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JOHANNESBURG

THE RELATIONSHIPS OF ACTIVITY PATTERNS AND HEART RATE PROFILES WITH PHYSICAL PERFORMANCE TESTS IN PREMIER LEAGUE CLUB FIELD HOCKEY PLAYERS IN JOHANNESBURG

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A Dissertation Submitted to the Faculty of Health Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Medicine (MSc Med) in the field of Sport and Exercise Science.

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EXERCISE SCIENCE AND SPORTS MEDICINE
WITS

Johannesburg, 2018

Declaration

I Khavish Harry declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in Medicine in the field of Sport and Exercise Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

_____

_____day of_____20_____in_____

Presentations arising from this research project

University of the Witwatersrand (Wits) Peak Performance Summit hosted by Wits Sport – 24 November 2017

Abstract

Purpose: The physical match demands in field sports such as football are well known, yet the description of these demands during field hockey, as well as their relationship with fitness tests are limited, specifically at club level. Therefore, the aims of this study were to describe the physical match performance (activity and heart rate profiles) of field hockey players in the premier league, and to determine the relationships between fitness capacity and high intensity match activity (running and sprinting). **Methods:** Fitness and physical match performance data were collected from 27 male and 29 female participants over nine matches with each player tested on one to three occasions. Fitness tests performed were the Yo-Yo Intermittent Recovery Test Level One, submaximal heart rate recovery (at 10, 20, 30 and 60 seconds), and repeat sprint ability. **Results:** The percent of match time spent above 95% maximal heart rate decreased significantly in both males ($p < 0.01$) and females ($p < 0.05$) in the second half. In addition, the percent of playing time spent running and sprinting decreased significantly ($p < 0.01$) in the second half in males only. The Yo-Yo Intermittent Recovery Test Level One was significantly correlated to percent of playing time spent running during matches in females ($r= 0.54$, $p < 0.05$). Heart rate recovery (10s, 20s, 30s) was significantly correlated with percent of playing time spent sprinting during matches in females ($r= 0.73$, $p < 0.01$, $r= 0.53$, $p < 0.05$ and $r= 0.58$, $p < 0.05$) respectively. Furthermore, heart rate recovery (60s) was significantly correlated with percent of match playing time spent running in females ($r= 0.77$, $p < 0.01$). **Conclusion:** Both male and female club level field hockey players experience a high physiological stress during matches, and male players have a decrease in running and sprinting performance during the second half of competition. This information can be used to optimize training interventions. Additionally, fitness tests such as the submaximal heart rate recovery can be used to assess a player's capability to perform high intensity activity during matches. Such tests are less fatiguing than maximal tests and may be implemented as a field hockey specific fitness test at club level.

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NOMENCLATURE

VO2max: Maximal oxygen uptake

GPS: Global positioning system

HRmax: Heart rate maximum

PCr: Phosphocreatine

Milliliter per kilogram per minute: (ml·kg·min)

kg: Kilograms

KM·H: Kilometre per hour

Yo-Yo IR1 – Yo-Yo Intermittent Recovery Test Level One

RSA: Repeat sprint ability

ATP: Adenosine triphosphate

%: Percentage

s: Seconds

m: (Metre)

CV: Coefficient of variation

SWC: Smallest worthwhile change

ICC: Intra-class correlation

TE: Technical error

HRR: Heart rate recovery

VMU: Vector magnitude units

Hz: (Hertz)

(bpm): Beats per minute

vs: Versus

CHAPTER 1. INTRODUCTION

Field hockey is a sport which requires a high level of muscle strength, power, speed and aerobic fitness in order to be competitive (1). During a field hockey game, players are required to sustain high intensity intermittent activity over the 70-minute period and are reported to exercise at a high percentage of their maximal aerobic capacity (1). The ability to repeatedly perform sprints with minimal recovery during crucial moments of the game are vital and may result in a considerable supply of energy from the anaerobic pathway (1,9). In order to optimally prepare players for these intense demands, fitness testing and field side monitoring should be performed regularly to improve the specificity of training interventions and give a reasonable prediction of an athlete's physical match performance capability (2).

Match performance can be assessed by using various methods to analyse the physical, tactical and technical aspects of competition (2). For example, technology such as global positioning systems (GPS), accelerometers and heart rate devices have recently been used to record locomotor activity (such as walking, jogging, running and sprinting) and heart rate profiles to gain insight into the physical and physiological demands during team sport matches (3,4,6,8). Additionally, activity and heart rate data are commonly presented as a percentage of playing time spent within a specific intensity zone (i.e. low, moderate and high intensity) within a match to gain a more complete understanding of an individuals physical match demands (3,4,5,6,7,8,9). Studies on elite field hockey players have investigated the physical match demands, however, there is limited research reporting on activity patterns and heart rate profiles comparing first and second halves (3,8,9,47).

Research in team sport has suggested that for the precise measurement of heart rate during competition, heart rate recordings should be presented over two halves of a match to obtain detailed information relating to periods where players perform more intense exercise (4). In elite football and basketball, authors have reported a decrease in high intensity activity and time spent in high heart rate zones during the second half of matches, which could be related to fatigue or match tactics (5,16). Moreover, it has been suggested that competiting in team sports at the highest level is characterized by the athletes ability to perform high intensity work repeatedly which is a key factor in maintain involvement with the ball, which in turn may affect the match outcome (5). This highlights the importance of well-developed physical fitness of individuals competing in team sport.

Research suggests that better developed physical qualities may lead to greater physical match performance in team sport (16). Specifically, studies on elite male footballers have shown significant correlations between intermittent running tests (such as the Yo-Yo Intermittent Recovery Test Level One and repeat sprint ability) and high intensity activity during matches (5,46). Additionally, research in elite football has observed that male referees with a faster heart rate recovery during physical performance tests can maintain high intensity activity during competitive matches (14). In field hockey, researchers have determined the relationship between laboratory based fitness tests and physical performance by simulating movement patterns performed during matches (20). However, laboratory based testing requires the use of specialised equipment, highly trained personnel and may fail to replicate match specific activity (18,21). Therefore, there is a need to establish field hockey specific test protocols which are valid when assessing a players physical match preparedness.

Recently, there has been a growing interest to increase the competitive level of field hockey in South Africa. This can be seen through the introduction of the Premier Hockey League (PHL) over the past two years which aims to recruit the best players within the country to compete in a "semi-professional" league lasting four weeks. The emergence of such a competition warrants the need for better developed physical conditioning programmes in club level field hockey. Indeed, research in team sports has reported on the relationship between fitness tests and high intensity activity (10,13,19). However, there is limited information relating to fitness tests and high intensity activity, which is suggested to be of importance in field hockey (9,37). Therefore, determining the relationship between fitness tests and match activity may aid in the selection of field hockey test protocols and in identifying players that are able to maintain a higher level of physical performance during matches. In addition, the description of physical match demands are limited in field hockey, therefore , further research may assist to replicate the specificity of training intensities and improve preparation of field hockey players for competition.

1.2 Research Questions

Are there differences in activity patterns and heart rate profile between first and second half of premier league club field hockey matches?

Are there relationships between fitness tests and time spent in high intensity activity in premier league club field hockey players?

1.3 Aim

The aims of this study were firstly, to describe the physical match performance, and secondly, to determine the relationships between fitness tests and time spent in high intensity activity in premier league club field hockey players.

1.4 Objectives

1. Describe the activity patterns and heart rate profiles during matches in premier league club field hockey players.
2. Compare first and second half activity and heart rate profiles.
3. Determine the correlation of the Yo-Yo IR1, repeat sprint ability and heart rate recovery (at 10, 20, 30 and 60s) with time spent in high intensity activity in premier league club field hockey players.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The initial part of the literature review will provide an overview of field hockey and the physical characteristics of athletes involved in the sport. Thereafter, the core of the literature review will focus on activity and heart rate profiles during matches, as well as the relationship between match activity and fitness tests. Due to limited research in field hockey, research on other team sports (i.e. elite football and basketball) relating to the content of the study will also be included.

FIELD HOCKEY

2.2 Game format

Field hockey is a formal sport in both the Olympic and Commonwealth Games and is also contested for in a World Cup format. Field hockey is played by two teams of eleven players which include 10 outfield players and one goalkeeper. The pitch or hockey astro turf is rectangular (approximately 55m in width and 90m in length). A match normally consists of two halves of thirty-five-minutes each. The aim of the game is to hit the hockey ball with a specifically designed stick into the opponent's goal. A goal can only be allowed if the ball is struck by an attacking player inside the D (16-yard semi-circle around the goal). Moreover, penalty corners are a significant goal scoring opportunity awarded for infringements by opposition players inside the D. Playing positions can be categorised into: Goalkeepers, defenders, fullbacks, midfielders, inside forwards and strikers with each playing position assigned different roles. A maximum of 16 players can compete during a game and substitutions are unlimited. The rules of the game have evolved considerably over recent years. For example, the introduction of the artificial playing surface over recent years has been reported to increase the effective playing time of matches (1), as well as the number of ball touches and distance covered by players with the ball (29). Therefore, there is increased physiological demands of matches compared to playing on grass (29). The abolishment of the off-side rule may allow for the ball to be kept in play for longer, therefore defending teams cannot negate space on the

pitch, subsequently increasing the tempo of the match (23). The unlimited "rolling" substitutions rule may also allow for increased work rate demands of players as they may be expected to perform at a high intensity when they get substituted back onto the field (23). This could lead to an increase in the intermittent nature of the game as players perform at high intensities for short durations with variable recovery between each period of exercise (23).

2.3 Seasonal structure in field hockey

Training in field hockey is usually divided into two phases, namely preseason and competitive season. Training during the pre-season is focused on developing aerobic capacity while competitive season training is the period where sport specific technical drills are performed together with tactical training and anaerobic conditioning (23,24). In addition, matches in tournaments are often played over consecutive days, therefore the competitive schedule during the field hockey season is physically demanding (15,75).

2.4 Physical demands of field hockey competition

Field hockey players require several aspects of fitness which include both aerobic and anaerobic capabilities to maintain high intensity activity over the period of a field hockey match (1). Research has observed that the average oxygen consumption during competition has been reported to be in the range of 70-92% of maximal oxygen uptake (VO2max) (22,25). In addition, elite and sub-elite players have been reported to spend more than 60% of a match above 85% of their maximal heart rates (HRmax) (8), eliciting positive changes in aerobic capacity (26).

Approximately 60% of energy required during matches is provided by the aerobic system, while the anaerobic pathway is responsible for the remaining 40% (1). Despite the aerobic pathway providing the dominant energy contribution, the anaerobic pathway has been suggested to

contribute significantly to the crucial moments of a match such as winning possession of the ball and the scoring of goals (15,24). In addition, anaerobic power is also essential in accelerating the body during short movements and rapid changes of direction (15). The intermittent nature of running due to patterns of repeated short bouts of high intensity activity, interspersed with periods of active and/or passive recovery also requires the removal of lactate and rapid resynthesis of phosphocreatine (PCr) stores to maintain performance (9,27). Athletes who can sustain a high work-rate during matches are likely to gain an advantage over equally skilled players who may experience fatigue due to depletion of energy stores (i.e. PCr and glycogen) or after a considerable amount of high intensity efforts (28).

2.5 Physiological and physical profile of field hockey players

Research has reported a 5-8% increase in VO2max from preseason to postseason in university female field hockey players, with players recording values of up to 42 milliliters per kilogram per minute (ml·kg·min) during the in-season (30). The increase in VO2max may be due to the training stimulus of interval running during games combined with aerobic workouts during the in-season (30). Previous research in field hockey suggested that VO2max distinguished between playing standards as county level players were observed to have higher values than club level players in England (31). Therefore, highlighting the importance of aerobic capacity for field hockey players (30). A study on elite international male players reported VO2max values of 55.79 - 57.9 ml·kg·min (8,9). The high areobic capacity of elite players could be due to competing at a higher level, as well as a greater utilization of the use of sport science interventions in developing training programmes (32). Body composition has been reported on in field hockey, with body fat percentages of approximately 17% for both Olympic level and Division Two female players (33,34). Additionally, a body mass of approximately 76.7 and 64.2 kilograms (kg) respectively, has been observed in elite male and female players (9,47).

PHYSICAL MATCH PERFORMANCE

2.6 Analysis of physical match performance

In team sports, individual players must combine into an effective unit to achieve the desired result, therefore, the assessment of a player's contribution to team effort is important to the coach (2). Match performance can be assessed by using performance methods that analyse the physical aspects of competition (2). Micro-devices such as accelerometers and heart rate monitors have been used for monitoring the physical performance of athletes during competitive team sport matches (2,4,8,16,36). Reporting on the external and internal physical demands such as locomotor activity and heart rate may contribute to the development and design of sport specific tests or training interventions (1,4,17).

2.7 Activity Profile

2.7.1 Activity profiles in team sport

Time motion analysis has been used to measure the external activity demands which can describe the physical stress that a player generates in team sport (5,9,16). Reporting on activity variables such as match time (as a percentage) spent standing, walking, jogging, running and sprinting form a key component of physical match performance in team sport (7,9). In addition, studies on time motion analysis have compared differences in activity patterns between periods of the game, playing positions and between level (elite versus sub-elite) of play (3,5,8,9,16).

2.7.2 Activity monitoring devices

Various monitoring devices and time motion methods have been used to document activity in team sport (2). These include, cinematographic tracking or video based time motion, automated tracking analysis and global positioning systems (GPS) (37,38,39). These methods of

determining activity have provided a general insight into the locomotor patterns and physiological demands of team sport (2,17). Although such systems may be an effective method of quantifying activity profile in field hockey (40), other methods may also be useful. For example, high sample rate tri-axial accelerometers which are capable of detecting movement in three planes and have demonstrated validity and reliability in team sport specific movement patterns (41). Sensors within an accelerometer contain a seismic mass that is attached to an accelerometer case via a "beam" which can be compared with a spring structure. With external acceleration, the seismic mass will allow for a deformation of the spring with respect to the accelerometer case (42). The magnitude of this deformation is proportional to the external acceleration (43) and can be measured via a specific sensing scheme contained in the sensor (44). Despite these various methods used to analyse and describe match activity profile, it has been suggested that there is no gold standard for determining movement patterns in competitive field sport (45).

