiovascular system and use it in skeletal muscle" (The British Association of Sport and Exercise Science, 2007). With reference to aerobic fitness relating to the performance of repeated sprints, it has been highlighted as essential in aiding recovery between sprints and enabling consistency in sprint performance (Impellizzeri *et al.,* 2005). Aerobic fitness in terms of match performance is predominant in ATP production, due to the prolonged duration of the match (Aziz *et al.,* 2000).

Coutts, (2005) stated that hockey, along with other team sports, requires participants to be capable of covering large distances as well as performing maximal bouts of high intensity work. Previous research in this area has shown that a large percentage of match time and distance covered is spent performing low intensity activity, which is entirely dependant on aerobic metabolism (Reilly & Gilbourne, 2003), suggesting that the aerobic system makes the largest contribution to energy delivery out of all the metabolic systems. In agreement with this, the game has been classified as having a

larger aerobic component (60%) than anaerobic component (40%) in terms of the energy continuum, although still highlighting the combined contributions of all the metabolic systems (Sharkey, 1986).

In addition to the combined contribution of the energy systems, performers who are capable of tolerating high levels of lactic acid, have an increased rate of PC resynthesis. This enables them to maintain higher levels of performance for longer durations (covering greater distances and maintaining higher intensities) (Spencer, 2005). Furthermore, high aerobic fitness has been shown to improve recovery between intermittent high intensity activities in soccer. Movement patterns in soccer are similar to those exhibited in hockey, and therefore the findings could also be applied to hockey (Tomlin & Wenger, 2001; Impellizzeri *et al.,* 2005).

Time-motion and notational analyses are key tools in the efforts to provide evidence to allow the quantification of work done and contribution to play. Without these it would not be possible to calculate the energy demands placed upon the body in a match situation (Spencer *et al.,* 2005).

Limited information currently exists about the movement patterns of hockey players (Spencer *et al.,* 2004). Also, due to the changes that have occurred, research with reference to physiological demands and time-motion, is dated and may not be highly relevant or valid in terms of the current game. However, other sport's especially football/soccer has an extensive research base, with many conducted studies (Mayhew & Wenger, 1985; Bangsbo *et*

al., 1991; Mohr *et al.,* 2003; Rampinini *et al.,* 2007). The extent of the football/soccer research clearly highlights the need for further research to be undertaken within hockey.

Therefore, due to all the afore mentioned reasons RSA fitness and aerobic fitness are worth investigating, because the information generated will address the question as to whether or not the aspects of fitness being assessed relate to match performance. Additionally, it will evaluate the validity of the two tests procedures being used and examine to an extent the physiological requirements of hockey.

This investigation will hopefully expand upon previous research in both the fields of sports physiology and notational analysis, examining and critiquing both assessment methods and physiological demands and their influence upon performance.

Statement of Research Questions

In this study the specific research questions going to be investigated are; does aerobic fitness, or RSA fitness, influence contribution to play in female university hockey players? Together with, are the fitness tests valid methods of assessing specific forms of fitness, in the context of invasion games players (hockey)?

CHAPTER III

METHODOLOGY

The data collected was quantitative, and came directly from the results of the fitness tests and the results of the notational match analysis. All of the data were numerical.

Participants

The sample group consisted of 12 female out-field players, all of whom had represented one of the three University of Wales, Institute Cardiff (UWIC) hockey squads. Before recruiting any participants for the study, ethical approval had to be obtained, from the UWIC University Research Ethics Committee (UREC), for the procedures that were involved. Prior to testing all participants were given pre-exercise questionnaires (PAR-Q), to ensure they were able to fully participate in the investigation. They were then informed of the protocol and requirements of the testing, before being asked to sign a form of informed consent formalising and completing their recruitment. (see appendix) Participants were asked to wear astro turf shoes for all of the tests, not only allowing a closer simulation to match conditions, but removing footwear as a possible performance variable, whilst also aiding safety because of the extra grip provided.

Procedures

The aim of the investigation was to examine aerobic fitness and repeated sprint fitness in relation to match performance. Both, aerobic fitness and repeated sprint fitness tests are used within hockey, but whether these aspects of fitness relate to match performance is unclear. The investigation also allowed the validity of the fitness tests to be examined. The investigation

involved each participant performing a multi-stage fitness test (MSFT) (National Coaching Foundation, 1998), two repeated sprint tests (RSTs) (10x40m on 40 seconds) and notational analysis occurring during a competitive match. Heart rate (HR) was recorded throughout.

Multi-Stage Fitness Test (MSFT)

A standardised warm up took place, involving a two-lap jog around the hockey pitch, followed by appropriate static stretches (see appendix).

