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THE ASSOCIATION OF TECHNICAL AND TACTICAL PERFORMANCE INDICATORS WITH THE PHYSIOLOGICAL RESPONSES OF ELITE FEMALE NETBALL PLAYERS

Christy Mullender

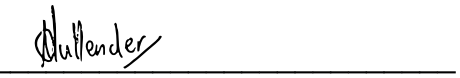
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A dissertation submitted to the Faculty of Health Sciences, University of Witwatersrand, in fulfillment of the requirements for the degree of Master of Science in Medicine by Research.

Johannesburg, June 2018

DECLARATION

I, Christy Mullender, 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 Witwatersrand. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

20th day of June 2018 in Bedfordview.

ABSTRACT

Background

Research shows in a laboratory-type setting that high heart rates can influence technical performance. High physical exertion levels in athletes have been shown to influence technical performance negatively.

Aim

The aim of this study was to investigate if an association between technical and tactical performance indicators existed with the physiological responses of elite female netball players in a competitive match setting. The following objectives were addressed: 1) Record the duration of possession, number of passes and location of centre pass movements, 2) Compare heart rates of all the players involved in the movements which ended in points scored or possession lost 3) Compare the heart rate of the player, at the specific time the ball was released from when a goal was scored or a possession was lost.

Methods

Twenty-nine (n=29) female netball participants (age = 24 ±4.1 years) competed in the Netball World Youth Cup and a national selection camp. The participants' technical and tactical performances were filmed and their corresponding heart rates were monitored with the uses of Zephyr^{TM} Bioharness^{TM} over ten competitive games. Synchronization of data timelines from filming (technical and tactical) and heart rate monitoring were then used to determine the mean heart rates of all players involved in each attacking centre pass movement.

Results

Successful centre pass movements displayed a median of 5 passes (IQR = 4-7) and were 17.0 ±9.1 seconds in duration, both significantly greater compared to unsuccessful centre pass movements ($p < 0.000$ and $p < 0.001$). The mean relative heart rate for successful centre passes was not significantly different from the mean relative heart rate for unsuccessful centre passes (88.5 ±7.4% versus 88.9 ±7.1%, $p > 0.05$).

Conclusion

Although no association was found between heart rate and technical performance, coaches and trainers should utilize this knowledge when designing and implementing training sessions that focus on play from centre passes, to ensure that the players' decision making and ball skills are performed at a heart rate intensity that mimics match play conditions.

DEDICATION

To Domino, I wouldn’t have been able to do this without you. Your chilled vibes, constant reminders that it IS going to be okay and ability to put a smile on my face got me through this.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

Abbreviation	Term
HR	Heart rate
% HR_{max}	Percentage heart rate maximum
BMI	Body mass index
bmp	Beats per minute
CP	Centre pass
hh:mm:ss	Hours: minutes: seconds
kg	Kilogram
kg/m^2	Kilograms divided by height in meters squared
KPIs	Key performance indicators
m	Metres
ms	Millisecond
n	Number
RPE	Rate of perceived exertion
s	Second
vs.	Versus

CHAPTER ONE

1 INTRODUCTION

Netball is a quick and skillful game of fair contest (INF, 1997). The ultimate aim in netball is to outscore the opposition, through scoring more goals and conceding fewer goals than the opposing team (Broome, 2011). For this to occur, possession of the ball needs to be kept in hand and not relinquished which will ultimately prevent the other team from scoring. To prepare a team for such a contest is a complex process involving multiple interactions between technical and tactical behaviours that are influenced by the fitness characteristics of each player (Sampaio et al., 2013).

Sport analysts and coaches make use of performance analysis to evaluate their team and the opposition (Hughes and Bartlett, 2002, pp. 739–754). This is undertaken through the development of technical (skills) and tactical (movement) performance indicators (Hughes and Bartlett, 2002, pp. 739–754). A performance indicator is a range or group of action variables that aims to determine some or all aspects of a performance (James et al., 2007). The performance indicators most often used in netball relate to shots at goal and ball possession (Gasston, 2004). A study by Phillips (2011) investigated possession changes in different performance levels of netball, focusing specifically on the amount of variability in frequency and type of turnovers that occurred during matches. Overall the total number of turnovers was significantly lower for World Class netball teams compared to every other level. The mean for the total number of turnovers for World Class teams was 25.5 (standard deviation not provided) compared to 92.9 (standard deviation not provided) for the lowest performance level, district teams ($p < 0.003$) (Phillips, 2011).

There have been a number of laboratory-based studies investigating the causes of technical error in different sporting codes such as football (Smith et al., 2016), water polo (Royal et al., 2006) and rugby league (Gabbett, 2008). Smith et al. (2016) found an increase in ball control and passing errors when soccer players were mentally fatigued. The authors concluded that mental fatigue may have a negative impact on technical performances during soccer matches. Royal et al. (2006) also discovered that shooting proficiency in water polo players deteriorated as physical exertion increased. It was

concluded that the physiological responses of heart rate and blood lactate were related to exertion, demonstrating that these two factors may be linked to the decline in skill (Royal et al. 2006).