2.7.3 Methods for describing activity

Studies in team sports have categorised activity according to different speed zones. For example, research have commonly used five to seven speed zone categories which is referenced in accordance with locomotor activity (i.e. standing: 0 km·h, walking: 6 km·h, jogging: 8 km ·h, low speed running: 12 km·h, moderate speed running: 15 km·h, high speed running: 18 km·h and sprinting: 30 km·h) (3,5,16,46). Additionally, these speed categories are also grouped according to low (i.e. standing and walking), moderate (i.e. jogging, low speed running) and high (i.e. moderate speed running, high speed running, striding, sprinting) intensity activities (5,16,47).

Research in field hockey and football has reported on the percent of match time spent performing each movement activity as well as the total distance (m) covered in each category (3,9,13,47,65). Studies in field hockey have also reported on sprinting during matches (i.e. mean number of sprints; average duration of sprints (seconds); average rest period between each

sprint) (9,47), relative distance covered (m/min) (3,48) as well as average number of changes in motion activity (3).

Research in team sports have also used methods which compared movement activity over different periods of a match such as five to fifteen-minute periods (5,9) and across halves (3,9,16). These methods have been used to identify periods in which there are significant changes in activity patterns (decrease or increase in amount of activity performed) which may allude to the development of fatigue over the duration of a match (3,5).

2.7.4 Activity during field hockey matches

A study by Johnston et al (49) on 15 field hockey players in the Scottish national league used video footage to analyse match activity on one player per match over 15 weeks. Findings showed that players spent 4% of playing time standing, 80.5% walking and jogging, while only a small percentage of playing time was spent engaging in high intensity activity such as striding (10.1%) and sprinting (4.7%). Similar results were observed by Spencer et al (9) who used a similar system and method to describe activity over the course of a single international match in elite male Australian hockey players. However, Spencer et al (9) also assessed activity for five-minute periods over the duration of the match and found that when comparisons were made between the initial five-minute period of the second half and the subsequent 30 minutes, playing time spent walking and standing increased significantly while a significant decrease in percent playing time jogging was reported. No significant differences in activity between the first and second halves were observed (9). Recently, Lythe and Kilding (3) used GPS technology to classify activity into six speed zones in elite male field hockey players from the New Zealand national team over five friendly matches and reported similar findings. Therefore, the results of the study by Lythe and Kilding (3) are similar to the study by Spencer et al (9) despite different technology and classification used to describe activity.

In female field hockey, a study on players participating in the Western Province grand challenge in South Africa used video recording and reported that players spent 1.5% of playing time standing, 82.3% walking, 13.7% jogging, 1.86% cruising and 0.69% sprinting (168). The study also compared speed displacement between halves and reported a significant decrease in sprinting distance during the second half (168). In a study on elite female international matches, Macutkiewicz and Sunderland (47) used GPS technology to record activity and reported that players spent 5.8% of playing time standing, 49.8% walking, 25.9% jogging, 12.3% running, 4.9% fast running, 1.5% sprinting (47). Similar observations have been made by MacLeod et al (32) using video recording to analyse female players competing in the English national league during a single match. For example, players spent 11.4% of playing time standing, 45.1% walking, 35.6% jogging, while the remainder of playing time was spent performing activity such as running, sprinting and lunging to strike the ball. Despite differences in the methods applied to analyse physical match performance, the studies on female field hockey players have reported similar findings for time in different activity zones.

2.7.5 Differences in activity between high and low standard players

Buglione et al (8) reported no significant differences between elite and sub-elite Italian male field hockey players for playing time spent or distance covered in the six speed zones used in the study. While in contrast, Jennings et al (37) reported that elite Australian international players performed 42% more high speed running than national players competing in the Australian field hockey league.

2.7.6 Activity according to playing position

Team tactics during matches can be a factor causing differences in activity profiles between positions (51). Spencer et al (9) used video recording to analyse match activity and found differences in playing time and motion frequency between positions in elite male field hockey players. The most notable was the significantly higher number of sprints performed by the inside forwards and strikers compared with the fullbacks and halfbacks (9).

Similarly, research high level female field hockey players reported that forwards spent significantly more time running, fast running and sprinting than midfielders and defenders (47). Moreover, rsearch on national and international male field hockey players using GPS observed that midfielders at an international level performed significantly more high-speed running compared to strikers and defenders, while strikers and midfielders competing at national level covered significantly more distance at high speed running than defenders (37).

Research in field hockey have commonly investigated match activity profile per playing position over the the 70-min match duration (3,9,47), rather than examining the physical demands of the individual player (167), who may leave and enter the game an unlimited number of times (167). While such data is useful, research has suggested that the presentation of data for each individual player is of importance (167). For example, forwards may perform high-intensity activity during a game, however it would be very different if three forwards share this load, or if one forward takes most of the load (167). Therefore, individual data would allow for a better understanding of the physical load required of the players (167).

2.8 Heart rate profiles

2.8.1 Heart rate monitoring

Heart rate monitoring has been used to quantify the physiological load during matches and training in team sport such as football as early as the late 1960's (52). Methods such as analysis of blood lactate (53), depletion of glycogen stores (54) and maximal oxygen update (VO2max) using portable analysers to monitor physiological demands (55) have certain limitations in a field setting. Therefore, heart rate monitoring has become a more commonly used alternative method of measuring player intensity due its ease and being relatively lower in financial cost (56). The use of heart rate as an indicator of aerobic demand during football activities and in testing of footballers has been validated previously (57,58). Heart rate values expressed as a percentage of time below and above 85% of maximal heart rate (HRmax) has been established as the threshold between aerobic and anaerobic energy supply in footballers (57,59). Moreover,

heart rate analysis suggests that field hockey players rely largely on aerobic metabolism for energy production (1). The aerobic pathway is under moderate stress for most part of field hockey matches (1,15), and can be heavily taxed during substantial periods of match time in team sport (60). Heart rate monitoring can therefore be useful to determine the most intense parts of competition in team sports and has been used to provide an indication of the intensity of exercise during football and field hockey matches (3,8,14).

2.8.2 Heart rate profile in team sports

Heart rate response is a valid indicator of the physiological load of football players during matches (6,53), and has been suggested to be a result of the type of movement performed and situational demands (i.e. one-on-one with an opponent) (56). The demands of competition in elite team sport such as field hockey and football requires a considerable amount of high intensity actions (5,6,7,9). Moreover, exercise intensity is constantly changing in team sport due to the intermittent nature (3). For example, research in elite male field hockey players observed an intensity change on average every 5.5 seconds (9).

The method of presenting match intensity based on maximal heart rate (HRmax) has been used by research for interindividual comparisons (7). The addition of field and laboratory based measures of maximal heart rate using heart rate monitors and the division of heart rate data into intensity zones makes the analysis more applicable and meaningful (15). Dellal and colleagues (4) suggested that the precise evaluation of heart rate responses should be interpreted according to the different halves during games. For example, studies in football and basketball have divided match heart rate data into time segments to make comparisons between physiological load and work rates over the duration of a game (16,26). During the second half of team sport matches, the exercise intensity and subsequently the heart rate decreases compared to the first half (1,4). Moreover, the drop in exercise intensity during the second half could be due to a multitude of factors such as team tactics, match score-line, fatigue and/or player motivation (3,4,5,11,16).

2.8.3 Heart rate response during competition

Heart rate response during competition provides a valid and useful global measure of physiological strain despite the intermittent nature of team sports (57). Research has shown that when exercise intensity is considered as a function of time in relation to the maximal heart rate intensity zones, there is a redistribution of time spent in each zone in the second half (26) For example, Helgerud et al (26) reported a decrease in time spent within the 85-90% maximal heart rate zone, with an increase in time spent in the lower intensity (75-80%) zone during the second half. Abdelkrim et al (16) reported similar results in junior elite male basketball players and suggested that the reduction in heart rate during the second half of matches could be due to fatigue or less distance covered in high intensity running (16).

When analysing time spent in different heart rate zones in elite field hockey matches, Lythe and Kilding (3) reported that players spent 60% of playing time above 85% maximal heart rate and 4% above 95% of maximal heart rate. Despite players spending 40% of playing time engaged in low intensity activities (<85% maximal heart rate), mean heart rate was recorded at 85.3% maximal heart rate. Similar observations were reported by Buglione et al (8) in which elite male field hockey players spent approximately 61 % of playing time above 85% maximal heart rate.

2.8.4 Summary of physical match performance

Objective measurements of activity and heart rate within sports are vital in the understanding of the physical match demands (4,16). In addition, first half activity has also been suggested to influence activity performed in the second half (51) as studies in team sport have reported a decrease in high intensity activity in the second half of a match, which may influence the outcome of a game (5,16). Moreover, despite the significant amount of match time spent standing and walking, players still exercise at intensities greater than 80% maximal heart rate for a considerable amount of time during field hockey matches (3,8). This indicates that the physiological load during game time is high.

Research has suggested that future studies of activity patterns in team sport are to be combined with heart rate monitoring to determine the precise variation of heart rate according to the physical nature of match play (4). Therefore, a comprehensive description of the physical match demands is much needed and can assist field hockey coaches at premier league level in South Africa to improve the development of more appropriate practice routines. For example, the intensity of training sessions needs to simulate the intensity of match demands, as research in elite female field hockey players have suggested that training sessions often fail to simulate the physical match demands occurring during competition (48). This may result in inadequate physical preparation ahead of competition.

PHYSICAL PERFORANCE TESTING

2.9 Performance testing

Field based fitness tests are designed to be carried out in the typical training environment, are relatively easy to administer and in some instances do not require the use of sophisticated equipment (21). Improvements in fitness tests may be reflected through enhanced physical performance during competitive matches (2).

Previously, team sport athletes were assessed using continuous running protocols (i.e. leger shuttle run test and 12-minute run test) in which the emphasis was on estimating VO2max or distance achieved in a set time (21). Due to the intermittent nature of team sports such as field hockey, the continuous nature of these protocols has been questioned (21).

Field based aerobic tests that focus on intermittent endurance are more specific to team sport performance and easily to administer (21). Other field based tests such as the repeat sprint ability and heart rate recovery tests are also relevant in a team sport context due to the many sprints a player is required to make with minimal quality recovery in between efforts (9,63).

2.10 Yo-Yo Intermittent Recovery Level One (Yo-Yo IR1)

Optimal performance in team sport is associated with the amount of high intensity activity performed over the duration of a match (5,7,9). Therefore, evaluating the aerobic fitness of an athlete using a test that mimics the movement pattern of the sport is vital. Moreover, research in football has shown that an individual's aerobic capacity can determine the outcome of a match (21).

An individual's aerobic endurance capacity can be assessed through the Yo-Yo IR1 test, which involves performing repeated bouts of intense exercise interspersed with periods of active recovery (21). Studies have observed a strong relationship between performance in the Yo-Yo IR1 and high intensity activity during a football match (13,64,65). However, the relationship between the Yo-Yo IR1 and match activity (specifically high intensity) in field hockey is still unknown.

2.10.1 Physiological response during the Yo-Yo IR1

Muscle and blood lactate has been shown to increase significantly during the Yo-Yo IR1 test, while muscle creatine phosphate and glycogen levels have been observed to decrease from rest to post-test (67). Moreover, research suggests the anaerobic system is highly stimulated towards the end of the Yo-Yo IR1 test while the aerobic pathway reaches maximal levels (66).

2.10.2 Yo-Yo IR1 performance across levels and playing positions

Research has suggested that the Yo-Yo IR1 is able to distinguish between individuals playing at different competitive levels and different playing positions (21). For example, top-level football players were reported to have covered a 10.7% greater distance in the test than

moderate level players (5), while fullbacks were reported to cover 17% greater distance than central defenders and 14% more distance than forwards (66). In addition, it is suggested that players who achieve higher distances in the test should exhibit a lower physiological strain in comparison to a player with a poorer performance during the test (67). For example, professional footballers have been reported to have lower metabolic disruptions during the Yo-Yo IR1 compared to amateurs (67). Variations in physiological response between players of different fitness levels have been suggested to be the reason for lower performance levels during the Yo-Yo IR (67).

2.10.3 Yo-Yo IR1 and match activity

Significant correlations have been reported between Yo-YoIR1 performance and high intensity running distance during matches in both elite male ($r= 0.58$, $p < 0.05$), female ($r= 0.76$, $p < 0.01$) and youth footballers ($r= 0.63$, $p= 0.022$) (13,64,65,66). Moreover, in elite female footballers, the total amount of high intensity running distance performed during the last 15-minute periods of each half correlated significantly ($r= 0.83$, $p < 0.05$) with Yo-Yo IR1 distance (13). These findings highlight the greater specificity of the Yo-Yo IR1 test to intermittent sports over continuous test protocols (65,68).

In field hockey, no studies have reported on the relationship between Yo-Yo IR1 and match activity. However, one study in field hockey reported that Australian international players performed 42.0% more high speed running compared to national players competing in the Australian field hockey league. These differences in match running performance could be related to international players greater aerobic endurance capacity measured during field based running tests (international: 2859 m versus national: 2568 m) (37).

2.11 Repeat sprint ability (RSA)

The use of the repeat sprint ability test (here in after referred to as "repeat sprint") is becoming increasingly popular in intermittent team sports such as field hockey and football (19,20,46, 69,70). Many field based team sports require players to engage in high intensity or maximal sprints of a short duration (usually 1-7 seconds) interspersed with brief periods of recovery (passive or low to moderate intensity activity) which vary in duration (9,20). Therefore, repeat sprint ability refers to the ability to produce maximal or near maximal sprint efforts regularly, and has been reported to be a valid test to evaluate physical performance in team sports (20,46,71).