The MSFT test area was set up on the pitch, prior to the test commencing. Using the side line, 20m was measured using a tape measure and four cones laid in a straight line parallel to the side line. This formed the shuttle distance. The participants were then instructed to listen to the instructions contained on the CD, which stated the need to adhere to the audio cues provided to maintain the correct speed. It also stated that once a participant failed to meet two consecutive shuttles within the defined time, they were disqualified.

The test had 23 levels, each lasting one minute. The test began with an initial running speed of $8.5kmh^{-1}$, and this increased at a rate of $0.5kmh^{-1}$ with each increase in level. Progression from one level to the next was signaled by 3 rapid beeps. Subjects were given verbal encouragement to run to volitional exhaustion, completing as many shuttles as they could, but continuing to turn on the lines in time with the beeps. Results were recorded as a stage level

and shuttle number, at the point where either voluntary withdrawal or disqualification occurred.

Results obtained from the test and used in subsequent analysis included, the level and shuttle number reached, maximum HR and calculated from this, 85% of maximum HR (max HR / 100) x 85).

Repeated Sprint Tests (RSTs)

A standardised warm up took place, involving a two-lap jog around the hockey pitch, followed by appropriate static stretches. The RSTs involved the use of the Smart Speed System (SSS) (Fusion Sport, Australia).

The repeated sprint test area was set up on the pitch, prior to the test commencing. Using the 25m line, 40m was measured using a tape measure at which two SSS tripods were located parallel to those that were placed on the 25m line, at a 1.5m distance between one another. Each end of the 40m lane consisted of a tripod with a reflector on, and another with a sensory unit. This formed the 40m sprinting distance.

The participants were then instructed to perform 10 sprints, commencing on 40 seconds. They were to go in accordance with the visual prompts provided - 2 Green flashes followed by a sustained green light, which they had to break to maintain the correct timing. In addition to this, verbal communication was also given in terms of a count down from five seconds (using the SSS handsets timer), to aid the accuracy of the timing.

Participants were permitted to be passive or active during their recovery between sprints; they were to remain at the end of the lane where they had finished their last sprint, resulting in the alternating of direction. Five seconds prior to performing the subsequent sprint they stood back from the tripods in the ready position (standing start). Subjects were given verbal encouragement to run at maximum speed and to complete the 10 sprints. Results were recorded automatically from the sensory units to the SSS handset. These were then downloaded and transferred into an excel spreadsheet. The test was performed twice (two trials) to increase the reliability of the results.

Results obtained from the tests and used in subsequent analysis included, maximum and minimum sprint times from both trials. Average sprint time, fatigue % ((slowest sprint - fastest sprint) / fastest sprint time) x 100) and HR were calculated using the averages from both trials.

During both the MSFT and the RSTs tests HR was also recorded at five second intervals using Polar S610 heart rate monitors (Polar Electro Oy, Finland); this enabled a heart rate trace for each participant to be obtained.

Notational Analysis

Pilot study:

One match was video recorded, the camera (Panasonic NV-GS75) was positioned away from the pitch on a tripod, at an elevation of 8m in order to maximise the field of view, but maintain easy identification of the player being analysed.

The video was then taken and an inter-reliability test was performed on a 20 minute period; using the same five movement category approach as Spencer *et al.,* (2004). The results showed that a more simplified approach was required. Defining the 5 movement categories (standing, walking, jogging, striding and sprinting) and the boundaries when the movements changed category resulted in multiple discrepancies and inaccuracies. A second inter-reliability study was then performed; this showed the classifications of either low or high intensity activity, was far more suitable and produced more accurate and reliable results (see appendix).

The decision was also made that video analysis was more complex and gained additional information than was required; the data could be immediately notated (in action – real time) into P.O'Donoghue's Power System.

Main study:

Each of the 12 players were then analysed during a competitive match for 35 minutes, using the Power System adopting the low or high intensity approach. Results obtained from the notation and used in subsequent analysis included, the % time spent at low and high intensity, frequencies of both high and low intensity bouts, mean durations of high and low intensity bouts. These were all automatically produced by the Power system. In addition, duration and the percentage of the time spent at 85% or above, maximum HR was also calculated.

Heart Rates

HR for each participant was recorded at five second intervals throughout the match duration, using Polar S610 heart rate monitors. The notational data and HR monitors were synchronised using a Casio stopwatch. This allowed HR values and notational data, collected whilst the participants were not playing, to be removed (Half time, post match and whilst the participant was being a substitute).

Each participant ended up with 35 minutes 40 seconds of active match time HR data, due to 35 minutes being the designated notation time as it is representative of half a match. The 40 seconds allowed for any delays or errors in operating the recording of the data or its synchronisation.