Not only are researchers investigating the link between physical exertion and technical and tactical parameters but coaches and trainers are making use of scientific methods of measuring and monitoring training intensity. This is done to monitor levels of fatigue during the training cycle for both adaptations to training as well as for match-play performance (Halson, 2014). When designing training programmes for specific sports it is imperative to have an understanding of the physical demands that the player experiences during competition (Miller and Bartlett, 1994). The training stimulus should replicate the physical demands that are experienced during competition in order for optimal performance benefits to be attained (Deutsch et al., 1998).

Research exists regarding the physical demands of netball players (Beesley, 2015) and causes of technical error in different sporting codes (Smith et al., 2016). However, there is a lack of research investigating the association between technical and tactical performance indicators, and the physiological responses of elite netball players in competition-based match play. Therefore, this study specifically investigated the physiological responses of players on court during their attacking centre passes.

By recording heart rate responses of netball players during their attacking centre passes, this research study aimed to compare the physiological responses of centre pass movements which ended successfully in a goal to attacking centre passes where possession was lost. The researcher wanted to investigate if heart rate response played a role in the successful outcome of the team's centre passes.

The findings of this study which was carried out in a competitive-match setting, can guide coaches when designing optimal training and conditioning sessions as well as formulating playing strategies to assist coaches in making data-driven decisions.

1.1 Research Question

Is there an association between physiological responses of elite female netball players and the technical or tactical performance indicators during competition?

1.2 Aim

The aim of this study is to investigate if there is an association between technical and tactical performance indicators with the physiological responses of elite female netball players.

1.3 Objectives

1. To record the technical and tactical performance indicators of match play resulting from a centre pass, in relation to duration of possession, number of passes and location of movement (both starting and end positions) on court during competitive matches.
2. To compare heart rates of all players involved in the centre pass movements that end in points scored or possession lost.
3. To compare the heart rate of the player, at the specific time the ball is released from when a shot is taken at goal or a possession is lost.

Hypothesis: During competitive matches, there will be an association between centre pass movements and heart rates. In CP movements that end in possession lost, a higher mean heart rate for all players will be observed.

Null hypothesis: During competitive matches, there will not be an association between centre pass movement success and heart rates. Therefore, no difference in mean relative heart rates will be observed between CP movements that end in either a goal or possession lost.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Netball

2.1.1 The format of the game

Hughes and Franks (2007) describe netball as an invasion game between two teams played with seven on-court players and five substitutes per team. The objective of the game is to score more goals than the opposition team and to ensure possession of the ball is kept in order to win.

The seven on-court players have specific positions limiting their movement to certain areas on the court (Davis, 2006). The two players allowed in the attacking circle, are known as the shooters namely, goal shooter and goal attack (circle players). They are the only players allowed to score goals. Similarly, the two defenders known as the goal keeper and goal defence are the only players allowed in the defensive circle to stop the opposition shooters from scoring goals. The three centre-court players, wing attack, wing defence and centre, are the link between the defence and attack and are free to move in the central third of the court like the goal attack and the goal defence. However, unlike the goal attack or goal defence, the wing attack, wing defence and centre are not permitted into the shooting circles. The centre is the only position that operates in all three zones of the court (attacking, centre and defending thirds) while the other players are restricted to two out of the three thirds (goal attack and wing attack operate in the attacking and centre thirds while the goal defence and wing defence work in the defending and centre thirds) (Hickey, 2007). Figure 1 illustrates the areas on court where each position is allowed to enter (ActiveSG, 2017).

A standard game is made up of four 15-minute quarters. Players are not allowed to move with the ball once they have caught it, or more specifically the landing foot cannot be lifted and placed back down, which is one of the rules which differentiates netball from basketball. Additionally, players have to make sure the ball is released in less than three seconds (3s). If either of these rules are broken possession is given to the opposition.