Multiple sprint sports include accelerations, decelerations and turns (73), therefore these actions are difficult to simulate within a laboratory setting. In addition, it has been suggested that repeat sprint test protocols should simulate sprint patterns occurring in matches (72).

2.11.1 Repeat sprint in team sport

Analysis of time motion in team sports have reported that sprinting contributes between one and 10% of total distance or alternatively constituting approximately 1-3% of match time (9, 74,75). The development of fatigue during team sport matches has been associated with a decrease in sprinting ability (77). Subsequently, a reduction in sprinting ability following the first sprint during a repeat sprint test has been reported to be related to fatigue (76).

Periods of intense sprinting activity may determine the outcome of a match by impacting on the ability to concede goals or win possession of the ball (78). The importance of repeat sprints can be highlighted where a 0.8% impairment in sprint speed over the course of a match may impact

negatively on a player's ability to secure ball possession in a one on one duel against an opponent (79).

In a study on elite male field hockey players, Spencer et al (9) reported on activity patterns of repeat sprint during a single match. For the criteria of repeated sprint activity to be met during matches, players had to perform a minimum of three sprints with a mean recovery duration between sprints of less than 21 seconds. The criteria for repeat sprint were met on 17 occasions during the match with an average of four sprints per bout, in addition, repeated sprint bouts of six to seven sprints were performed on four occasions. Players performed an average of 30 sprints over a 71-min duration (full match plus one minute of extra time). This amounted to approximately two-minutes of mean recovery time between sprints. The differences in the duration spent performing each activity was also observed, with a mean sprint duration of 1.8 to 4.1 seconds. Moreover, almost 25% of the recovery time between sprints was 20 seconds or less. Mean recovery time between sprints was reported at 14.9 seconds with 95% of recovery being of active nature (i.e. Walking, jogging, striding) (9).

Spencer et al (9) suggested that it is vital to consider maximal sprint duration in the evaluation of repeated sprint in respect to the physiology and over load stimulus. Therefore, a repeat sprint test protocol designed to mimic a period of intense repeat sprint activity occurring during field hockey matches may require as many as six to seven sprints with less than 21 seconds recovery between sprints of a four second duration (9). Although some players may play a full match and perform an average of two repeat sprint bouts, these repeat sprint bouts may prove vital in deciding the outcome of a match (9).

2.11.2 Physiological response to repeat sprints

An efficient adenosine triphosphate (ATP) turnover rate within the muscle is required to perform bouts of maximal sprints. ATP needs to be consistently resynthesized as muscle ATP

stores can sustain muscular activity for only a few seconds (less than five seconds) (80). Energy required to resynthesize ATP during brief bouts of maximal sprints is provided by phosphocreatine and glycogenolysis (80). Factors that facilitate oxidative energy production during repeated sprints are also important for repeat sprint performance (81) while concentration of aerobic enzymes, mitochondrial size and number (82), and capillary density (83) are all vital for repeated sprint bouts (81).

Maintenance of speed during repeated sprint bouts of short duration is dependent on the phosphagen system (84,85). During a six second maximal sprint, phosphocreatine (PCr) contributes approximately 50% of anaerobic energy supply (29). Phosphocreatine (PCr) stores are significantly reduced following repeat sprints with shorter rest intervals (i.e. 21 to 24 seconds) (86). The time-period for the restoration of phosphocreatine levels to approximately 50% is reported to be between 21 to 57 seconds (87,88), thus improving performance in repeat sprint ability may require the efficiency of phosphocreatine resynthesis (75). Moreover, research has reported that 45% of phosphocreatine (PCr) stores are depleted after a single six-second sprint (86) and approximately 20% following a 15 m sprint (89).

Anaerobic glycolysis supplies approximately 40% of total energy during a single six-second sprint (80). This contribution from the glycolytic pathway is progressively inhibited as sprints are repeated (80), while energy contribution via oxidative phosphorylation to energy expenditure may increase up to 40% during the final repetitions of repeated sprint test (90).

2.11.3 Repeat sprint ability protocols and variables measured

The implementation of test protocols consisting of several sprints interspersed with short recovery periods, instead of a single sprint test elicits physiological responses similar to the most intense periods of match play (91,92). Fitzsimons et al (72) suggested that a repeat sprint protocol needs to tax the energy system in a manner that replicates a match situation, therefore,

various field test protocols have been developed to replicate the physiological mechanisms involved during repeat sprint activity performed in matches (9,20,69).

Each sprint within the protocol is measured (usually in seconds) along with a mean, fastest (or best) sprint time, and sprint decrement as a percentage (69,93). The sprint decrement is often used as fatigue index to quantify the ability to resist fatigue during a repeat sprint protocol (46,69). Studies have highlighted the necessity to contextualize the calculated decrement indices when repeat sprinting is assessed because a lower or higher decrement score does not always result in a better or worse performance (94).

2.11.4 Repeat sprint ability and match activity

Rampinini et al (46) examined the validity of the repeat sprint test as an indicator of match related physical performance in elite male footballers. A 6x40m with 20 seconds rest protocol showed significant correlations ($r = -0.60$, $p < 0.01$ and $r = -0.65$, $p < 0.01$ respectively) between repeat sprint ability mean and very high intensity running as well as sprinting distance during matches (46).

Similar findings to Rampinini et al (46) were reported by Weston et al (19) on elite football referees. However, Weston et al (19) also reported a significant correlation between repeat sprint ability best with high intensity running and sprinting distance during matches. These associations could be mediated by the metabolic characteristics of the repeat sprint test (contribution of the anaerobic glycolytic system, decrease in phosphocreatine, pH and ATP) (91), which are similar during the most intense periods during a football game (98). Moreover, studies that investigated repeat sprint decrement in elite male football reported no correlation with match activity (19,46).

Weston et al (19) reported no significant decrement for 40m repeat sprint. This contrasted with Rampinini et al (46) study on professional footballers who reported a 3.3 percent (%) decrement in repeat sprint performance. The difference in findings between the two studies could be due to different recovery times within the protocols. For example, Weston et al (19) incorporated a 90 seconds passive recovery between each sprint while Rampinini et al (46) used a 20 second passive recovery. The absence of a performance decrement with a long recovery (such as 90 seconds) is in line with previous findings which incorporated 60 seconds of recovery and observed that 40m sprint time did not decrease till the 12th sprint repetition (99). Moreover, a recovery duration of 90 seconds is not specific to physical performance during matches as studies on team sports have shown that individuals have less than 30 seconds to recovery between high intensity bouts (9,100,101).

Research in field hockey have investigated the relationship between repeat sprint ability testing and match activity. However, the study examined the validity of a repeat sprint protocol consisting of five repetitions of six seconds on a cycle (i.e. 5x6 seconds) in relation to a circuit designed to simulate movement patterns observed during field hockey matches (20). The circuit began with a 15 metre (m) maximal sprint and was repeated 15 times over three 15-minute periods. Significant correlations ($r= 0.76$, $p < 0.05$) were reported between power decrement during the repeat sprint test and decrement in 15m time across the three 15-minute periods. The authors suggested that sprint performance decreases during field hockey match simulation and that sprint decrement appears to be specific to the sprint duration implemented during testing. Therefore, the 5x6 seconds cycle test was reported to be valid for assessing decrement in 15m sprint time during a simulated hockey circuit (20). However, the use of this method of assessing repeat sprint ability is questionable, as physical performance is likely to decrease during a simulated circuit in which movements are repeated, compared to a match, in which movement patterns are more variable.

2.12 Heart rate recovery (HRR)

Heart rate recovery is the rate at which the heart rate decreases following moderate to high intensity exercise and is dependent on the combination of parasympathetic reactivation and sympathetic withdrawal (102,103). A quicker heart rate recovery has been suggested to reflect a positive adaptation to physical training and performance capacity in endurance events (104,105,106), making it a convenient monitoring tool for fitness trainers (107). Measuring heart rate recovery on a regular basis may allow coaches to monitor how athletes are responding to exercise and therefore assess training efficiency (108).

Most research regarding the relationship between heart rate recovery and aerobic fitness has been conducted on endurance athletes (109,110), and limited information exists on the differences in the ability of heart rate recovery to detect fitness changes in intermittent team sports (111). In addition, research has suggested that studies should investigate the post exercise heart rate recovery after high intensity intermittent exercise (4). Research in football has suggested that since match play requires a combination of aerobic and neuromuscular fitness (74), the ability of heart rate measures to potentially predict changes in aerobic fitness may offer a possible tool to evaluate an individual's readiness to compete at a high intensity (112).

2.12.1 Physiological mechanism involved in heart rate recovery

Cardiac output is adjusted on metabolic demand during exercise (113). This mechanism occurs via intrinsic autoregulation of cardiac pumping, and by sympathetic activation and parasympathetic deactivation, which causes an increase in heart rate (114). Increased sympathetic activity along with parasympathetic withdrawal during physical activity results in increased blood flow to the muscles (115). At the end of submaximal and maximal exercise, heart rate decreases towards resting levels (116). The rapid decrease in heart rate is attributed to the restoration of parasympathetic tone at the heart, whereas the further reduction is linked to the progressive decrease of sympathetic tone and hormonal factors (117,118,119). Furthermore, heart rate recovery measured up to one-minute after submaximal exercise is

predominantly dependant on parasympathetic activity and independent on the intensity of exercise and cardiovascular condition (118,120).

2.12.2 Methods assessing heart rate recovery

Various methods have been used to determine heart rate recovery, for example, parameters which are subject to variation between protocols are the exercise mode such as running on a motorized treadmill (121,122) or cycling on an ergometer (123), the exercise intensity (i.e. maximal and submaximal) (121,124), and recovery duration which has been shown to vary from one to five minutes (121,125). In addition, different heart rate recovery modes such as active (124) or passive (121,122) have been implemented, as well as different postural positions (i.e. seated, supine, upright) assumed during recovery (126).

Research has quantified post-exercise heart rate recovery by calculating the absolute difference between the final heart rate at exercise completion and heart rate recorded following 60 seconds of recovery (HRR60s) (112). Research has also examined ultra-short-term heart rate recovery (10-30s) in athletes participating in continuous and intermittent sports (127). Other methods of recording heart rate recovery include semi-logarithmic regression analysis to measure heart rate recovery during the first 30s of recovery (118). Raw or actual heart rate (heart rate obtained at a given time during the recovery period) has also been used (107), while determining percentage of peak heart rate, as well as the time constant of heart rate decay obtained by fitting the post-exercise heart rate recovery by a first order exponential decay curve (119).

2.12.4 Heart rate recovery in athletes

Athletes with a quicker recovery after brief bouts of intense exercise are likely to perform better in intermittent sports (127). Research suggests that it may be valid to study heart rate recovery following a certain sub-maximal heart rate level (i.e. 90% of maximal heart rate) as athletes

competing in intermittent team sports need to recover after brief-intense activities that usually elicit sub-maximal rather than maximal heart rate (127). In addition, the quick recovery of heart rate after moderate to heavy exercise may be a vital mechanism in preventing excessive cardiac work which could potentially have important implications for training and competition (108).

Studies have reported on the association between heart rate recovery and aerobic fitness, and have examined cross sectional differences between trained and untrained participants (129,130, 131). For example, a quicker heart rate recovery in female marathon runners compared to age-matched untrained counterparts after maximal exercise has been reported (132), while trained men and women have been shown to have a faster heart rate recovery than untrained men and women at absolute submaximal workloads (130). Sugawara et al (105) observed that heart rate recovery during the initial 30s after submaximal exercise increased (i.e. improved) after a period of training and decreased (i.e. worsened) during a subsequent period of detraining in sedentary men.

In team sport, Buccheit et al (112) examined whether heart rate recovery after 60s of rest measures derived from a submaximal intermittent running test could be used to track changes over the course of a season in highly trained junior footballers. A substantial improvement in heart rate recovery was not associated with beneficial changes in aerobic fitness performance, while a moderate correlation was observed between individual changes in heart rate recovery and repeat sprint ability performance when adjusted for body mass. This study suggested that players displaying a quicker heart rate recovery at the beginning of the season can improve more over the season (112). The findings were in accordance with previous research by Buccheit et al (133) in which changes in the time constant of heart rate recovery after training were moderately correlated to improvements in repeat sprint performance but not maximal intermittent running velocity. The findings between heart rate recovery and repeat sprint (112) could be related to differences in training background, study population, training content and duration (structured study design versus simulated training conditions) as well as different repeat sprint protocols used (134). For example, the repeat sprint ability test used in Buchheit et al study (133) employed shorter recovery between sprints (30 versus 14s) which potentially

increases the aerobic contribution in the test (135). In addition, different heart rate recovery methods (number of beats recovered in a minute versus heart rate curve fitting) may have also influenced the different findings (112).

2.12.5 Ultra short-term heart rate recovery

Studies have suggested that both acute (134) and chronic (133) training induced changes in heart rate recovery are potentially modality specific (i.e. intermittent or continuous training). Athletes involved in intermittent sports are likely to have a quicker heart rate recovery at 10 and 20s after maximal exercise compared to athletes participating in continuous endurance sports (127). Such differences may be due to differential adaptation of the autonomic nervous system to intermittent interval versus continuous endurance sports (127). For example, Ostojic et al (127) examined the difference in ultra-short-term heart rate recovery between athletes participating in intermittent (soccer, basketball, handball) and continuous sports. The results showed that the two groups had a similar aerobic capacity, however those engaged in intermittent sports were likely to demonstrate a significantly faster heart rate recovery at 10 and 20s but not at 60s after maximal exercise (127). Therefore, post exercise ultra-short-term heart rate recovery can be used to monitor training status in intermittent based endurance athletes (127).