Statistical Analysis

As mentioned previously, the aim of the investigation was to examine whether aerobic fitness and/or repeated sprint ability relates to match performance. The Statistical Package for Social Sciences (SPSS 12.0 for windows) was used for the statistical analysis of this investigation. The Shapiro-Wilk test was conducted to evaluate the normality of the results obtained. If the sig. value of the test was ≤ 0.05 then the data is normally distributed making it parametric, however if the value was ≥ 0.05 then the data is not normally distributed and is non-parametric. For the parametric variables Pearson's product moment correlation coefficient was used, to quantify the relationships between the test results and results from the match analysis, with Spearman's rho test being conducted for the non-parametric variables. Significance was accepted at $P < 0.05$.

CHAPTER IV

RESULTS

Multi Stage Fitness Test (MSFT)

The mean level of performance achieved in MSFT was 8.7 ± 1.8 (range: 6.1 – 11.7 level-shuttles), with an average and maximum HR of 163 ± 5 bpm and 192 ± 5 bpm respectively (range: 148-189 bpm; 183-201 bpm). 85% of maximum HR was calculated at 163 ± 5 bpm.

Repeated Sprint Tests (RSTs)

The mean and standard deviations (SD) for the test results are displayed below in table 1.

Table 1. Mean and SD of the performance variables from the two trials of RSTs

	Mean ± SD
Minimum Sprint Time (s)	6.41 ± 0.34
Maximum Sprint Time (s)	7.30 ± 0.51
Average Sprint Time (s)	6.83 ± 0.33
Fatigue (%)	10.60 ± 3.78
Average HR (bpm)	152 ± 7
Max HR (bpm)	182 ± 8

Match-related results

The mean percentage of time spent at low intensity was 94.17 ± 2.70 % (range: 88.92 – 96.97%), with the mean percentage of time spent at high intensity being 5.83 ± 2.70 % (range: 3.03 – 11.08%), resulting in an approximate 1:16 high intensity to low intensity ratio. Mean average match HR was 167 ± 12 bpm (range: 148-189 bpm) with a mean maximum match HR of 190 ± 8 bpm (range: 186-202).

The mean duration of match time spent ≥ 85% maximum HR was 1405 ± 562.29 s which equates to 23 minutes, 25 seconds (range: 480-2130 s). The mean percentage of match time which was proportional to this time was 65.65% ± 26.28% (range: 22.43 – 99.53%). Table 2 below displays the results from the notational analysis, with reference to the frequencies, duration and the % of match time spent performing either low or high intensity activity.

Table 2. Frequency and duration of motions during the field hockey game (mean ± SD)

	Low Intensity	High Intensity
Frequency (n)	34 ± 10	33 ± 10
Duration (s)	57.76 ± 3.94	19.18 ± 1.42
Match time (%)	94.14 ± 5.83	2.67 ± 2.70

Relationships between fitness tests and match performance

There were only statistically non-significant correlations between the fitness test results and the match-related results. The following variables were selected as they were considered to be most representative of the test and match performances. For the MSFT it was performance level and shuttles achieved, average and maximum sprint times (s) plus fatigue index (%) were elected to represent the RSTs results, with the % of time spent performing low and high intensity activity chosen to represent match performance.

The correlations between the MSFT performance result (level-shuttle) and the % of time spent at low and high intensity were (r = -0.203 P = 0.527; r = 0.203 P = 0.527) respectively. The correlations between average sprint time (s) and the % of time spent at low and high intensity were (r = 0.392 P =

0.208; r -0.392 P = 0.208), with the correlations between maximum sprint time (s) and the % of time spent at low and high intensity being (r = 0.525 P = 0.80; r = -0.525 P = 0.80). The correlations between fatigue % and the % of time spent at low and high intensity were (r = 0.168 P = 0.602; r= -0.168 P = 0.602).