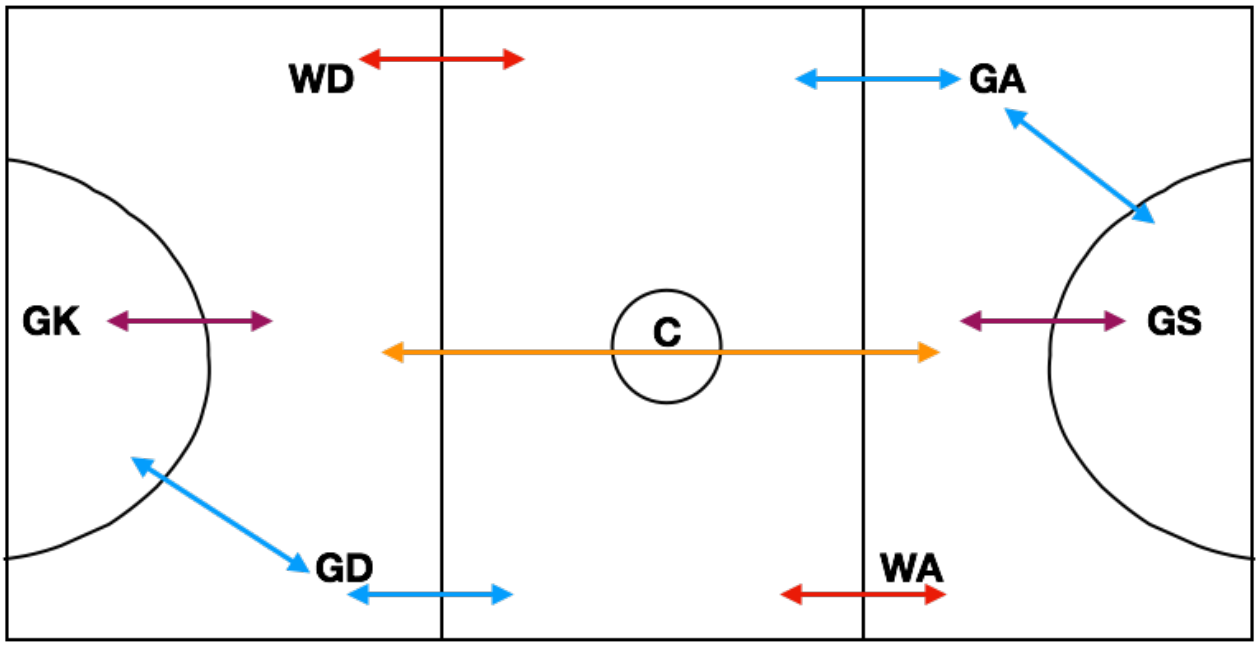


Figure 2.1: The netball court layout with positions identifying which parts of the court the different positions are allowed to enter.

The game starts with the centre passing the ball from the middle of the court with the primary aim of getting the ball to their players in the attacking circle. Shakespear and Caldow (2009a) stated that once the shooters receive the ball in the shooting circle, a shot at goal can be taken. In most cases, a shot is taken from a stationary shooting position thus reducing the dynamic tempo of down-court play to a sudden stop. As soon as the ball leaves the shooter's hands, the tempo increases again as the defending team try to intercept the shot or anticipate a rebound. If the ball passes through the hoop, a goal is scored and one point is given to the attacking team. If the ball does not pass through the hoop but still hits it, and the shooters retain the rebound, another shot can be taken. If the defenders win the rebound ball there is a change in possession and play continues in the opposite direction with a counter attack. If the ball lands out of court, a throw-in is awarded against the team that last made contact with the ball.

Eshman (2017) established that there were on average 110 centre passes per match or 55 per team in an international tournament. These data clearly illustrate the importance of the centre pass during match play. A centre pass restarts play at the beginning of each quarter and after a goal has been scored. It is then alternated between the teams,

regardless of which team scored the last goal. In a netball match if both teams retain possession of the ball during their own centre pass the score in essence should be equal (Eshman, 2017). This rule differs to basketball, in which the team that conceded the goal gets possession (Shakespear and Caldow, 2009b).

To win a netball match a team must outscore their opposition (Broome, 2011) by effectively passing the ball around the court to reach the attacking circle from where a shot at goal can be made. The greater the number of goals that are scored the higher the prominence play from a centre pass has. It would therefore, seem logical to suggest that movements of both the ball and players from a centre pass will be highly influential in determining the outcome of a match. However, little research provides any indication of the technical or tactical requirements or the intensity the players must work at. The simplest way to gain insight into these plays would be to quantify the number of passes and to measure the duration of possession. Possession can be measured (in seconds) as a period of play where one team controls the movement of the ball around the court and ends when the umpires indicate that a goal has been scored, a foul has been committed or when possession changes to the other team, excluding the time the ball is out of play. Each unit of possession (or movement) ends either by points being scored or by possession being lost to the opposition (i.e. a turnover occurs and possession reverts to the opposition) (van Rooyen and Noakes, 2006a and van Rooyen and Noakes, 2006b).

O'Donoghue et al. (2008) conducted a study on netball teams that were either top half or bottom half of the league based on their final position in the league table for that season. The strength of the opponent was found to effect teams in the top half of the league differently to teams in the bottom half of the league. It was found that netball teams who played a higher quality of netball (i.e. finished higher in the league), were more likely to score goals when they had possession of the ball. As the quality of play decreased (i.e. teams that finished in the lower half of the league), more turnovers occurred in open play, which resulted in fewer goals being scored. When top half teams played bottom half teams the percentage of centre passes to goals scored was 54.3% (median value), in comparison to when bottom half teams played top half teams the percentage of centre passes to goals was 31.0% (median value) ($p < 0.001$) (O'Donoghue et al. 2008).

A case study conducted by O'Donoghue and Longville (2004) provided details about the creation of a match analysis and video feedback system for netball. The centre pass was identified, by the national coach, as a vital area to focus on during the analysis (O'Donoghue and Longville 2004). Each centre pass was categorized according to the end result of the movement, such as goal scored, forced or unforced error, loss of possession through an intercepted pass or rule violation, a missed shot either rebounded by the defence or by ball being lost over the backline (O'Donoghue and Longville 2004). The data from this 2004 case study found that there were approximately 90 centre passes per match. A more recent study from a premier netball league in Australia, recorded on average, 109.3 centre passes per game (Eshman, 2017). The data were also expressed according to playing quarter, with quarters one and three having the fewest centre passes averaging 27.0 ±3.3 or 1.8 centre passes per minute. Quarter two was slightly higher with 27.8 ±3.3 centre passes or 1.81 centre passes per minute. However, quarter four averaged the most centre passes with 28.2 ±3.8, equivalent to 1.87 centre passes per minute. The reason given for this higher observation in the later stages of a match was that both teams wanted to score as many goals as possible to win the match and scoreboard pressure is at its highest in the last quarter (Eshman, 2017).