Buchheit et al (136) looked at the relative change in heart rate recovery among two groups of junior athletes who engaged in repeat sprint ability or high intensity interval training. No significant differences were observed between groups with regards to heart rate recovery at 60s, however the interval training group demonstrated a larger decrease in the 30s heart rate recovery time constant (136). Therefore, high intensity interval training may focus on shorter recovery periods in contrast to the common heart rate recovery (i.e. HRR60s), resulting in a quicker heart rate recovery during the earlier stages of recovery (111). These observations suggest that different types of training may elicit positive changes in ultra-short-term heart rate recovery which may be vital among intermittent sport athletes (111).

It has been observed that the time to recover after high intensity exercise bouts in intermittent team sports is often less than 30s (100, 101, 137). Therefore, research has suggested that assessing ultra-short-term heart rate recovery could be of importance when monitoring recovery during football training (74). In support of this, Ostojic et al (108) used the heart rate recovery time constant method (T30) to calculate the short-term time constant when examining differences in ultra-short-term heart rate recovery (i.e. 10 and 20s) between a group of elite and sub-elite footballers. The study reported that the elite group showed a significantly quicker heart rate recovery at 10 and 20 s, while no difference was observed during heart rate recovery at 60s. Therefore, ultra-short-term heart rate recovery may also be able to distinguish between high and low standard players (108).

2.12.6 Heart rate recovery and match activity

A study on elite male football referees investigated the relationship of heart rate recovery during an aerobic interval test and physical match performance (14). Heart rate recovery at 60 s showed a significant correlation ($r= 0.70$, $p < 0.05$) with time spent performing high intensity running during matches. This suggests that referees with a quicker heart rate recovery were able to perform more intense exercise during the match, possibly due to a faster recovery in between high intensity effort (14). Additionally, there is no published research examining the relationship of ultra-short-term heart rate recovery and physical match performance in team sport.

2.13 Summary of physical performance tests in relation to match activity

Research in football have reported on the relationship between fitness tests and high intensity activity (10,13,19, 46). However, there is limited information relating to fitness tests in relation to high intensity match activity, which is suggested to be of importance in field hockey (9,37). Studies in field hockey have highlighted the importance of repeat sprints during matches (9), yet there is a lack of evidence pertaining to the relationship of repeat sprint testing and match activity. Moreover, investigating the physiological response (i.e. heart rate recovery) during

submaximal fitness tests in relation to match activity is important to team sport athletes (14), as there is limited research in this area. Such information may allow fitness trainers and coaches to select only appropriate tests that are specific to the nature of field hockey, subsequently reducing the physical burden of over testing athletes.

CHAPTER 3. METHODS

3.1 Study design

A prospective, cross sectional study design was used to determine the relationships between physical fitness tests and the time spent in high intensity activity zones during competitive premier league field hockey matches.

3.2 Study population

The study population consisted of male and female club field hockey players competing in the Southern Gauteng Hockey Association Premier League, one of the strongest provincial associations in South Africa. Within Southern Gauteng, senior club teams participate at different levels depending on ranking, with the Southern Gauteng Premier League being the highest level of club participation in the district. Players in this league are often chosen to represent the Southern Gauteng team annually at the Inter Provincial Tournament (IPT) and/or to compete in the national Premier Hockey League (PHL). Additionally, four players (one female and three males) from the sample were at the time, either training with or had represented the South African national field hockey team. The teams normally commence their pre-season approximately eight to twelve weeks prior to the start of the competitive season. Typically, teams train on average two to four times per week (during the pre-season and competitive season) for approximately two hours per session. This includes, two technical and tactical based sessions with the coach and field based conditioning (i.e. aerobic intervals, small sided games, and agility training sessions) during the same session. The University of the Witwatersrand male and female players also have two strength or resistance training sessions a week in the gymnasium which are on separate days to the field based sessions. In addition, each team played an average of one league match per week during the competitive season.

3.2.1 Sample size

The sample (n= 56) was drawn from two male and two female premier league field hockey clubs in Southern Gauteng. A power calculation was conducted for both male and female groups and was based on a significant p-value of 0.05 with 80% power for the correlation analysis. Therefore, a total of 30 participants per group were required for the study. In total, participants included 27 males (Age (Years): 23.4 ±4, Mass (kg): 75.1 ±7.9, Height (cm): 177.3 ±6.8) and 29 females (Age (years): 23.4 ±3.6, Mass (kg): 58.9 ±6.6, Height (cm): 165.4 ±6.8).

3.2.2 Sample recruitment

Permission to conduct the study was requested from the head of sport at the University of the Witwatersrand as well as the head coach for Wanderers Club hockey. Male and female players from both clubs were then invited to participate in the study.

3.3 Site of study

Physical fitness tests were conducted at the respective clubs home turf (University of the Witwatersrand and the Wanderers Club astro turfs). The designated match venues (all had astro turf playing surfaces) where physical match performance data were collected were a combination of home, away and neutral venues.

3.4 Inclusion/exclusion criteria

Inclusion criteria

- Male and female field hockey players between the ages of 18-35 years playing for the University of the Witwatersrand and Wanderers club and competing in the Southern Gauteng Hockey Association premier league.
- Participants who had not sustained any upper or lower limb injuries that required medical attention within the past six months and/or during the data collection process.
- All outfield players from each team were included.

Exclusion criteria

- Any player who had a current injury and/or medical condition.
- Goalkeepers from the respective teams.
- Players who did not willingly volunteer and those who did not sign the participant informed consent approved by the University of the Witwatersrand Human Research Ethics Committee (Medical) (HREC).

3.5 Data collection and measurement procedures

All physical fitness testing and match data collection took place during the competitive season which started in March 2017 and ended in August 2017 (Figure 3.1). Prospective match data was collected on one to three occasions on each player over a period of between three to eleven weeks. (Table 3). All the participants had been training for a minimum of eight weeks at the start of the data collection period and were therefore assumed to be match fit.

Participants performed each of the physical fitness tests (Yo-Yo IR1, sub-maximal Yo-Yo IR1 heart rate recovery and repeat sprint ability) once only, and on separate days (i.e. one fitness test per day). To reduce fatigue, participants were asked not to exercise the day before each fitness test, and were given 48 hours of rest between each testing session. Additionally, participants were asked to refrain from consuming beverages containing caffeine on the day of testing and to avoid eating a heavy meal within three hours before testing. To minimize possible

circadian effects, all tests were initiated around the same time of day (±2 hours) (126). Fluid intake was allowed between tests to avoid dehydration. Prior to testing, a standardised 15-minute warm-up consisting of a light jog, dynamic stretching, striding and submaximal shuttle sprints were performed.

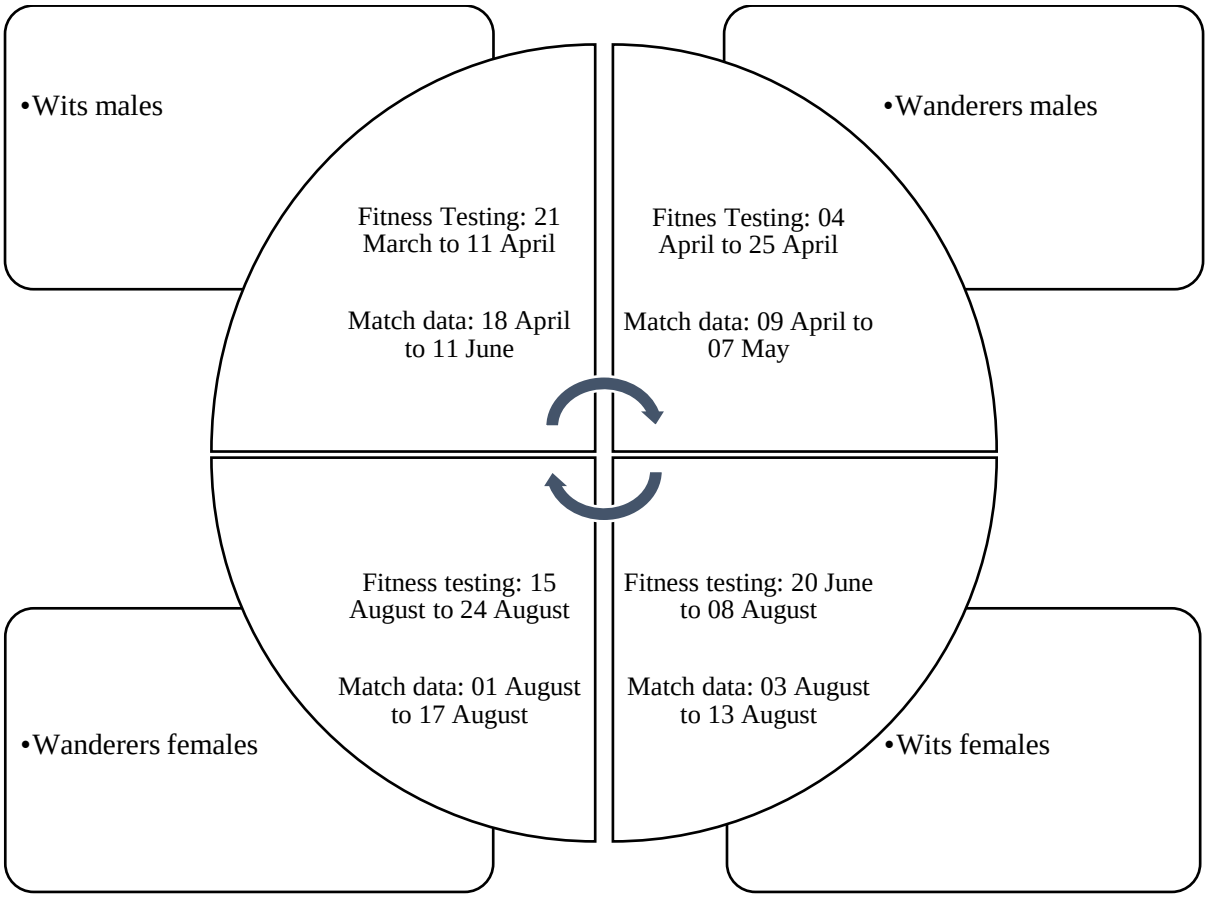


Figure 3.1: Diagram of fitness testing and match data collection timeframe.

3.6 Instrumentation and outcome measures

3.6.1 Zephyr System

The Zephyr Bioharness 3 system (Zephyr Technology 2013, Annapolis, USA) is a field-based monitoring system which allows for the simultaneous assessment of activity and heart rate

variables. The monitoring device (Figure 3.2) is attached onto a chest strap and acts as a data logger or transmitter (138). The data is downloaded from the device after the activity and is time stamped (in one second epochs) before being exported to Microsoft Excel (138).

Prior to all data collection, the Zephyr Bioharness was fitted around each participant's chest with the centre line of the device positioned in line with left mid-axilla and the ziphoid process (Figure 3.2).



Figure 3.2: Diagram of Zephyr Bioharness fitment

Activity recorded in Vector Magnitude Units (VMU's) was obtained through a tri-axial accelerometer contained within the Zephyr Bioharness, sampling at 100 Hertz (Hz). The device is sensitive along three orthogonal axes [vertical (x), sagittal (z) and lateral (y)] and allows for acceleration data to be monitored as VMU which is an integrated value over the previous one second epoch (138). In addition, the Zephyr Bioharness contains electrode sensors that detect r waves and capture the heart rate data at 250 Hz reported as beats per minute (b·min) (138). The Zephyr system has been proven to be valid and reliable within a field setting (138). Previous research has reported the relationships of heart rate and accelerometer activity readings with gold standard measurement to be ($r= 0.91$, $p < 0.01$, CV <7.6) and ($r > 0.97$, $p < 0.01$, CV < 14.7) respectively, suggesting that the Zephyr Bioharness is reliable (138).

3.7 Match analysis

The researcher was present on the side-line of each game noting down the exact timings of the matches which included the start and end of each half, timing of substitutions, stoppages and injuries. The timing of substitutions was used so that data only included actual playing time (referred to hereafter as "playing time") during the first and second half of matches and consequently excluded half time data and time spent off the field (i.e. bench time, injury time and suspensions) (referred to hereafter as "bench time") (139). This distinction between match playing time and bench time has been suggested to be important in intermittent team sport which allows for unlimited substitutions (139). For example, eliminating bench time data provides a distinctive physical profile of a player which can be analysed based on the actual events taking place during the contest (139). Moreover, a players match data was only included if he or she completed a minimum 20-minutes per half of playing time. A video camera (Sony DCR-SX45E) was placed at the side of the field, and recordings were replayed after the game to ensure that the timing of substitutions were correct.

3.7.1 Activity

Match activity was measured in vector magnitude units (VMU's) and categorized into four zones (Table 3.1). The percentage of playing time that a player spent in each activity zone was recorded for further analysis.

The selected activity zones are suggested by the manufacturers of the Zephyr Bioharness and were also verified during a multi-stage fitness test (level one to six) with 10 field hockey players (Intra-rater CV of 2.53 – 5.81%) by a fitness coach and a sport scientist at the University of the Witwatersrand.

Activity zone	VMU
Standing and walking	< 0.8
Jogging	0.8 - 1.09
Running	1.1 - 1.39
Sprinting	≥ 1.4

Table 3.1: Activity classification zones

3.7.2 Heart rate profiles

Match heart rates were referenced to the maximal heart rate obtained during the Yo-Yo IR1 test or matches (3,21,16,140). Heart rate data was calculated as the percentage playing time that participants spent in four different heart rate zones based on previous studies in elite male field hockey and other field sports (Table 3.2) (3,8,12,16).