Figures 1, 2 and 3 display three of the relationships, which have statistically non-significant correlations, but are crucial to answering the question of whether or not the fitness tests relate to match performance. (See appendix for additional graphs of non-significant correlation)
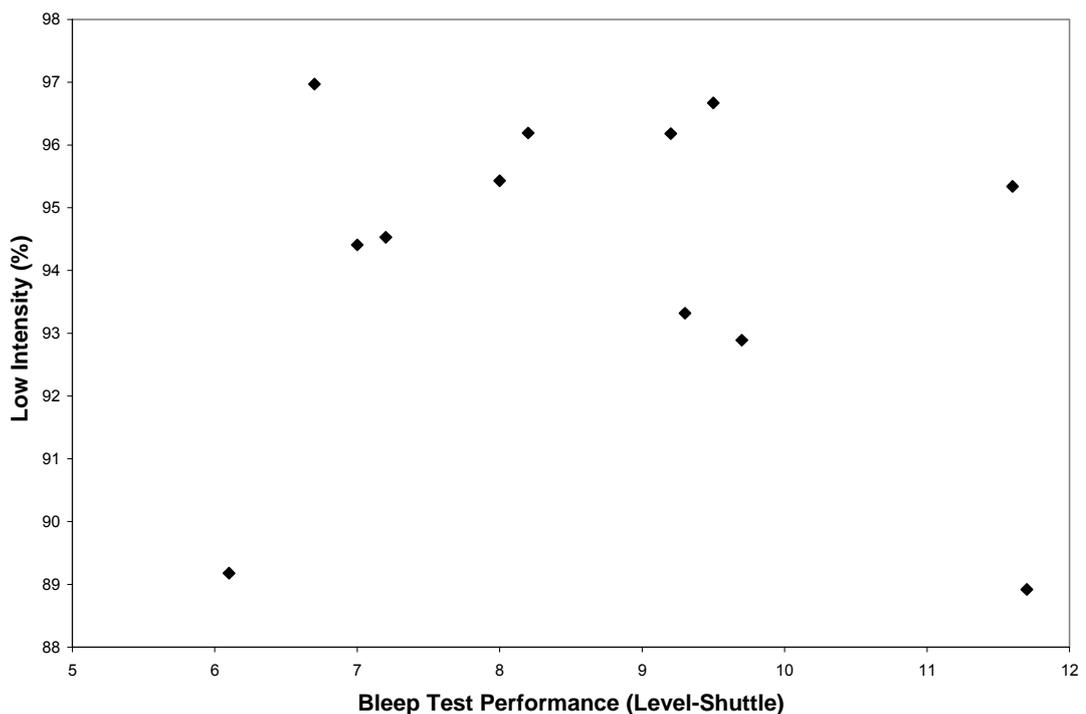
Figure 1. Scatter plot of the correlation between the MSFT performance (Level-shuttle) and % of match time spent in low intensity activity (r = -0.203 P = 0.527)
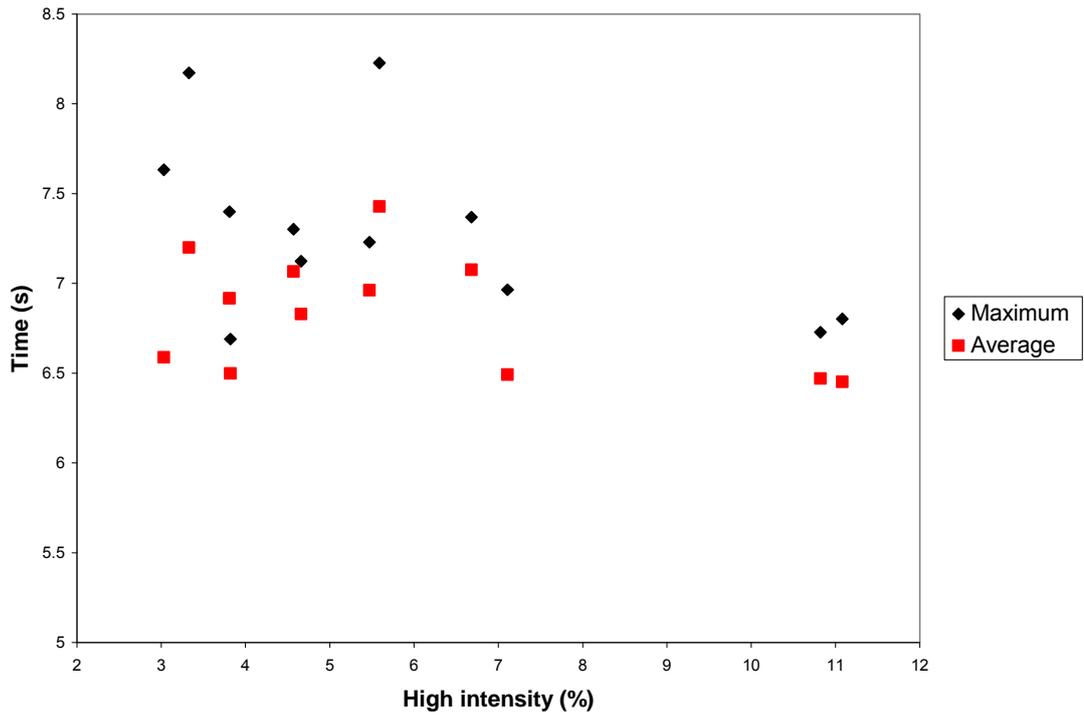
Figure 2. Scatter plot of the correlation between maximum and average sprint times (s) and % of match time spent in high intensity activity (r = -0.525 P = 0.80; r -0.392 P = 0.208)
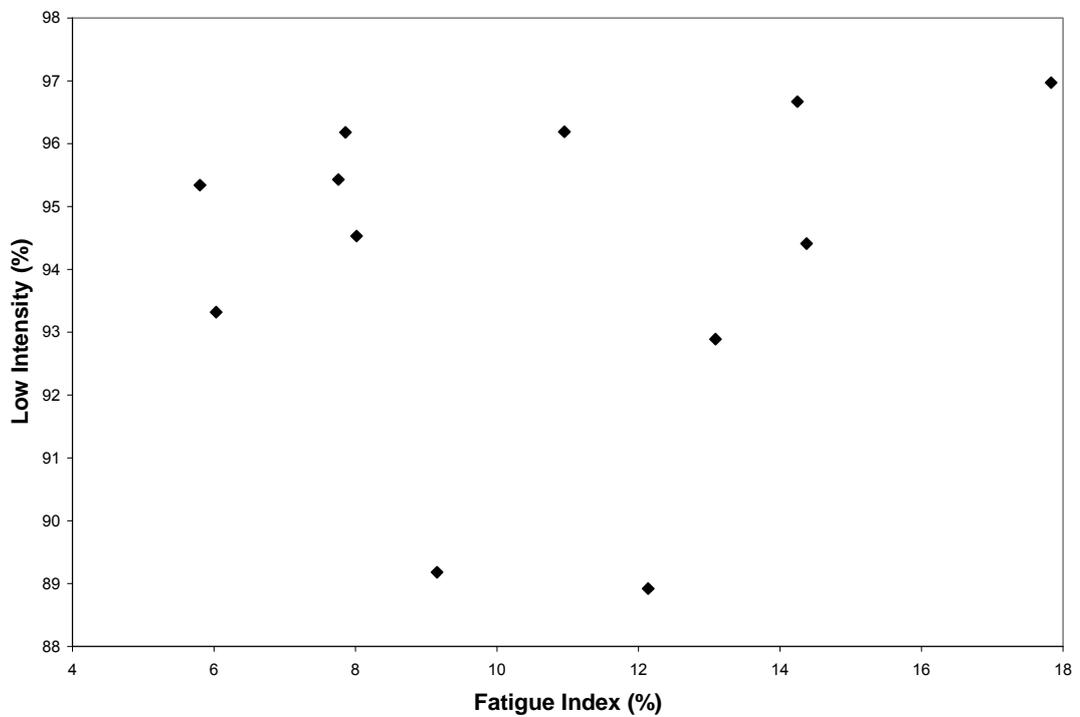
Figure 3. Scatter plot of the correlation between the fatigue index (%) and % of match time spent in low intensity activity (r = 0.168 P = 0.602)