2.1.2 Possession, Turnovers and Errors in Netball

A turnover occurs when possession changes hands. O'Donoghue et al. (2008) have defined a turnover as follows, when the defending team gains possession by intercepting the ball, successfully rebounds the ball after the attacking shooter takes a shot, when an attacking player throws the ball or shoots the ball out of court and a sideline or backline pass is given to the defending team or when the attacking team is penalized for a foul by the umpire and the defending team is awarded a free pass or penalty pass.

Turnovers can be categorized into two types; namely live and restart turnovers (Woodlands, 2006). Live-ball situations are characterized as periods of play uninterrupted by fouls or by the ball leaving the court of play. Live turnovers are subsequently changes in possession, such as a rebound that the opposition picks up, where play continues with a counter-attack. Whereas a restart turnover is a change in

possession when play has been stopped either from the ball leaving the court or by a player committing a foul (Woodlands, 2006). Restart turnovers, as the result of one player committing a foul on an opposing player, are under the discretion of the umpire, as the umpire dictates when a rule has been infringed upon or not (Phillips, 2011).

2.1.3 Causes of Turnovers: Forced Errors, Unforced Errors and Missed Shots

The aim of defending is to pressurize the opponent into making a mistake (Shakespear and Caldow, 2009a) either by missing a shot at goal or by losing possession of the ball. Millar (2012) added that by executing a good defensive strategy and limiting the opponent's options the number of errors will increase, thus turnovers will be created that can lead to more scoring opportunities for the 'defending' team. However, if the attacking team has the freedom to pass the ball and move on court wherever they want to, very few forced errors will occur (Shakespear and Caldow, 2009a).

Errors that are caused by the opposition applying pressure are known as forced errors in tennis (Macmillan Dictionary, 2017). To apply the same terminology to a netball example, when a player is caught in possession of the ball for longer than three seconds (3s), (held ball) then a foul is committed. This type of foul can be considered as a forced error, as it may have been the result of the defending team reducing the options for the player with the ball to make a pass within the permitted three seconds (3s). If a held ball is adjudicated to have occurred by an umpire, a forced turnover will ensue (INF, 2017).

Unforced errors occur when the team with the ball makes an incorrect decision or does not execute a skill correctly, resulting in a poor pass without the influence of the defending team (Shakespear and Caldow, 2009a). Incorrect decisions or unforced errors can result in a turnover of possession which increases the likelihood of the opposition scoring a goal (Main, 2011).

Another type of turnover that could be considered to be either a forced or unforced error depending on the situation, occurs when one of the shooters misses a shot and loses possession through the defenders winning the rebound or the ball going over the back line. Shooters in netball are required to be able to shoot from different angles and distances within the shooting circle (Woodlands, 2006) and the inability to do this could

be due to a poor shooting technique or as a result of pressure from the defending players.

Netball is a game of possession which is made up of successful passes and avoidance of errors or turnovers, as well as scoring goals (Main, 2011). The best way to determine the exact constructs of a netball game is to break these factors down through a method known as performance analysis.

2.2 Performance Analysis

2.2.1 Performance analysis defined

Performance analysis is a method for analyzing physical, technical and tactical aspects of performance and plays a major role in the coaching process of sports (Lythe, 2008). The monitoring of athletes during competition enables sports scientists to develop an understanding of the physical and technical demands within sports. This information is important specifically in elite sporting codes (Lythe, 2008). A study completed by Gasston (2004) found that performance analysis had a significant role to play in the performance enhancement of international netball teams. However, in order for performance analysis to provide constructive evidence to team members and coaches, the information extracted must be applicable to the most important elements of the game (Csataljay et al., 2009).

By extracting these crucial aspects of the game, a number of key performance indicators (KPI's) specific to a sporting code are created. This is supported by Hughes and Bartlett (2002) who define a key performance indicator as a group of action variables that attempt to describe parts of a successful performance or a positive outcome. These indicators can be subcategorized into general match indicators, or as tactical, technical and biomechanical indicators (Franks and Hughes, 2004). Identifying sport specific performance indicators is a means of improving playing efficiency therefore a significant opportunity for performance enhancement (Garganta, 2009).

Through the use of notational and video analysis, it is possible for coaches to ascertain their own and/or their opponents' strengths and weaknesses in technique, tactics and

movement. Objective statistics can also be used to identify effective attacking patterns of play to assist players with their decision-making processes (Elliott and Smith, 1983).

2.2.2 Key performance Indicators in Netball

Research across team sports has shown that ball possession and shots at goal are key performance indicators (KPI's) for successful teams in soccer (Araya and Larkin, 2013). Rugby research has additionally shown that teams who reach later stages of tournaments have a higher percentage of ball possession than teams who were knocked out in the earlier rounds (van Rooyen et al., 2008). It would therefore be intuitive to suggest that the effective use of ball possession would also be a KPI for success in netball as all three sports are similarly classified as intermittent high intensity invasion sports.