Heart rate zone	Percent (%) of maximal heart rate
Low	< 75%
Moderate	75-84%
High	85-95%
Maximal	> 95%

Table 3.2: Heart rate classification zones

3.8 Physical performance tests

3.8.1 Yo-Yo Intermittent Recovery Test - Level One (Yo-Yo IR1)

The Yo-Yo IR1 (Bitworks Design, Cheltenham, UK, Team Beep Test 20 meters, version 4:0) is a valid and reliable test of an athlete's ability to perform intermittent exercise during matches (21, 66). Performance of the Yo-Yo IR1 by elite male footballers has been shown to be similar when the test was repeated within a week (1867 ±72 m versus 1880 ±89 m). In addition, the co-efficient of variation (CV) was reported as 4.9% (66). Moreover, Thomas et al (166) measured

the test-retest reliability of the Yo-Yo IR1 in 16 amateur female field hockey players and found a correlation coefficient (r) of 0.95 ($p < 0.01$), with a CV of 8.7%.

At the sound of an audible beep, broadcasted using a portable CD player, participants were required to reach a set of cones 20m away and return to the starting line before the next beep. The interval between the beeps progressively shortens at the start of each stage (66). Between each 40m running-bout the participants were given a ten second active rest in which to jog five meters out and back to the starting position. Participants were asked to stop the test if they twice failed to complete the shuttle in the time period designated by the beeps. The total distance achieved in meters (m) by the participant was recorded for further analysis.

3.8.2 Heart rate recovery

Heart rate recovery was measured with a Zephyr Bioharness during a submaximal Yo-Yo IR1 test. Taking the absolute difference in heart rate recovery at 60s (i.e. heart rate at the end of exercise minus heart rate achieved after 60s of rest) during submaximal exercise has been shown to be reliable (Intra Class Correlation = 0.43, Standard Error of Measurement = 7.92% and Minimum Difference = 15.65) (107). The same procedures were used for both maximal and submaximal Yo-Yo IR1 tests, except during the submaximal test, participants ran for six minutes (or 700m). At the completion of the six-minute running bout, players were given a ten second count in which they had to assume a supine position on the hockey turf. The supine position was used to ensure that participants would not physically move around during the recovery period (126). Heart rate recovery (measured in beats per minute) was calculated by taking the difference between the final heart rate achieved immediately after the submaximal Yo-Yo IR1, and the heart rate obtained following 10, 20, 30 and 60 s of passive recovery (108, 121, 141).

3.8.3 Repeat sprint ability test

The repeat sprint ability test measures an individual's ability to produce repeated maximal sprints interspersed with brief periods of active recovery (20, 69, 72). The Fusion Sport Smart Speed System (Fusion Sport, 2 Henley ST, Coopers Plains, QLD, 4108, Australia) uses infra-red timing gates and was used to measure the time (s) taken by each participant to complete each sprint shuttle. The following procedure was used: Six maximal repetitions of two 15m out and back sprints departing every 20s (133). This protocol was selected based on research conducted in elite male field hockey matches where players are reported to perform repeat sprint bouts consisting of six to seven sprints interspersed with less than 21s of recovery (9). Additionally, the test was adapted from a study in field hockey which examined the reliability of a repeat sprint test using a protocol of six sprints of 30m (i.e. 6 x 30m). The results showed a technical error (TE) of measurement of 0.7% for this variable. Moreover, the smallest worthwhile change (SWC) was reported as 0.15s (0.6%) (69).

At the start of each sprint, the participant took up a stationary position 0.5m behind the starting line. The researcher provided a three second verbal count down after which the participant sprinted in a linear direction through the first timing gate (starting the timer) to a line 15m away, then turned and sprinted back through the same timing gate (stopping the timer). Participants were given strong verbal encouragement during the test to avoid a pacing strategy (142). Recovery between sprints was active, while times were recorded to the nearest 0.01s. The following outcomes were recorded for statistical purposes: 1) Repeat sprint mean (average of all six sprints recorded in seconds); 2) Repeat sprint best (fastest sprint recorded in seconds); 3) Repeat sprint decrement (recorded as a percent). The repeat sprint decrement was calculated according to the following equation proposed by Spencer et al (69) and validated by Glaister et al (143): 100 - (total time / ideal time x 100), where ideal time = 6 x repeat sprint best (142).

3.9 Data management and statistical analysis

After each match, activity and heart rate were downloaded from each Zephyr Bioharness pod in the Zephyr Analysis module and then exported as a comma separated values (csv) file into

Smartabase (Fusionsport, Brisbane, Australia). Percentage time (playing time) in each activity and heart rate zone were then automatically calculated in Smartabase.

Match data used for the correlation analysis was collected over nine league matches (five male matches and four female matches) and included a total of 98 match data sets (56 males and 42 females). The participation for each fitness test was as follows: Yo-Yo IR1: 32 players (9 males and 23 females), repeat Sprint Ability: 38 players (17 males and 21 females) and heart rate recovery: 40 players (23 males and 17 females).

Statistica Version 12.0 (Series 0313b, StatSoft) was used for analysis. All data was reported in means ±SD. Data was tested for normality using Shapiro Wilk's test. Comparison between percentage playing time spent in different activity and heart rate zones for the first and second half were analysed using paired T-Tests when the data was normally distributed, and the Wilcoxon test if the data was not evenly distributed. To determine the correlation between percentage playing time spent performing high intensity activity (running and sprinting) during matches with fitness tests, the Pearson product moment correlation test was used when data was normally distributed, and the Spearman's test was used when data was not evenly distributed. The study included analysis of high intensity activity and fitness tests based on previous studies in elite football and basketball (13,14,16,46). The magnitude for correlation coefficients were considered as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect (> 0.9) and perfect ($r = 1.0$) (144). Statistical significance was set as $p < 0.05$.

3.10 Ethical consideration

The research commenced once the University of the Witwatersrand Human Research Ethics Committee (Medical) approved the study (See Appendix F). University of the Witwatersrand

and Wanderers Club granted permission to the researcher to conduct the study using the University of the Witwatersrand and Wanderers Club hockey teams. At the start of the hockey season and prior to any data collection, the hockey players were approached to explain the purpose of the research. The players were invited to participate in the study and information sheets were then be handed out after which the players were allowed to ask any questions before deciding whether or not they would like to participate. All players who volunteered to participate signed a University of the Witwatersrand (Medical) approved informed consent and were informed that the results of the study are strictly confidential, and that they could withdraw from the study at any point without any discrimination or prejudice. The study was approved by the University Ethics committee (M161168).

CHAPTER 4. RESULTS

4.1 Physical match performance

4.1.1 Activity Profile

Males

Players were walking, jogging, running and sprinting for 67.0 ±6.2%, 13.1 ±4.0%, 16.6 ±4.7% and 3.3 ±2.5% of playing time, respectively. Compared to the first half, percent playing time spent walking in the second half increased significantly (1st half: 64.9 ±6.7% versus 2nd half: 69.1 ±6.2%, $p < 0.01$). In contrast, percent playing time spent jogging (1st half: 14.0 ±4.7% versus 2nd half: 12.2 ±3.4%), running (1st half:17.7 ±4.9% versus 15.6 ±4.7%) and sprinting (1st half: 3.5 ±2.6% vs 2nd half: 3.1 ±2.3%) were significantly ($p < 0.01$) reduced in the second half compared to first half .

Table 4.1: Percent of playing time spent in each activity zone in first and second half in males (Mean ±SD).

	n	Match	1st Half	2nd Half	p-value
Sprint (%)	27	3.3 ±2.5	3.5 ±2.6	3.1 ±2.3	0.003
Run (%)	27	16.6 ±4.7	17.7 ±4.9	15.6 ±4.7	0.0001
Jog (%)	27	13.1 ±4.0	14.0 ±4.7	12.2 ±3.4	0.0006
Walk (%)	27	67.0 ±6.2	64.9 ±6.7	69.1 ±6.2	0.000006

% = percentage of playing time; 1st = first; 2nd = second

Females

Female participants were walking, jogging, running and sprinting for 68.5 ±8.8%, 17.8 ±5.7, 12.6% ±6.2% and 1.0 ±1.1% of playing time respectively. There was no significant difference between halves for percent of playing time spent in different activity zones.

Table 4.2: Percentage of playing time spent in each activity zone in first and second half in females (Mean ±SD).

	n	Match	1st Half	2nd Half	p-value
Sprint (%)	26	1.0 ±1.0	1.1 ±1.27	1.0 ±1.0	0.96
Run (%)	27	12.6 ±6.2	12.7 ±6.7	12.4 ±6.0	0.46
Jog (%)	29	17.8 ±5.7	18.6 ±6.4	17.5 ±5.7	0.10
Walk (%)	29	68.5 ±8.8	68.6 ±8.3	69.1 ±8.7	0.69

% = percentage of playing time; 1st = first; 2nd = second

4.1.2 Heart rate profile

Males

Mean heart rate during matches was 173 ±9.0 (bpm) or 86.9% ±4.0% of HRmax and decreased significantly between the first and second halves ($p < 0.01$). Players spent 7.6 ±7.1%, 25.4 ±14.0%, 55.7 ±15.1% and 11.3 ±10.6% of playing time in low, moderate, high and maximal heart rate zones respectively. Compared to the first half, the percent of playing time spent in the maximal heart rate zone decreased significantly in the second half (1st half: 14.4 ±12.8% vs 2nd half: 8.8 ±9.2%, $p < 0.01$). Compared to the first half, the percent playing time in the low heart rate zone increased significantly in the second half (1st half: 5.8 ±5.7% vs 2nd half: 9.4

±8.9%, $p < 0.01$), while the time spent in the moderate heart rate zone also increased significantly in the second half (1st half: 22.1 ±15.1% vs 2nd half: 28.7 ±13.9%, $p < 0.01$).

Table 4.3: Percentage of playing time spent in heart rate zones in first and second half in males (Mean ±SD).

	n	Match	1st Half	2nd Half	p-value
Low (%)	26	7.6 ±7.1	5.8 ±5.7	9.4 ±8.9	0.0009
Moderate (%)	27	25.4 ±14	22.1 ±15.1	28.7 ±13.9	0.0002
High (%)	27	55.7 ±15.1	58.0 ±14.7	53.6 ±17.8	0.08
Maximal (%)	23	11.3 ±10.6	14.4 ±12.8	8.8 ±9.2	0.0002

% = percentage of playing time; 1st = first; 2nd = second; Low = < 75% HRmax; Moderate =75-84% HRmax; High = 85-95% HRmax; Maximal = > 95% HRmax

Females

Mean heart rate during the match was 171 ±10 bpm or 86.0 ±4.5% of HRmax. Mean heart rate decreased significantly in the second half compared to the first ($p < 0.05$). Players spent 8.9 ±10.2%, 27.8 ±17.4%, 51.8 ±17.7% and 11.5 ±14.3% of match playing time in a low, moderate, high and maximal heart rate zone respectively (Table 4.4). There was no significant difference in time spent in the low, moderate and high heart rate zones between first and second half of matches. Players spent significantly less time in the maximal heart rate zone in the second half then the first half (1st half: 15.3 ±18.5% vs 2nd half: 8.6 ±12.2).

Table 4.4: Percentage of playing time spent in heart rate zones in first and second half in females (Mean ±SD).

	n	Match	1st Half	2nd Half	p-value
Low (%)	28	8.9 ±10.2	8.1 ±9.9	9.7 ±11.6	0.36
Moderate (%)	29	27.8 ±17.4	27.2 ±19.1	28.6 ±17.2	0.21
High (%)	29	51.8 ±17.7	50.2 ±17.5	53.4 ±20.6	0.22
Maximal (%)	25	11.5 ±14.3	15.3 ±18.5	8.6 ±12.2	0.01

% = percentage of playing time; 1st = first; 2nd = second; Low = < 75% HRmax; Moderate =75-84% HRmax; High = 85-95% HRmax; Maximal = > 95% HRmax

4.2 Physical performance tests

Male

The mean distance reached in the Yo-Yo IR1 was 2220 ±603m (Table 4.5). Repeat sprint ability test results were 5.80 ±0.17s for repeat sprint ability mean, 5.57 ±0.20s for repeat sprint best and 4.2 ±1.1% for repeat sprint ability decrement respectively (Table 4.5). Heart rate recovery (HRR) at 10, 20, 30 and 60s was 17 ±9.0, 30 ±9.0, 39 ±10 and 71 ±10 bpm respectively (Table 4.5).

Females

The mean distance reached in the Yo-Yo IR1 was 929 ±267m (Table 4.6). Repeat sprint ability test results were 6.72 ±0.26s for repeat sprint ability mean, 6.40 ±0.24s for repeat sprint ability best and 4.9 ±1.5% for repeat sprint ability decrement respectively (Table 4.6). Heart rate recovery (HRR) at 10, 20, 30 and 60s was 11 ±5, 21 ±5, 30 ±6 and 60 ±17 bpm respectively (Table 4.6).

Table 4.5: Physical performance test results in males.

	n	Mean (±SD)	Minimum	Maximum
Yo-Yo IR1 (m)	9	2220 ±603	1200	3000
RSA mean (s)	17	5.80 ±0.17	5.43	6.11
RSA best (s)	17	5.57 ±0.20	5.18	5.95
RSA decrement (%)	17	4.2 ±1.1	2.6	6.1
HRR10s (bpm)	23	17 ±9.0	3	45
HRR20s (bpm)	23	30 ±9.0	12	54
HRR30s (bpm)	23	39 ±10	20	59
HRR60s (bpm)	23	71 ±10	49	85

Yo-Yo IR1 = Yo-Yo Intermittent Recovery Level One; RSA= Repeat Sprint Ability; HRR = Heart Rate Recovery; bpm = beats per minute.

Table 4.6: Physical performance test results in females.

	n	Mean (±SD)	Minimum	Maximum
Yo-Yo IR1 (m)	23	929 ±267	460	1500
RSA mean (s)	21	6.72 ±0.26	6.21	7.45
RSA best (s)	21	6.40 ±0.24	5.95	6.91
RSA dec (%)	21	4.9 ±1.5	2.8	7.8
HRR10s (bpm)	17	11 ±5.0	5	21
HRR20s (bpm)	17	21 ±5.0	13	30
HRR30s (bpm)	17	30 ±6.0	19	43
HRR60s (bpm)	17	60 ±17	39	101

Yo-Yo IR1 = Yo-Yo Intermittent Recovery Level One; RSA= Repeat Sprint Ability; HRR = Heart Rate Recovery; bpm = beats per minute.