Relationship between fitness tests results

There were also only statistically non-significant correlations between the level of performance achieved in the MSFT (level-shuttles) and the results obtained during the RSTs. The correlations between level of performance achieved in the MSFT with average sprint time, maximum sprint time and fatigue % were ($r = -0.183$, $P = 0.570$), ($r = -0.256$, $P = 0.421$) ($r = -0.258$, $p = 0.419$) respectively.

CHAPTER VI

CONCLUSION

Findings

The main finding of this investigation was the establishment of statistically non-significant correlations between the test results and match-related performance. This infers neither aerobic fitness nor RSA are related to match performance, however, these concepts are more complicated than this. The results more accurately reflect no support being provided, with reference to the validity of the MSFT or the RST in relation to match performance, in female university hockey players. Interestingly, there were also only non-significant correlations discovered between the variables of the MSFT and those of the RSTs, suggesting that these tests assess entirely different components of fitness.

Limitations and Delimitations

There were several limitations to this investigation, the most influential being the small sample size (n = 12). Therefore, the influence of climate, playing surface, significance of the match and the opposition may have impacted upon the results (Coutts *et al.,* 2003). The sample was homogenous with reference to gender age and sport, containing only females, aged between 19 and 22 years who played hockey, reducing its ability to be generalised to a wider population.

Participants were fully explained to about the test procedures for both the MSFT and the RSTs, however, familiarisation sessions or practice attempts prior to the recorded tests, may have further improved the accuracy of the results obtained. Familiarisation would have eliminated the aspect of the

performance being influenced by the participant's ability to perform in an unknown situation (Weinberg & Gould, 2003). The MSFT and two RSTs were conducted on separate days, meaning climatic conditions and psychological state of the participants could have influenced the results. The recovery between sprints in the RSTs was not standardised, allowing any variation in recovery to be adopted by the participants, which may have also had an influential affect on performance.

Another notable limitation of the investigation was each participant was only notational analysed for a 35 minute duration, which is equivalent to only half a match. Some participants were notated during the first half of a match, with others being notated during the second half. However the results have been used to make inferences in terms of a complete match, which may not provide a true representation of match performance.

Future Recommendations

From observing the limitations mentioned in the previous section, many recommendations can be made to enhance a repeat of this investigation, or for further investigations in the future. In terms of the sample, a larger sample size is vital in increasing reliability and allowing confirmation of findings. A sample containing both females and males, with players of different ages, abilities (recreational, non-elite and elite) and positions would provide greater scope, increasing the ability of the results to be generalised to a wider population.