A brief review of previous netball research shows that a variety of performance indicators have been investigated. Possession and shooting are the two main areas in netball that have been focused on when matches were analyzed (O'Donoghue and Longville, 2004; O'Donoghue et al., 2008; Gasston, 2004; Kift, 2012 and Abbott, 2006).

Centre passes (O'Donoghue and Longville, 2004) and errors are two other aspects of the game that coaches define as important KPI's however, very little research has been published in this area (personal communication: South African Netball coaching staff).

Key Performance Indicator - Possession

A study by Edwards and O'Donoghue (2004) investigated the differences between winning and losing performances. They examined the technical and tactical analysis of passing and shooting within netball and their results established that teams who generally win execute a higher number of successful passes than teams who usually lose. This was supported by Bruce et al. (2009), who found a significant increase in the percentage of successful passes thrown by expert netball players (89.28 ±3.47%) in comparison to developmental players (84.64 ±2.10%). A team able to complete a series of successful passes will experience a greater chance of maintaining possession of the ball (Edwards, 2004). In order for a team to capitalize on its possession, the sequence of

successful passes must be converted into goals (Phillips, 2011).

Key Performance Indicator - Shooting

Shooting (technical skill) is the most important factor that distinguishes between winning or losing and cannot be analyzed in isolation when investigating factors that determine team success (Edwards, 2004). Scoring goals is one of the most fundamental areas in netball as without converting shots a game cannot be won (Crouch 1992).

Edwards and O'Donoghue (2004) found that significantly more shooting opportunities were created by winning teams (an average of 76.7 shots per match) in comparison to losing teams (an average of 52.3 shots per match) ($p < 0.01$). Roberts and O'Donoghue (2013) wanted to establish if netball shooters were influenced by momentum during matches. However, their only significant results reflected the opposite of momentum, with shooters more likely to score a goal after a missed shot than they were to miss consecutive shots, with $p = 0.009$. The study also ascertained three factors that affected a successful netball shot: 1) the location in the semi-circle where the shot was attempted from, 2) the type of defensive strategy executed by the goal defence and goal keeper and 3) whether or not a contact or obstruction rule infringement was made by the opposition's defensive players against one of the shooters.

A team can only be successful if the shooters have an opportunity to score a goal. This will only be possible if the team is able to get the ball successfully from a centre pass or a turnover to the shooting circle without executing any errors (Main, 2011).

Key Performance Indicator - Errors

The frequency of errors is another important technical area to analyze when assisting coaches and players to understand where possession is being lost (Millar, 2012). This is underlined up by previous studies from O'Donoghue et al. (2008) and Bruce et al. (2009) who emphasized the importance of evaluating error rates within any sport. Main (2011) investigated error rates of netball teams (at the top of the league and the bottom of the league) when playing different qualities (strengths) of opposition. The study found that the quality of the opposition does have an effect on the type and number of errors made

during matches. When teams at the bottom of the league played teams at the top of the league the mean total number of errors made was 139.6. In comparison to when bottom half teams played against teams of the same standard the mean total error rate was 117.3 ($p < 0.05$). In another study, Millar (2012) found that lower quality teams had a higher error rate in the shooting circle when it came to the number of missed shots. However, whatever the cause of the error on court the result is the same, the team in possession with the ball loses possession as a turnover.

Key Performance Indicator - Centre Passes

A sub-category of performance analysis is tactical analysis which looks into the effectiveness of strategies and tactics (O'Donoghue, 2009). Movements or patterns of play, such as the centre pass, is another key area which coaches analyze in the game of netball (Richards et al., 2012). As centre passes are alternated throughout the game it means that each team has an equal number of opportunities to control play. The ultimate aim is to convert the centre pass into a goal scoring opportunity, which is known as a centre pass completion and is the main objective for all netball teams (Richards et al., 2012). However, if an error occurs by the team who took the centre pass, a turnover will ensue and the centre pass will be classified as unsuccessful.

There are limited studies on centre passes in netball, however Palmer et al. (1994) conducted a study on patterns of play of successful and non-successful international netball teams and found that passing the ball forward at the centre pass was a tactical play employed by the more successful international teams. Bateman (2006) compared the centre and back-line passing patterns of World Class and International teams. The findings of this study were that World Class teams: 1) used more passes without losing possession from the centre pass to the goal circle 2) were able to score from the centre pass 3) have a more active goal shooter 4) perform more passes around the goal circle than International teams.

2.3 Physiological Monitoring

2.3.1 What is physiological monitoring

Physiological monitoring can be performed in many different ways from laboratory-

testing to in-field monitoring. Heart rate monitoring in particular has historically been used to facilitate training in different sports (Achten and Jeukendrup, 2003). More recently, advanced technologies have led to an evolution in wearable and portable devices to assist individual athletes, sports teams and physicians to enhance performance and reduce injury (Li et al., 2016).