4.3 The relationship between physical performance tests and physical match performance

4.3.1 Yo-Yo IR1 and match activity

Males

There were no significant correlations for Yo-Yo IR1 and high intensity activity during matches ($p > 0.05$) (Table 4.7).

Females

The Yo-Yo IR1 was moderately correlated with playing time spent (%) sprinting during the first half ($r= 0.49$, $p < 0.05$), and playing time spent running during matches ($r= 0.54$, $p < 0.05$) (Table 4.8).

4.3.2 Repeat sprint ability and match activity

Males

There were no significant correlations between repeat sprint ability mean, repeat sprint ability best and repeat sprint ability decrement with high intensity activity during matches ($p > 0.05$) (Table 4.7).

Females

There were no significant correlations between repeat sprint ability mean, repeat sprint ability best and repeat sprint ability decrement with high intensity activity during matches ($p > 0.05$) (Table 4.8).

4.3.3 Heart rate recovery and match activity

Male

HRR at 10s was moderately correlated to the percent playing time sprinting in the first half ($r = 0.43$, $p < 0.05$). No significant correlations were reported for HRR at 20, 30 and 60s and high intensity activity ($p > 0.05$), (Table 4.9).

Females

HRR at 10, 20 and 30s showed moderate to large correlations (r= 0.73, $p < 0.01$, r= 0.53, $p < 0.05$, r= 0.58, $p < 0.05$) with percent of playing time spent sprinting during matches. In addition, a large correlation (r= 0.77 $p < 0.01$) was observed with HRR at 60s and percent of playing time spent running during matches (Table 4.10).

Table 4.7: Summary of the correlations between the Yo-Yo IR1 and repeat sprint ability test variables with percentage playing time spent in high intensity activity in males.

	Yo-Yo IR1 r (p-value)	RSA mean r (p-value)	RSA best r (p-value)	RSA dec r (p-value)
Sprinting 1st half (%)	0.32 (0.41)	0.36 (0.16)	0.34 (0.19)	0.21 (0.42)
Sprinting 2nd half (%)	0.03 (0.93)	0.31 (0.22)	0.28 (0.27)	0.20 (0.44)
Sprinting match (%)	0.20 (0.61)	0.34 (0.19)	0.32 (0.21)	0.21 (0.43)
Running 1st half (%)	0.06 (0.87)	-0.33 (0.19)	-0.26 (0.31)	-0.02 (0.92)
Running 2nd half (%)	0.13 (0.74)	-044 (0.07)	-0.37 (0.14)	0.04 (0.87)
Running match (%)	0.10 (0.79)	-0.39 (0.11)	-0.32 (0.20)	0.007 (0.97)

% = Percent of playing time; Yo-Yo IR1 = Yo-Yo Intermittent Recovery Level one; RSA = Repeat Sprint Ability

Table 4.8: Summary of the correlations between the Yo-Yo IR1 and repeat sprint ability test variables with percentage playing time spent in high intensity activity in females.

	Yo-Yo IR1 r (p-value)	RSA mean r (p-value)	RSA best r (p-value)	RSA dec r (p-value)
Sprinting 1st half (%)	0.49 (0.02)	-0.04 (0.85)	-0.23 (0.31)	0.18 (0.43)
Sprinting 2nd half (%)	0.28 (0.20)	-0.13 (0.58)	-0.30 (0.19)	0.29 (0.21)
Sprinting match (%)	0.36 (0.10)	-0.13 (0.58)	-0.31 (0.17)	0.24 (0.29)
Running 1st half (%)	0.57 (0.01)	0.07 (0.77)	-0.05 (0.83)	-0.13 (0.58)
Running 2nd half (%)	0.47 (0.03)	0.09 (0.69)	-0.06 (0.81)	-0.09 (0.70)
Running match (%)	0.54 (0.01)	0.12 (0.60)	-0.03 (0.91)	-0.10 (0.67)

% = Percent of playing time; Yo-Yo IR1 = Yo-Yo Intermittent Recovery Level one; RSA = Repeat Sprint Ability

Table 4.9: Summary of correlations between heart rate recovery at 10s, 20s, 30 and 60s with percentage playing time spent in high intensity activity in males.

	HRR10s	HRR20s	HRR30s	HRR60s
Sprinting 1st (%)	0.43 (0.04)	0.42 (0.05)	0.19 (0.38)	0.24 (0.27)
Sprinting 2nd (%)	0.33 (0.12)	0.40 (0.06)	0.17 (0.43)	0.25 (0.24)
Sprinting match (%)	0.39 (0.06)	0.40 (0.06)	0.18 (0.42)	0.24 (0.26)
Running 1st half (%)	0.10 (0.64)	0.20 (0.36)	0.10 (0.64)	0.04 (0.85)
Running 2nd half (%)	0.35 (0.11)	0.31 (0.15)	0.22 (0.32)	0.17 (0.45)
Running match (%)	0.22 (0.32)	0.26 (0.23)	0.16 (0.46)	0.10 (0.63)

% = Percent of playing time; HRR = Heart Rate Recovery

Table 4.10: Summary of the correlations between heart rate recovery at 10, 20, 30 and 60s with percentage playing time spent in high intensity activity in females.

	HRR10s	HRR20s	HRR30s	HRR60s
Sprinting 1st half (%)	0.68 (0.003)	0.45 (0.08)	0.45 (0.08)	0.48 (0.06)
Sprinting 2nd half (%)	0.72 (0.002)	0.44 (0.09)	0.50 (0.04)	0.45 (0.08)
Sprinting match (%)	0.73 (0.001)	0.53 (0.04)	0.58 (0.02)	0.46 (0.08)
Running 1st half (%)	0.45 (0.08)	0.18 (0.51)	0.19 (0.48)	0.79 (0.0002)
Running 2nd half (%)	0.49 (0.05)	0.30 (0.27)	0.32 (0.23)	0.76 (0.0006)
Running match (%)	0.40 (0.12)	0.20 (0.46)	0.23 (0.39)	0.77 (0.0005)

% = Percent of playing time; HRR = Heart Rate Recovery

CHAPTER 5. DISCUSSION

Introduction

The main purpose of the study was to investigate the relationships between match activity and fitness tests, and secondly, to describe the physical match performance in Premier League field hockey in Johannesburg. Limited research in field hockey have reported on the relationship between match activity and fitness testing. Studies in elite field hockey have reported no decrease in high intensity activity during the second half of matches (3,9). In contrast, the present study demonstrated that male players experience a significant decrease in high intensity activity during the second half of matches, while both males and females spent significantly less time in a maximal heart rate zone (>95%) during the second half. In addition, physical performance tests such as heart rate recovery showed moderate to large correlations with match activity in both male and females.

PHYSICAL MATCH PERFORMANCE

5.1 Activity profile during matches

5.1.1 Male participants

This study demonstrated that male players spent over half the amount of match playing time walking, while only 3.3% of playing time was spent sprinting. These results are similar to findings in elite men's field hockey despite different systems and methods used in analysis (9,49). For example, Spencer et al (9) used video recording to categorise activity and reported that elite male field hockey players in Australia spent 46.5% of playing time walking while 5.6% of playing time was spent engaging in high intensity activity (striding and sprinting). Similarly, Johnston et al (49) reported that walking and jogging accounted for 80.5% of playing time, while 4.7% of time was spent sprinting in male field hockey players competing in the Scottish league.

In contrast, Buglione et al (8) used GPS and reported that both elite and sub-elite players in Italy spent approximately 0.4% of playing time sprinting which is considerably less than the 3.3% of time spent sprinting reported in the current study. However, these differences could be related to the team's style of play (10). For example, teams that perform more high intensity running may be working harder to regain the ball back once they have lost possession, as well as to create space to receive passes (10). In contrast, teams that perform less high intensity running during matches may incorporate tactics which involves a more possession based type of play (10), subsequently resulting in less high intensity activity.

Compared to the first half, the second half was characterized with a significant decrease in the percentage playing time spent jogging, running and sprinting, and a significant increase in time spent walking. These findings are similar to research in which a significant decrease in the distance covered in sprinting, running and jogging during the second half of matches was reported in elite Chinese male field hockey players (146). In contrast, Lythe and Kilding (3) reported a significant decrease in distance covered in low intensity across all playing positions during the second half of matches in elite male field hockey players, while no differences were reported for moderate and high intensity zones. Similarly, Spencer et al (9) reported no differences in activity when comparisons were made between halves in elite male players in Australia. The studies by Lythe and Kilding (3) and Spencer et al (9) analysed activity according to playing position, whereas the present study analysed activity of individual players. Therefore, it is possible that a significant decrease in high intensity running will not be detected when comparisons between first and second half are being made according to playing positions. For example, a defender could be substituted by a defender that has a greater ability to sustain high intensity activity, this may therefore result in the defenders (as a group) being able to maintain high intensity activity throughout the match. This may explain why the previous studies in elite male field hockey did not observe significant changes in high intensity activity over the course of a match (3,9), compared to the present study.

There are a few possible explanations for a drop in high intensity activity in males in the present study. Firstly, fatigue may have contributed to the significant decrease in activities such as

sprinting and running during the second half in males. Research has shown that fatigue may occur after an intense period of high intensity activity (5). For example, a 12% decrease in physical performance in the five-minute period following a peak in high intensity running has been observed in elite male footballers (5). Such findings have been attributed to "temporal" fatigue (5), which may be related to the accumulation of potassium in the muscle (147). The decline in time spent sprinting and running during the second half could be related to "depletion" fatigue which involves physiological mechanisms such as a progressive decrease in phosphocreatine, muscle pH and glycogen in muscle fibres (148). Fatigue development could be of significance, as a decrease in physical activity during a match could result in decreased involvement with the ball (11). However, this is speculation as the current study did not include analysis of technical events. Additionally, research has suggested that the occurrence of fatigue during football matches is multi-factorial, and not always related to a decrease in high intensity running performance (148).

Secondly, the decrease in high intensity activity during the second half in males could be due to an increase in other locomotor activities during the second half which were not analysed in the present study. For example, a high frequency of tempo changes suggests that a considerable amount of additional energy is utilized during accelerating, decelerating and lateral movement, as well as running backwards (149). Therefore, these type of movements may have increased the level of fatigue, which resulted in a drop in high intensity activity in the second half. In addition, it is important to take into consideration that although players may not be reaching speeds that meet the criteria for running or sprinting, players may be producing maximal efforts through accelerating yet do not reach sprinting speed as defined by the criteria (8). The intensity zone approach may therefore report this as low intensity which may not be an accurate measure of the real physiological cost of the activity (8).

5.1.2 Females particiapnts

Similar to the male, the female players spent over half of the playing time walking, while only a small amount of playing time was spent running and sprinting. This is supported by

Macutkiewicz and Sunderland (47) using GPS and reported that elite female players spent 49.8% of playing time walking, with 12.3% of time spent running and 1.5% of sprinting. Moreover, Macleod et al (32) reported that elite female players in England spent 45.1% of playing time walking, while less than 10% of time was spent running and sprinting respectively.

In contrast to the male group, no significant decrease across halves was observed in the percent of time spent in each activity zone in the female hockey players. Studies in division one female field hockey players have reported a significant decrease in high intensity running distance for midfielders and defenders during the second half of the game (150). Similarly, Lothian and Farrally (151) reported a significant reduction in mean playing time spent performing high intensity activity during competition in first and second division national league female field hockey player (151).

The ability to maintain running and sprinting activity in the second half may be related to more frequent substitutions in the female matches. Coaches may strategically co-ordinate substitutions in a way as to maintain the team's physical intensity (37). A study that examined the interchange of rest periods in relation to match exercise intensity in Australian football reported that the number of substitutions affected the time spent performing high speed running during the first, third and fourth quarters (152). The authors suggested that regular substitutions contributes to the maintenance of high speed running (152), and may assist with the re-synthesis of phosphocreatine (Pcr) stores prior to bouts of high intensity (152).

One could also speculate that female players in the study may have also adopted a pacing strategy to maintain high intensity activity in the second half. For example, it has been reported that Australian Football League (AFL) players regulate the amount of low-intensity activity undertaken to preserve the important high-intensity components of running during matches (51, 153). However, no significant changes were reported for low intensity activity (i.e. walking) during competition in the participants which is in contrast with the theory of pacing (154).

Moreover, if a pacing strategy was adopted then the highest work rate of the female players may have occurred during the final stages of a game, described by the "end-spurt" phenomenon (155). Subsequently, this would have resulted in significantly more running and sprinting during the second half which was not the case in the female group of the present study.

The level of competition or playing standard of the opponents may have also been a contributing factor which allowed the females participants to sustain high intensity activity throughout the second half. For example, the females could have been able to sustain activity in the second half as they may have been technically and tactically better than their opponents, and therefore spent less time performing high intensity activity compared to the opposition, subsequently leading to the ability to maintain activity. In support of this, successful elite level teams in football perform less high intensity running than unsuccessful teams (11).

In summary, despite different technology and methods used, the findings on match activity for male and females are similar to studies in elite hockey (3,8,32). For example, the analysis of the external physical demands during competition confirm the findings of research which reported that field hockey players spend most of the time performing low intensity activity (i.e. walking) with periods of high intensity (i.e. running and sprinting). Moreover, the results showed a decrease in activity such as running and sprinting during the second half of matches in the male group. However, many factors could have contributed to a reduction in activity during the second half, specifically in males. For example, a favourable score-line, change in match tactics, level of competition (i.e. low versus high standard), home and away fixtures, physical fatigue, as well as players not using full capacity are all factors that may have contributed to a decrease in high intensity activity during the second half of competition.