With reference to the MSFT and the RSTs, familiarisation sessions or practice attempts should be incorporated into the warm-up period prior to final testing (Spencer *et al.,* 2006). The tests should ideally be conducted as close together as possible, but allowing enough recovery, for fatigue not to become an affecting performance variable. Recovery between the sprints of the RSTs should be standardised, for example active recovery as found to be optimal by Spencer and others (2004), to eliminate it from being a potential affecting performance variable.

The notational analysis aspect of the investigation should be improved, either by having each participant being analysed for a longer duration (70 minute match duration), or each participant being analysed over several matches to eliminate the possible influences on a single sample of performance. Alternatively, applying both methods would further strengthen the reliability of the results. Another way to improve the notational analysis component of this investigation would have been to gain further information such as density of repeated sprints, mean distance of sprints, total distance covered within the match. This additional information would then have provided a more detailed and accurate interpretation of match performance. Also, having more than one person analysing the match, would allow for intra-reliability tests to be performed, increasing the reliability of the results further.

Further research needs to be conducted using larger samples to give a better representation of the population being studied. The main focus should be placed upon test performance and match performance in relation to one another. The relative importance of RSA to match performance also needs to be explored further.

CHAPTER VII

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APPENDICES

APPENDIX TABLE OF CONTENT

APPENDIX A

Informed Consent Form Example

Dear Subject,

I am a Level 3 undergraduate student in the School of Sport, PE, & Recreation, at the University of Wales Institute Cardiff. I am doing a dissertation on how fitness relates to performance in hockey and wonder if you would be kind enough to help with my research. The research aims to discover whether or not there is a link between fitness levels of players and the contribution to play they make in a game situation.

As a subject, you will be asked to
- Complete the multi stage fitness test (bleep test) twice
- Complete a repeated sprint ability test (10x40m sprints, on 40 seconds) twice
- Be willing to be videoed whilst playing a match.
  You will be asked to wear a heart rate monitor throughout all the procedures, including whilst playing the match although this will not interfere with play at all.

The research might prove beneficial since a greater knowledge about this area could influence training, selection, youth development and coaching of the game.

The only risk of participation is the minor one that you may experience fatigue once you have completed the fitness tests. This risk will be minimised by ensuring you are fully fit, free from illness and injury and hydrated before beginning the test. That you cool down and rehydrate yourselves once you have finished the test, to prevent dehydration and injury.

Participation is entirely voluntary. You are free to withdraw at any stage of the research process.

Confidentiality will be upheld as far as is humanly possible. Your name will not appear anywhere at any time, and the features cited are only those relevant to the research. During the research process, the data will be kept secure. Access will be restricted to you, the principal investigator (me) and my supervisor. The final dissertation will be kept by the principal investigator and UWIC. Access will be restricted to uwic staff only, unless placed within the library stores.

If you are willing to participate, then please read the slip below/overleaf carefully, and sign. If you have any queries, do not hesitate to contact me.

Thank you.

Miss Caroline Bickerstaff

I have read and fully understood the request to be a subject of Miss Caroline Bickerstaff's research. I understand what I have to do. I understand the risks involved, and the measures in place in the event of accident. I understand that participation is entirely voluntary, and that withdrawal is possible at any time. I understand the measures that will be taken to uphold confidentiality as far as possible.

I agree to participate.

Signature   **Date**

APPENDIX B

Static Warm-up Stretches

Some examples of those stretches which were adopted prior to commencing the MSFT and the RSTs.

Stretches for the neck:

1. Sit or stand with arms hanging loosely at sides
2. Turn head to one side, then the other
3. Hold for 5 seconds, each side.
4. Repeat 1 to 3 times

1. Sit or stand with arms hanging loosely at sides
2. Tilt head sideways, first one side then the other
3. Hold for 5 seconds
4. Repeat 1-3 times

1. Sit or stand with arms hanging loosely at sides
2. Gently tilt head forward to stretch back of neck
3. Hold 5 seconds, repeat 1-3 times

Stretches side of shoulder and back of upper arm

1. Stand or sit and place right hand on left shoulder
2. With left hand, pull right elbow across chest toward left shoulder and hold 10 to 15 seconds and repeat on other side

Stretches shoulder, middle back, arms, hands, fingers, wrist

1. Interlace fingers and turn palms out
2. Extend arms in front at shoulder height
3. Hold 10 to 20 seconds, relax, and repeat

Stretches triceps, top of shoulders, waist

1. Keep knees slightly flexed
2. Stand or sit with arms overhead
3. Hold elbow with hand of opposite arm
4. Pull elbow behind head gently as you slowly lean to side until mild stretch is felt
5. Hold 10 to 15 seconds and repeat on other side