Responses to exercise intensities or fatigue experienced by athletes can be measured through oxygen uptake, heart rate, blood lactate and rating of perceived exhaustion (RPE) (Scanlan et al., 2015). To accurately assess physiological stress one can measure oxygen uptake by using a breathing apparatus; however, this method is impractical in a competition setting, bulky, costly and difficult to use (Shepherd et al., 2007). Blood lactate testing is a rather invasive method of measuring levels of exertion while RPE is an athlete's subjective quantification of effort. The measurement of heart rates of athletes seems to be the most widespread method of determining exercise intensity (Halson, 2014).

According to Li et al. (2016) heart rate is a valuable, objective gauge of intensity or effort level and physiological adaptation. There is a direct relationship between heart rate and oxygen uptake during intermittent activity, so instead of using intrusive methods, wearable heart rate monitors are increasingly being used to monitor physical activity (Li et al., 2016).

Lythe (2008) reported on a number of different studies where heart rate monitoring was used in different sports such as hockey, waterpolo, soccer and basketball. The studies that Lythe (2008) was referring to looked at athlete's activity profiles, physical demands, physical activity intensities and energy expenditure during competition in conjunction with lab based testing. The mean competition heart rate recorded for Irish elite male hockey players was 159 ±8 beats per minute (bpm) (Boyle et al., 1994), the competition mean heart rate for waterpolo (gender not specified) was 156 ±18 bpm (Platanou and Geladas, 2006), Danish female professional soccer players' mean competition heart rate was recorded at 168 ±1 bpm (Krustrup et al., 2005) and Tunisian elite male basketball mean heart rate was a measured at 171 ±4 bpm during competition (Abdelkrim et al., 2007).

Fernandez et al. (2006) carried out a review on the intensity of tennis match play and suggested that heart rate alone might not be the most accurate indicator of stress intensity. Heart rate does not always reflect VO_2 variations and it is recognized that heart rate can be affected by other environmental influences such as dehydration and thermal stress. Studies by Therminarias et al. (1991) and Bergeron et al. (1995) have found a correlation between heart rate and body temperature, reflecting that climate can have an effect of heart rate. Novas et al. (2003) found that heart rate was slower to recover and recovered less completely than VO_2 and heart rate to VO_2 ratio was increased when participants were recovering during the game of tennis. There was no significant difference in heart rate during rallying and recovery. Therefore, RPE has been suggested to be used in conjunction with monitoring heart rate during research studies (Lyons, 2011).

O'Donoghue (2004) explained in an article on the activity profile of senior netball competitions, that once the activity profile of a particular sporting code is understood by the coaches, a sport-specific high intensity training programme can be designed. By understanding the demands of the sport, the coach will have an idea of the intensity of match-play and the associated work-rest ratios and therefore be able to introduce overload training principles for better gains (O'Donoghue, 2004). The thought behind performing repeated high-intensity training will help players cope with the intermittent nature of the sport, slow down the symptoms of fatigue, reduce the effect of fatigue-induced technical errors thus bettering the chances of winning a match.

2.3.2 Physiological demands in netball

There are limited netball specific studies that have examined the physical demands of netball players (Paget, 2015). However, the revisited findings of the study performed by O'Donoghue (2004) on position-specific work and rest efforts, found that 80% of the activity bursts made by netballers during competition lasted less than six seconds (6s) with a range of low intensity recoveries of short (0-2s, 2-4s, 4-8s), average (8-12s, 12-20s, 20-45s) and long durations (45-90s and 90+s). This suggests that the ATP-PC system is responsible for the shorter high intensity bursts during a netball match, however energy from the glycolytic and aerobic sources will supply the longer bursts of

activity (O'Donoghue, 2004). In their study the centre, wing attack and goal attack had a higher frequency of effort compared to the goal defence and the goal keeper. The goal shooter had a lower activity rate in comparison to the goal attack. This is indicative that attacking players are more active when a team is successful.

Chandler et al. (2014) studied the physical demands of training and competition in collegiate netball players and concluded that the physical demands of match play differ between playing positions and importantly found that netball training did not reproduce the same intensities as match play. Time motion studies have shown that position specific programmes should be designed (Davidson and Trewartha, 2008) and suggest that coaches include overload to the aerobic and anaerobic systems to ensure all positions are able to perform the skills and tactics required of netball during match time (Beesley, 2015).

A study on the work-rate of netball players in training and competitive matches performed by Hale (2004) found that netball players perceived competitive matches as more important than match-play during training sessions. It was shown that levels of cognitive and somatic anxiety were higher for netball players before competitive match-play in comparison to training matches. This could have a roll-on effect, when there is high pre-match anxiety it could lead to a greater work-rate on-court. However, a greater work-rate may not necessarily mean an optimal performance. Some players reacted well to the anxiety which facilitated better play, however others were negatively affected by the anxiety which affected their performance (Hale, 2004).

In conclusion, heart rate can be a measure of physical exertion, however as mentioned in the studies above should not be used in isolation. Wik (2015) for example investigated the activity profiles of handball players in relation to the development of fatigue. The results suggested a decline in activity between halves could be linked to fatigue.