5.2 Heart rate profiles during matches

The mean heart rate observed during playing time in both male and females groups are similar to studies in elite and sub-elite male field hockey (3,8), and are suggestive of a high level of physical exertion in matches (3,156). In addition, there was a significant decrease in mean heart rate from first to second half in both male and females.

Despite over 60% of playing time spent walking, both male and females groups spent over half of the playing time in a high heart rate zone (85-95% HRmax), which suggests that players aerobic system is highly taxed throughout matches (13), and that recovery is limited between bouts of high intensity activity. Similar observations have been reported in elite and sub-elite male field hockey players (3,8). An explanation for the substantial amount of playing time spent in a high heart rate zone could also be related to the additional physiological strain of body positions and changes in tempo (15), as well as isometric muscle contractions which can elevate heart rate (157). Moreover, movements in field hockey that involves crouching and slapping the ball may have little impact on locomotor activity but may be reflected by increase in heart rate values (15). In support of this, research has reported an increase in energy expenditure equal to approximately 15% of VO2max with an elevated heart rate of 25 beats per minute when additional effort such as dribbling a hockey ball was performed (25).

Both male and female players also spent approximately 11% of playing time above 95% maximal heart rate which is considerably more than research on elite male field hockey (i.e. 4%) during playing time (3). This may be due to players in the present study being involved in a considerable amount of one-on-one situations or tackles, or possibly in direct contact with opponents for long periods. Research in elite football has reported that such events result in the maximum elevation of heart rate (58). Moreover, this intensity of exercise suggests that a large energy contribution comes from the anaerobic pathway during certain periods of the game, and possibly more so within certain playing positions (12). For example, Lythe and Kilding (3) observed that strikers in elite field hockey spent significantly more time above 95% HRmax than fullbacks, due to engaging in more sprinting (3).

In both male and female groups, over 30% of playing time was spent in moderate and low intensity zones (less than 85% HRmax), which indicates a lower degree of exertion during certain periods of the game. Therefore, reflecting the more intermittent nature of the game, which may also suggest that certain players recover quickly between bouts of high intensity activity (12).

There was also a significant increase in time spent in the low and moderate heart rate zone during the second half compared to the first half in males. Moreover, time spent in the maximal heart rate zone decreased significantly during the second half in both males and females. This is similar to studies in elite junior male basketball players and elite male handball which observed a significant increase in playing time spent in the moderate heart rate zone in the second half with a significant decrease in time spent in the maximal zone (16,35).

The reduction in mean heart rate and time spent in the maximal heart rate zone (> 95%) between first and second halves may suggest that field hockey is similar to team sport such as basketball in which the physiological strain is lower in the second half, despite substitutions being unlimited. From a match context, a decrease in heart rate from first to second half has been suggested to be related to decreasing physical outputs either through tactics, fatigue or total distance covered (15,21). Ali and Farrally (158) suggested that match score and relevance of matches could also impact the physical effort of players which tends to decrease when results and score-line are favourable. In support of this, research in Spanish football has shown that the team leading during a game spent more time in their own defensive zone and subsequently covered less total distance at high intensity (22). Other disparities between intensities measured through activity and heart rate has been suggested to be caused by factors such environmental conditions such as external temperature, relative humidity, atmoshpheric pressure, air resistance as well as hormonal variation during games (4).

The heart rate response observed during matches in the present study are similar to research in elite field hockey, which suggests that the physiological strain during matches are high despite

the majority of the game spent performing low intensity activity. Physical factors that were not included in the analysis of activity, and can contribute to a high physiological strain include; the number of accelerations, decelerations, rapid changes in direction, passing, interceptions, tackles, body posture and physical contact during one-on-one duels (3,4,8,15,16,56). In addition, the use of heart zones as a method of time spent in specific intensity zones could potentially be a better representation of the physiological load according to playing position. This method of match analysis may assist in differentiating physical loads between playing positions (4). Moreover, such data could provide important information to set goals for physical preparation, games and recovery strategies (4).

MATCH ACTIVITY IN RELATION TO PHYSICAL TESTS

5.3 The relationship between Yo-Yo IR1 and match activity

The study found a significant correlation with Yo-Yo IR1 and high intensity activity in the female group only. Specifically, Yo-Yo IR1 performance showed moderate correlations with the percentage time spent sprinting during the first half and percentage of match playing time running. These findings are similar to research on elite female footballers which reported a significant correlation between Yo-Yo IR1 and high intensity running during matches (13). Similar observations have also been reported in elite male junior and adult footballers (65,66).

No correlation was observed between Yo-Yo IR1 and high intensity match activity in males This is in contrast to Jennings et al (37) who reported that Australian international male field hockey players who achieved a 10.1% greater distance during an aerobic running test were able to perform significantly more high speed running during international matches compared to Australian national players competing in domestic competition.

Caution should be taken regarding the predictive associations of match activity profile based on Yo-Yo performance, as match context also needs to be considered (i.e. tactics and score-line) (152). Players may not be required to utilize their full physical capacity during matches

(13), possibly due to positional roles and substitutions (152). For example, a defender may be required to maintain a position in close proximity to the goalkeeper in order to prevent opposition from scoring goals, therefore limiting the amount of running performed. In support of this, research in elite football has reported that defenders perform less high intensity running during competition than midfielders and attackers (7,5,66), and it has been speculated as to whether this is due to tactical or physical limitations of defenders (7,66).

Previous studies have examined the relationship of Yo-Yo IR1 performance and activity over shorter periods (i.e. 15-minutes) of matches. For example, Krustrup et al (13) reported a large correlation between Yo-Yo IR1 performance and distance covered at high intensity running during the last 15-minute period of the two halves in elite female competition. It would however be difficult to investigate individual test performance in relation to match activity profile over shorter periods (i.e. 15minutes) in field hockey due to substitutions being unlimited. Furthermore, investigating test performance in relation to match activity within playing positions may also be difficult in field hockey as a player with a greater Yo-Yo IR1 performance may be replaced by a player with a lower performance in the same playing position. Therefore, making it impractical to examine the relationship of Yo-Yo IR1 and match activity based on playing position in field hockey.

5.4 The relationship between repeat sprint ability and match activity

No relationship was found between repeat sprint testing and high intensity activity in both male and female field hockey players which is in contrast to studies in elite male football (19,46). Both Rampinini et al (46) and Weston et al (19) observed significant correlations between mean repeat sprint ability and very high intensity running distance during elite male football matches. It is suggested that the findings in football could be mediated by the metabolic characteristics of the repeat sprint ability test (91), which are similar to the most intense periods during a football game (92,98).

Weston et al (19) also observed significant correlations between repeat sprint ability best and high intensity running and sprinting distance in elite football. However, Weston et al (19)

incorporated a passive recovery period of 90 s between each sprint which is substantially longer than the present study and the study by Rampinini et al (46). The longer passive recovery period between sprints in the study by Weston et al (19) may have allowed for the re-synthesis of phosphocreatine stores, enabling the ability to record a better time on the subsequent sprint.

The present study found no correlation between match activity and the decrement in repeat sprint ability which is line with studies by Rampinini et al (46) and Weston et al (19). Therefore, the inclusion of the repeat sprint decrement as a test measure is questionable. These findings however contrast with a study on male field hockey players which observed a significant correlation between power decrement during a 5x6 second cycle repeat sprint test and decrement in 15m sprint time over three 15-minute periods during a simulated field hockey match (20). However, it must be noted that decrements in performance during a simulated field hockey circuit are likely when the pattern of movement is constantly repeated, compared to a match where sprints and subsequent rest periods are variable.

It has been suggested that the lack of a relationship between repeat sprint ability best and match activity could indicate that athletes do not use their maximum running speed ability during competition (46). Support for this theory can be observed in elite field hockey which reported that players rarely reach their maximum speed during matches (3). The limitations of holding a hockey stick could be a contributing factor for field hockey players not reaching maximal sprint speed during matches (150). Therefore, maximum sprint speed during testing may not be reflective of a field hockey player's ability to meet speed demands during games (3,150). In addition to this, studies in male field hockey have reported that elite players performed significantly more accelerations during competition than sub-elite players (8), suggesting that the number of accelerations may be more important than maximal sprint speed in field hockey.

5.5 The relationship between heart rate recovery and match activity

The present study observed a significant correlation between heart rate recovery at 10s and time spent sprinting during the first half in males. This suggests that male players with a superior ultra-short-term heart rate recovery were able to spend more time sprinting during the first half. A quick heart rate deceleration in athletes during ultra-short-term recovery (not related to autonomic control) could be due to rapid changes in maximal left ventricular performance with enhanced ejection fraction and myocardial contractibility (160). The quick recovery of heart rate after exercise may be a vital mechanism in preventing excessive cardiac work (108), which may potentially lead to an enhanced ability to cope with the tempo of the game.

In females, heart rate recovery showed significant correlations with playing time spent running and sprinting during matches. Specifically, heart rate recovery at 10, 20 and 30s showed significant correlations with percent of match playing time sprinting. In addition, heart rate recovery at 60s showed significant correlations with percent of match playing time running. These results are similar to research by Mallo et al (14) which reported a significant correlation between heart rate recovery at 60s during an aerobic interval test and percent time spent performing high intensity running during matches in elite football referees. However, the findings of the present study relating to ultra-short-term heart rate recovery and match activity may be more relevant, as research has shown that the time to recover after high intensity exercise bouts in intermittent team sports is often less than 30s (100,101,137).

The relationship between heart rate recovery and match activity could also reflect a positive adaptation of the parasympathetic nervous system to high intensity intermittent training (127). Support for this theory can be observed through research in which athletes who engaged in high intensity training programs experienced significant changes between heart rate recovery and high intensity exercise performance (133,161). Additionally, Buchheit et al (136) investigated the changes in heart rate recovery among junior footballers after high intensity interval training and observed a decrease in heart rate recovery at 30s (136). These observations suggest that

different types of training may elicit positive changes (i.e. reduction in heart rate) in short term heart rate recovery, which may be vital among intermittent sport athletes (111).

It may also be useful to monitor heart rate recovery according to playing position in field hockey. For example, studies in elite female field hockey have shown that defenders have a significantly higher mean heart rate than midfielders even though midfielders spent more time performing high intensity running (47). This could be an adaptation of the parasympathetic nervous system response to the increased high intensity intermittent running of midfielders. In addition, forwards have been reported to have significantly less time to recover between moderate and high intensity activity then other playing positions (47), which could have a positive effect on their ability to recovery quickly.

Practically, the heart rate recovery and activity findings may have relevance to hockey coaches. For example, a player with a quicker heart rate recovery may not be required to be substituted as frequently due to the ability to recover quickly after intense bouts of exercise. However, when substituted, a player with a faster heart rate recovery may need less time to recover on the bench, which enables the individual to contribute significantly in terms of more minutes played, as well as more involvements (i.e. passes, interceptions, tackles) during crucial moments of the match. Moreover, an athlete with a faster heart rate recovery may be better suited for a strategy which demands a higher intensity of play (i.e. man to man marking of the opposition or a high press which is characterized by placing sustained pressure on the opposition in order to gain possession of the ball).

5.5.1 Factors affecting heart rate recovery

It is important to interpret the relationship between heart rate recovery and match activity with caution as many factors can affect heart rate recovery. For example, a decrease in body mass over the course of a week can result in an increase in heart rate recovery (162).

Standardization of testing relating to exercise intensity is also important (113) as heart rate recovery after maximal intensity exercise may be lower due to sympathetic activation carrying on into the initial stages of recovery (163). Therefore, protocols involving maximal intensity need to take this physiological response into account when monitoring heart rate recovery (163). Moreover, Lamberts et al (162) showed that under controlled conditions, submaximal heart rate varied by approximately seven beats per minute when exercising at approximately 90% of maximal heart rate.

Factors such as training status and accumulation of fatigue may also affect heart rate recovery (113). In addition, age could influence testing as research observed a slower heart rate recovery in older participants (164), while another study reported that participants with high peak heart rates have a better heart rate recovery, independent of age (165).

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The time spent in the maximal heart rate zone decreased during the second half and could be due to physical fatigue, a decrease in one-on-one situations or fewer physically demanding movements that include accelerating and dribbling the ball. A reduction in second half high intensity activity in the male group may suggest a change in match tactics or that these players were experiencing physical fatigue.

The correlation between the heart rate recovery test and high intensity activity suggests that submaximal fitness tests can be implemented in club field hockey to assess a players match readiness. Given the mixed findings for the Yo-Yo IR1 and repeat sprint test, field hockey fitness trainers should re-consider the use of these tests. Additionally, one needs to consider that components of physical fitness may not be the only factors that influence physical match performance as tactical and technical ability of players should also be considered (70).

Overall, these findings may contribute to the improvement in the specificity of physical conditioning and sport specific fitness testing for club level players, and provide a training foundation for players that have an ambition to compete at a higher level.

6.2 Practical Application

Field hockey at club level should apply fitness training practices which focuses on improving the ability to sustain high intensity activity and the ability to recover quickly between bouts of intense exercise. Players that experience a reduction in high intensity activity during matches may require additional conditioning through the use of high intensity interval running or high tempo small sided games to achieve a higher level of aerobic and anaerobic fitness, or may need to be substituted more often (37). Furthermore, fitness trainers should individualize programmes to ensure training specificity. For example, during small sided games, players can wear heart rate monitors to simulate physical match demands and ensure that they are spending sufficient time in each heart rate zone (specifically the higher heart rate zones). This may simulate similar metabolic responses occurring during competition, and prepare players for matches. In females, physical match performance can be improved through specific aerobic based conditioning. Submaximal tests such as the heart rate recovery test can be used by hockey fitness trainers to provide information on player match readiness. Such tests are are less demanding, therefore reducing the physical stress and injuries associated with maximal tests.