Stretches middle back

1. Stand with hands on hips
2. Gently twist torso at waist until stretch is felt
3. Hold 10 to 15 seconds
4. Repeat on other side
5. Keep knees slightly flexed

Stretches ankles

1. Stand and hold onto something for balance
2. Lift right foot and rotate foot and ankle 8 to 10 times clockwise, then 8 to 10 times
3. Counter clockwise and repeat on other sid

Stretches calf

1. Stand a little way from wall and lean on it with forearms, head resting on hands
2. Place right foot in front of you, leg bent, left leg straight behind you
3. Slowly move hips forward until you feel stretch in calf of left leg
4. Keep left heel flat and toes pointed straight ahead
5. Hold easy stretch 10 to 20 seconds
6. Do not bounce, repeat on both sides

Stretches front on thigh (quadriceps)

1. Stand a little a way from wall and place left hand on wall for support
2. Standing straight, grasp top of left foot with right hand
3. Pull heel toward buttock
4. hold 10 to 20 seconds, repeat on other side

Stretches inner thigh, groin

1. Stand with feet pointed straight ahead, a little more than shoulder-width apart
2. Bend right knee slightly and move left hip downward toward right knee
3. Hold 10 to 15 seconds
4. Repeat on other side

Stretches side of hip, hamstrings

1. Sit on floor with right leg straight out in front
2. Bend left leg, cross left foot over, place outside right knee
3. Pull left knee across body toward opposite shoulder
4. Hold 10 to 20 seconds, repeat on other side

Stretches lower back, side of hip, and neck

1. Sit on floor with left leg straight out in front
2. Bend right leg, cross right foot over, place outside left knee
3. Bend left elbow and rest it outside right knee
4. Place right hand behind hips on floor
5. Turn head over right shoulder, rotate upper body right
6. Hold 10 to 15 seconds, repeat again on other side

Stretches back of leg and lower back

1. Sit on floor, legs straight out at sides
2. Bend left leg in at knee
3. Slowly bend forward from hips toward foot of straight leg until you feel slight stretch
4. Do no dip head forward at start of stretch
5. Hold this developmental stretch 10 to 20 seconds
6. Repeat on other side
7. Foot of straight leg upright, ankles and toes relaxed

Descriptions provided from www.womensheartfoundation.org

APPENDIX C

Inter-Reliability Study:

Study 1:

A 20 minute section of video was taken and notated using the P.O'Donoghue's Power System, two different individuals (analysts) performed the testing on separate occasions in isolation. This tested the inter-reliability of the notational system being adopted for this investigation.

The first time the video was notated a system using 5 movement categories was adopted. The operational definitions used to define these movements were those used by Spencer *et al.,* (2004).

1. Standing – Motionless
2. Walking – Motion, but with both feet in contact with the ground at the same time at some point during the *gait* cycle.
3. Jogging – Motion with an airbourne phase, but with low knee lift.
4. Striding – Vigorous motion with airbourne phase, higher knee lift than jogging (included skirmishing movements of rapid changes of motion, forwards/backwards/laterally).
5. Sprinting – Maximal effort with a greater extension of the lower leg during forward swing and a higher heel lift relative the striding.

Results:

Table 1. Frequency, mean duration and % of match time, for each of the 5 movement categories produced by the Power system for each analyst.

Movement Category	Frequency		Mean Duration (s)		% of Match Time	
Analyst 1 or 2	1	2	1	2	1	2
Standing	34	32	2.47	3.53	8.57	8.71
Walking	63	63	11.65	14.36	71.21	69.83
Jogging	42	45	3.82	3.24	11.85	11.26
Striding	21	34	1.5	1.97	5.18	6.16
Sprinting	8	16	3	4.09	3.18	5.05

The next stage of the process was to calculate the percentage error for each of the variables. This was done by taking the results from analyst two away from the results produced by analyst one. Then dividing by analyst one's

result and then times by 100 (A1-A2)/A1x100). For example for frequency (n) when standing (34-32)/34*100). Table 2 below contains the percentage errors for each of the variables.

Table 2. Percentage errors for frequency, mean duration and % of match time at each of the 5 movement categories

Movement Category	Frequency	Mean Duration (s)	% of Match Time
Standing	6	43	2
Walking	0	23	2
Jogging	7	15	5
Striding	62	31	19
Sprinting	100	36	59

Conclusion:

The results illustrate the system is significantly unreliable with %errors of over 40% contained within all the variables. Frequency errors are clearly largest within the striding and sprinting categories, with percentage errors of 62 and 100% respectively. Percentage errors within mean durations cover the whole spectrum of movement, with the largest errors being in the walking (43%) and sprinting (36%) categories. The most representative figure in terms of match performance is that of % of match time, with a 59%error within the sprint category, this is clearly too high to be acceptable.