2.4 Physiological Responses to Exercise

2.4.1 Research on fatigue in sport

Fatigue in sport is a multifaceted and complex concept, which if not evaluated in the

correct context could be misinterpreted (Abbiss and Laursen, 2007). Taylor et al. (2012) performed a review on athlete fatigue where muscle physiologists describe fatigue as, a severe decrease in muscle force through performing exercise or a declined ability to perform at maximum effort. Cardiovascular, metabolic and/or neuromuscular factors can all lead to muscle fatigue as reported by Noakes (2000) in a review article on physiological models. Marcora et al. (2009) investigated the mental side of fatigue and defines it as a psychobiological state affected by long intervals of intense cognitive activity.

Fatigue comprises of psychological and physiological factors (Åstrand et al., 2003), therefore, fatigue is not a concept that should be studied in isolation or as a single process (Lyons et al., 2006a).

2.4.2 Exercise intensity linked to declining tactical and technical performance

A number of intervention studies have investigated the impact of induced fatigue on technical skills.

A review conducted by Bangsbo et al. (2007) provided an overview into the relationship between metabolic responses and the development of fatigue in a soccer match. The intermittent periods during the game of soccer, lead to high anaerobic-energy turnover, a build-up of lactate and a decrease pH in the muscles. Although these factors played a role in temporary fatigue, they are not the only influences. Bangsbo et al. (2007) reported that the depletion of glycogen in the muscle fibers could contribute to fatigue at the end of a soccer game. A recommendation was to combine laboratory based research and in-field studies to explore the cause of temporary fatigue (Bangsbo et al., 2007).

Gabbett (2008) observed an influence of fatigue on tackling technique in rugby league players. Participants performed one-on-one tackling drills before and after going through rugby-specific repeated-effort exercises at different intensities in order to induce fatigue. The intensity was measured and a progressive increase was recorded for the following variables: total repeated-effort time (effect size = 0.4-1.2), heart rate (effect size = 7.8-11.2), lactate accumulation in the blood (effect size = 7.9-9.5) and ratings of perceived

exertion (effect size = 7.5-61.8). Tackling technique demonstrated a gradual decrease in proficiency when fatigue was introduced, decreased ability to contact the target in the center of gravity (small difference effect size = 0.4), a failure to wrap arms around the target on contact (large difference effect size = 1.7) and a decreased alignment of the body (i.e., body not square/aligned) (small difference ES = 0.4). Therefore, in this study, the results showed a direct relationship between fatigue and a decrease in tackling technique.

The effects of fatigue on the kinematics of free throw shooting among highly skilled collegiate male basketball players was assessed by Uygur (2009). Participants were asked to perform free throw shots (two successful and two unsuccessful shots) in pre- and post-fatigue conditions. The fatigue protocol comprised of sprints and squat jumping, until participants reached volitional exhaustion. Heart-rate was taken pre- and post-fatigue protocol ($p < 0.01$). The study observed that fatigue did not influence free throw shooting and there was no significant joint angle (elbow, trunk, knee and ankle) difference ($p > 0.05$) between successful and unsuccessful shots. Uygur (2009) suggested that a possible reason for the lack of fatigue effects on kinematic free throw shooting in his study was because the participants were highly skilled basketball players. Uygur's (2009) assumption was based on the findings of Lyons et al. (2006b) study where detrimental fatigue was found to affect beginner basketball player's passing performance more so in comparison to highly skilled players.

Royal et al. (2006) investigated the effects of a waterpolo-specific fatigue test had on decision making, technical performance and shooting proficiency. The fatigue protocol consisted of sets of a water polo-specific drill performed at different intensities. A light intensity set was followed by a longer recovery interval (80s) in comparison to a higher intensity set which had a short rest period afterwards (10s). A task that involved video-based temporally occluded decision-making, where participants had to give verbal responses to different tactical situations, was carried out post-fatigue test. Results from this study established that when fatigue was increased in stages through declining rest-ratios, decision making accuracy improved ($18.0 \pm 21.8\%$, $p < 0.008$). Royal et al. (2006) discovered that shooting proficiency in water polo players deteriorated as exertion increased. According to the results of the lab-based study, heart rate and blood lactate

responses to the increased effort were directly related to the decline in skill observed ($p < 0.001$). Heart rate, rate of perceived exertion (RPE) and lactate concentration, which can all be indicators of exercise intensity and fatigue, increased in response to physical demands (exercise) resulting in a decline in technical performance (43 ±24%, $p < 0.001$) and accuracy while speed of the ball during a goal shot was unaffected.

Passing performance in soccer players was researched in a test-based setting, where localized muscle fatigue significantly decreased passing performance in three different fatigue states: rest and moderate fatigue and high fatigue ($F_{2.38} = 5.183$, $p < 0.01$, power = 0.797). The fatigue protocol consisted of a percentage of the maximal number of split squat repetitions in one minute (Lyons et al., 2006b).

The findings on physiological fatigue research that have been produced thus far have provided contradictory results. Lyons et al. (2006a) suggests one of the reasons for this is because the studies have not followed similar experimental designs and procedures.