6.3 Limitations

The researcher attempted to complete fitness testing and match data collection within four weeks for each group. However, after the fitness tests were conducted, matches were either postponed or moved to later dates due to changes within the league and/or opposition teams. This meant that by the time the match data was collected, the time frame between fitness tests and collection of data for matches on each team was between three to eleven weeks. Therefore, individual fitness levels may have changed over the course of the data collection period which may have influenced the results of the correlation with match activity.

Additionally, the study did not report on the CV pertaining to activity and heart rate however, it is acknowledged that a large inter-match CV was likely due to limited match data sets analysed (1-3 per player).

6.4 Recommendations

Future research on field hockey should include the analysis of activity and heart rate data along with tactical (i.e. formation, zonal versus man to man marking) and technical (i.e. number of passes, interceptions, tackles etc) information as these parameters should not be explored in isolation (70). Research should also consider the use of hockey sticks during fitness testing as this may improve test specificity. Investigating additional measures of internal load during matches such as heart rate variability and blood lactate levels may provide further details of how these physiological parameters impact on match performance. Additionally, the findings of heart rate recovery during fitness testing in relation to physical match performance suggest that submaximal tests may be preferred. However, due to limited research in this area, further studies are required.

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APPENDIX A: PARTICIPANT INFORMATION SHEET

Study: The relationships of activity patterns and heart rate profiles with physical performance tests in premier league club field hockey players from Johannesburg.

Good day,

My name is Khavish Harry and I am currently doing a master's degree in sport science at the University of the Witwatersrand and have a firm interest in hockey. I am doing a research study on the relationships of activity patterns and heart rate profiles (match profiles) with physical performance tests in field hockey players.

Very little is known research wise with regards to match profiles in relation to physical performance tests in premier league hockey players in South Africa, and that is why I feel it is vital to conduct research within this area of sport performance.

I invite you to participate in this research study to investigate the match profiles in relation to field physical performance tests in premier league club hockey players. Before you decide it is important that you read the following information in order for you to understand why the research is being done and what it will involve. Please feel free to ask any questions regarding this information if you may not be one hundred percent sure of anything pertaining to the study. Do take your time while deciding whether or not you would like to volunteer for this study as you do have the option to refuse to participate and this will not affect you and your position in the team in terms of training or selection should you decide not to volunteer. Thank you in advance for reading this.

The research will be conducted with two research assistants on six match days that will be discussed with your coach. The physical performance tests required for the research will be done on your team's home ground and will take place over four separate sessions. All data collected will be kept confidential and will be destroyed two years post publication or after six years if not published.

The aims of this research are:

- To determine the relationships of activity patterns and heart rate profile during matches with physical performance tests in premier league club hockey players.

Investigating physical performance in field tests in relation to match profiles may potentially assist coaches to implement training strategies to improve player performance in club hockey.

The reason you have been asked to participate is that you are all hockey players currently plying your trade in premier league club hockey and are older than 18 years of age.

The study involves the following:

1. Filling in a medical history questionnaire to ensure that you do not have a serious medical condition/s and/or injury/s that could affect your health and/or results.
2. Filling in and signing of a consent form.

The study involves testing and recording of the following:

Determining physical performance during field-based fitness testing which will include:

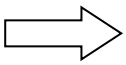
1) Performing two Yo-Yo IR1 tests to measure your fitness level



The Yo-Yo IR1 measures the distance in metres that you are able to run over the duration of the test which takes 10-20 minutes.

Test 1: Will take place 3 days before your first league match

Test 2: Will take place 3 days before your 4th league match



2) Recording your heart rate recovery

Your heart rate recovery will be measured in beats per minute immediately after both Yo-Yo IR1 tests.



3) Performing two repeat sprint ability tests (measuring your ability to sprint repeatedly)

This test will involve you performing 6 sets of 2x15 metre sprints with 20 seconds of recovery between each sprint.

Test 1: Will take place one week before your first league match

Test 2: Will take place one week before your 4th league match

The match profiles that will be recorded over matches:

1) Activity



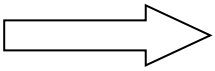
The following activity patterns will be recorded as the percent of match playing time that you spend:

Walking

Jogging

Running

Sprinting



2) Heart rate

Percent of match playing time that you spend in the following heart rate zones will be recorded:

Zone 1: < 75% maximum heart rate

Zone 2: 75-84% maximum heart rate

Zone 3: 85-95% maximum heart rate

Zone 4: > 95% of maximum heart rate

All participants will be asked to wear a Zephyr Bioharness around their chest during the Yo-Yo IR1 tests and during 6 league matches in order to allow us to collect the data that is required for the study.

The Yo-Yo IR1 and sprint ability test will require your maximal effort. There may be a very small possibility of you pulling a muscle and you may feel muscle soreness 24 – 48 hours after the test but having performed this test on previous occasions, this muscle soreness is expected to be minimal. Each testing session will take between 45 - 60 minutes.

There is no reimbursement for being involved in the study.

Once the results have been analysed, you will receive a personal report with your results. Individual results will be kept in a safe place and will not be made known to anyone. All the participant's names will remain anonymous so that all data and results are confidential. The results of this study may be written up into academic report however, you as a participant will not be identified. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.

Should you feel that your rights have been violated, you may report this to the Wits REC chairperson, Professor Cleaton-Jones. Email: peter.cleaton-jones@wits.ac.za

I would therefore like to invite you to participate in this study. Your permission to perform these tests is strictly voluntary. Should you do decide to take part, you will be given a consent form to sign and are still free to withdraw from the study at any time without giving a reason and without detriment to yourself. As mentioned above, you will also be required to fill in a medical questionnaire before taking part in the study which will entail disclosing of pre-existing or current medical conditions to avoid any harm being caused by the research.

If there are any questions or concerns they will be answered by the researcher and research supervisor namely:

Researcher: Mr Khavish Harry, 083 736 5085, khavs.harry@gmail.com

Supervisor: Mr Marc Booysen, 011 717 3371, marc.booysen@wits.ac.za

HREC (Medical) contact details:

Prof P Cleaton Jones, Tel 011 717 2301, email peter.cleaton-jones1@wits.ac.za

Ms Z Ndlovu/ Mr RhulaniMkansi/ Mr Lebo Moeng Administrative Officers 011 717 2700/2656/1234/1252 zanele.ndlovu@wits.ac.za; Rhulani.mkansi@wits.ac.za; and Lebo.moeng@wits.ac.za

Kind Regards,

Khavish Harry

APPENDIX B: INFORMED CONSENT

Study: The relationships of activity patterns and heart rate profiles with physical performance tests in premier league club field hockey players from Johannesburg.

Dear Participant,

The aim of this study is to determine the relationship of activity patterns and heart rate profile during matches with physical performance tests in premier league club hockey players.

I, as the participant want to confirm:

1. I am participating of my own accord.
2. I am aware of what will be required of me and I understand the benefits and risks involved in the study procedures of the research.
3. I have also been provided with a written information sheet explaining the study and have been given the time to discuss the research with the person conducting the study.
4. I as the participant am aware that the results of the research will be kept confidential and safe. The data will be destroyed two years post publication or after six years if not published as results will be put into the study report and may be written up into academic reports.
5. I am also aware that I can withdraw from the study at any time without prejudice, from any further study.

Kindly please sign to consent this in the form below. If there are any questions or concerns they will be answered by the researcher and/or supervisor namely:

Mr Khavish Harry, 083 736 5085, khavs.harry@gmail.com
Mr Marc Booysen, 082 495 7691, Marc.Booysen@wits.ac.za

Please return the completed form to the researcher Mr Khavish Harry in a sealed envelope. All data collected will be kept in a safe, locked environment to maintain confidentiality of the information provided.

It must be noted that the results will not influence your hockey career as all data will be coded and kept confidential. The intention of the study is to improve the understanding of club hockey players in relation to physical performance thereby aiding and facilitating the development of current and future

players. All personal information will not be shared with or amongst potential influencers such as coaches, managers or fellow players.

I have read the above and understand all the information about the research that is being done to investigate the relationship in activity patterns and heart rate profiles with physical performance tests in field hockey players.

I consent to participate in this study.

Signature: _____

Witness: _____

Date: _____

Code: _____

Sports Science Masters student:
I herewith confirm that the above participant has been fully informed about the nature, benefits and risks of the research.

Name: _____

Signature: _____

Date: _____

APPENDIX C: MEDICAL QUESTIONNAIRE

The medical questionnaire is made for your own protection in the research study as a preventative measure to see if any participant may not be fully fit to undergo the tests.

The researchers will need a background of pre-existing conditions or current conditions which could cause the participant to not give an accurate measurement of his physical and physiological performance or cause further harm to a pre or current condition.

Please circle **Yes** or **No**:

1. Has a doctor ever said to you that you have a heart condition and that you should not do physical activity other then what your doctor says you can? **(Yes) (No)**

2. Do you feel any pain in your chest when you do physical activity? **(Yes) (No)**

3. Do you lose balance because of dizziness or do you ever lose consciousness? **(Yes) (No)**

4. Do you have a joint or bone problem that you could be made worse by a change in your physical activity? **(Yes) (No)**

5. Has your doctor currently prescribed medication for blood pressure or a heart condition? **(Yes) (No)**

6. Is there any reason why you cannot do physical activity? **(Yes) (No)**

7. Elaborate on any condition/s you have marked **YES** in the above:

8. **I hereby confirm that all the information above is correct and that I have completed the questionnaire with honesty and accuracy.**

Signature:

_____

Date:

_____

PAR Q Adapted from Canadian Society for Exercise Physiology

APPENDIX D: DATA COLLECTION SHEET

Date: _____

Time of Testing: _____

Code: _____

DOB: _____

Gender: _____

Playing position: _____

Data collection pertaining to activity patterns and heart rate profile variables obtained during matches:

Match Profile variables

Activity

Activity: Measured in VMU			
% Time spent at	**1st Half**	**2nd Half**	**Match**
Walking (< 0.8)			
Jogging (0.8 - 1.09)			
Running (1.1 - 1.39).			
Sprinting (≥ 1.4)			

Heart rate

Heart rate recording			
Time spent in HR zones (%)	**1st Half**	**2nd Half**	**Match**
<75% HRmax			
75-84% HRmax			
85-95% HRmax			
≥ 95% HRmax			
90-100% HRmax			
Average Heart rate (HRmean) - bpm			
Maximum heart rate (HRmax) - bpm			

Data collection pertaining to variables obtained during field tests

Repeat Sprint Ability test (RSA)

RSA mean: _____

RSA best: _____

RSA decrement: _____

Aerobic Capacity (Yo-Yo IR1 Test):

Distance (m): _____

Maximum heart rate (HRmax)

bpm: _____

Heart rate recovery (HRR) at 10, 20, 30 and 60 s (bpm).

10 s: _____

20 s: _____

30 s: _____

60 s: _____

APPENDIX E: PLAGIARISM FORM

Postgraduate Office, Faculty of Health Sciences
Wits Medical School, 7 York Road, PARKTOWN, 2193, Johannesburg • Tel: (011) 717 2745 • Fax: (011) 717 2119 • e-mail: healthpg@health.wits.ac.za

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I _____ (Student number: _____) am a student registered for the degree of _____ in the academic year _____.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this in not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.

Signature: _____ Date: _____

APPENDIX F: ETHICAL CLEARANCE

RI 4/49 Mr Khavish Harry

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M161168

NAME: (Principal Investigator)	Mr Khavish Harry
DEPARTMENT:	Centre for Exercise Science and Sports Medicine School of Therapeutic Sciences
PROJECT TITLE:	The Relationships of Activity Patterns and Heart Rate Profiles with Physical Perfomance Tests in Premier League Club Field Hockey Players in Johannesburg
DATE CONSIDERED:	25/11/2016
DECISION:	Approved unconditionally
CONDITIONS:	Title Change (22/02/2017)
SUPERVISOR:	Mr Marc Booysen
APPROVED BY:	Professor P. Cleaton-Jones,Chairperson, HREC (Medical)
DATE OF APPROVAL:	20/02/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and ONE COPY returned to the Research Office Secretary in Room 10004, 10th f1001 Senate House/2nd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. l/We fully understand th the conditions under which I am/we are authorised to carry out the above-mentioned research and l/we undertake t ensure compliance with these conditions. Should any departure be contemplated,from the research protocol a approved, l/we undertake to resubmit to the Committee. I agree to submit a yearly. progress report. The date fc annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. i this case, the study was initially review in November and will therefore be due in the month of November each yea Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

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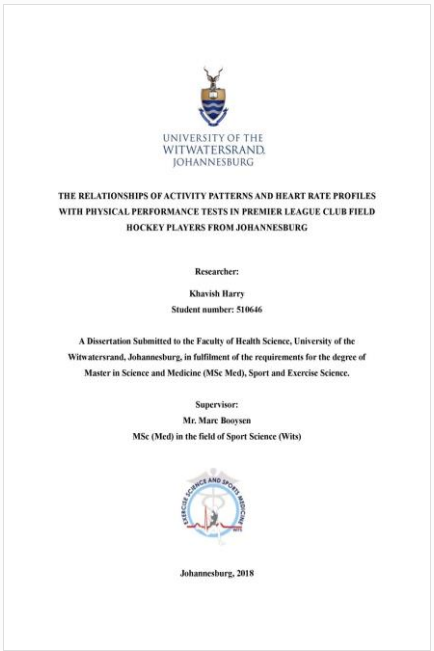
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UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

THE RELATIONSHIPS OF ACTIVITY PATTERNS AND HEART RATE PROFILES WITH PHYSICAL PERFORMANCE TESTS IN PREMIER LEAGUE CLUB FIELD HOCKEY PLAYERS FROM JOHANNESBURG

Researcher:

Khavish Harry
Student number: 510646

A Dissertation Submitted to the Faculty of Health Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master in Science and Medicine (MSc Med), Sport and Exercise Science.

Supervisor:
Mr. Marc Booysen
MSc (Med) in the field of Sport Science (Wits)

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