Study 2:

The video was then analysed a second time, but was notated adopting a system distinguishing the difference between simply high and low intensity activity. This involved the grouping of standing, walking and jogging as the low intensity category, with striding and sprinting forming the category of high intensity movement. The 20 minute clip of video was different to the one from the first analysis, to eliminate either analyst experiencing a learning affect.

Results:

Table 3. Frequency, mean duration and % of match time, at either low or high intensity produced by the Power system for each analyst.

	Frequency		Mean Duration (s)		% of Match Time	
Analyst 1 or 2	1	2	1	2	1	2
Low intensity	22	20	55.09	55.97	93.64	92.7
High intensity	21	19	4.19	4.34	6.86	7.3

Yet again percentage error for each of the variables was calculated, in exactly the same way as was done in study one.

Table 4. Percentage errors for frequency, mean duration and % of match time at either low or high intensity

	Frequency	Mean Duration (s)	% of Match Time
Low intensity	10	2	1
High intensity	10	4	6

Conclusion:

The %error for frequency, mean duration and % of match time were all ≤10%, which makes the results produced by this notation system far more reliable to use, than those produced by the notation system adopted in study one. Also, due to the reduced frequency values compared to study one, minor discrepancies have a larger influence on %error than they would with larger frequency counts. Therefore, due to these results the system which will be adopted in the main investigation will be the notation system defined by either low or high intensity activity oppose to that of the one involving the five movement categories.

APPENDIX D

Raw Data: For the Multi-stage Fitness Test (MSFT) & the Repeated Sprint Tests.

Participants	MSFT Level	MSFT Max HR	MSFT 85% HR Max		Min Sprint Time (s)	Max Sprint Time (s)	Aver. Time (s) for BT	Aver. F % for BT	Max HR for BT	Aver. HR for BT
1	7	198	168		6.845	8.227	7.43	14.38	187	152
2	11.6	198	168		6.55	7.124	6.83	5.80	176	137
3	6.7	190	162		6.003	7.633	6.59	17.83	187	157
4	11.7	193	164		6.013	6.802	6.45	12.14	200	157
5	9.7	196	167		5.98	6.965	6.49	13.09	176	150
6	6.1	187	159		6.076	6.728	6.47	9.15	177	150
7	7.2	183	156		6.597	7.229	6.96	8.02	180	158
8	9.3	186	158		6.753	7.369	7.08	6.03	170	148
9	9.5	201	171		6.71	8.172	7.20	14.24	177	152
10	8.2	189	161		6.533	7.399	6.92	10.95	178	147
11	8	192	163		6.729	7.302	7.07	7.76	183	163
12	9.2	192	163		6.098	6.69	6.50	7.86	187	152
Mean	8.7	192	163		6.41	7.30	6.83	10.60	182	152
ST DEV	1.82	5.43	4.62		0.34	0.51	0.33	3.78	7.88	6.61

Aver. = Average / BT = Both Trials / F = Fatigue

Raw Data: For Match-Related Performance

Participants	LI %	HI %	Seconds	% of MatchTime	Freq. LI	Freq.HI	Mean Dur LI	Mean Dur HI	% LI	% HI	Aver. HR	Max HR
1	94.41	5.59	2130	99.53	47	46	40.72	2.83	94.41	5.59	188.9627	202
2	95.34	4.66	990	46.26	34	33	59.75	3.01	95.34	4.66	162.6364	190
3	96.97	3.03	480	22.43	28	27	73.49	2.38	96.67	3.03	148.4079	180
4	88.92	11.08	1505	70.33	44	43	42.77	5.46	88.92	11.08	169.5478	195
5	92.89	7.11	1630	76.17	31	30	52.18	3.16	92.89	7.11	171.0303	198
6	89.18	10.82	1665	77.80	21	20	36.26	4.62	89.18	10.82	169.9604	190
7	94.53	5.47	2065	96.50	41	40	41.98	4.07	94.53	5.47	177.9231	195
8	93.32	6.68	1045	48.83	22	21	90.11	6.76	93.32	6.68	156.7949	182
9	96.67	3.33	1975	92.29	24	23	84.52	3.03	96.67	3.33	181.2261	201
10	96.19	3.81	590	27.57	27	26	75.04	3.08	96.19	3.81	150.4802	179
11	95.43	4.57	1045	48.83	34	33	60.16	2.97	95.43	4.57	160.1748	186
12	96.18	3.82	1740	81.31	50	49	36.10	5.91	96.18	3.82	168.4429	186
Mean	94.17	5.83	1405	65.65	34	33	57.76	3.94	94.14	5.83	167	190
ST DEV	2.70	2.70	562.29	26.28	9.90	9.90	19.18	1.42	2.67	2.70	12.16	7.95

LI = Low Intensity / HI = High Intensity / Freq. = Frequency / Dur. = Duration / Aver. = Average.

APPENDIX E

Non-Significant Relationship Graphs