Smith et al. (2016) investigated the effects of mental fatigue on soccer-specific physical and technical performance and concluded that mental fatigue impairs soccer-specific response accuracy and response time. Two studies were carried out, 1) the Yo-Yo Intermittent Recovery Test, Level 1 and 2) the Loughborough Soccer Passing and Shooting Tests. Both tests were conducted on two different occasions, one after 30 min of the Stroop task (mentally fatiguing treatment) and the other after 30 min of reading a magazine (the control group). Mental fatigue (subjective ratings) was measured before and after the test and motivation and mental effort were measured post-test. Response accuracy was lower in the mental fatigue condition (80.9 ±6.4%) compared to the control group (85.7 ±4.9%; effect size = −0.89 ± 0.73). Response time was slower in the mental fatigue condition (768 ± 134 ms) compared to the group condition (685 ±156 ms; effect size = 0.49 ±0.47). However, there was no significant difference observed for heart rate between the two conditions.

2.4.3 How Some Coaches Maintain Intensity During Competitive Play

A squad is selected before a match, which is made up of a starting line-up and bench players. Player substitution is when the coach replaces one player with another player, depending on the rules of that particular sport. Some sports have a restriction on the timing of when a substitution can be made and some only allow a certain number of players to be substituted.

Substitutions are made for a whole variety of different reasons which include: to replace an injured player, a strategic move based on the opposition's players, the score-line and the amount of time that is remaining. Higham et al. (2012) investigated the effects of tournament fatigue and substitute players, their work suggested that coaches perform a purely tactical move by substituting players towards the end of the match. This is in order to alleviate the possibility of fatigue negatively affecting individual and team performance. Coelho et al. (2012) found a similar result when they investigated the effect of player substitutions on the intensity of second-half soccer match play using heart rate as an intensity parameter. Comparisons were made between first half – effort intensity (86.3 ±3.3 $\%HR_{max}$), second half – effort intensity (80.6 ±4.4 $\%HR_{max}$) and second half with substitutions – effort intensity (83.6 ±2.8 $\%HR_{max}$). Effort intensity was reportedly higher when substitutes were included as opposed to the second half effort intensity without substitutions ($p < 0.05$). Therefore, bringing on substitute players at half time can ultimately maintain the high intensity of performance that was recorded during the first half, increasing the overall intensity of match play.

Another tactical substitution move made by coaches during competitive matches which is based on score-line, is to replace players when a guaranteed win or an unavoidable loss is on the cards (personal communication: South African Netball coaching staff). Replacements can also be made to prevent injury of key players likely to occur due to fatigue (Fuller et al., 2010).

2.5 A summary of the literature review

Netball is characterized as a high-intensity intermittent sport however, unlike the majority of team sports, netball players have very specific positional constraints that influence the way a match is played. Research has shown that the ability of teams to control the movement of players and the ball around the court are at a significant advantage and are more likely to be associated with a greater pass completion rate, fewer mistakes that result in a turnover of possession, the creation of more scoring opportunities and ultimately are more adept at scoring goals.

Physiological monitoring is an important technique for quantifying player load in sport. Time-motion studies have provided an indication of the activity demands of netball players and have found that the positions have different profiles. The centre position is involved in the greatest number of events while the goalkeeper and goal shooters perform the fewest. Heart rate devices are also commonly used to monitor physiological responses in athletes as they provide simple, efficient and non-intrusive ways to gauge exercise intensity. The physical requirements of netball need to be understood in order to develop appropriate training programs that mirror (or overload) the demands of competition. These specifically developed programs aim to reduce the negative influence that fatigue has on the physical and technical performances of the players and to promote a greater chance of winning.

Limited research studies have determined whether high physiological loads have adverse effects on technical and tactical indicators (i.e. centre pass movements). Research shows that there is a detrimental effect in the laboratory, however a lack of research has been completed in a field setting. Determining if there is a difference in physical exertion levels between centre pass successful and unsuccessful movements during competitive match-play is vital for the coach to develop and implement appropriate training programs as well as make data-driven decisions.

CHAPTER THREE

3 METHODS AND MATERIALS

3.1 Study Design

An observational, prospective study design was used to determine the association between physical match demands and tactical and technical performance in elite netball. Therefore, the junior World Cup tournament and senior national selection camp presented the only feasible opportunity to conduct research of this nature.

3.2 Sample

In this study, a non-probability sampling technique (convenience sampling) was used, thus no sample size calculation was performed. The available sample was based on the opinions of the national selectors. The players selected for the junior and senior squads, were then invited to participate in this study. Permission was granted by the chief executive officer (CEO) of Netball South Africa for the researcher to approach the junior and senior national teams, approval was also given by the head coaches and finally an invitation was sent to all the players inviting them to participate in this study. Of the elite junior players 100% volunteered to be part of this study, whereas only 79% of the elite senior players volunteered and took part.

Twenty-nine (n=29) elite female netball players volunteered to participate in the study and provided written consent. Twelve (n = 12) participants (age range: 20-21 years, body mass: 74.8 ±9.9 kg, height: 1.8 ±0.1m, and body mass index (BMI) of 23.7 ±1.5 kg/m^2) represented the national junior netball team in the Netball World Youth Cup 2017 and 19 participants (age range: 20-33 years, body mass: 71.7 ±9.0 kg, height: 1.8 ±0.1 m, and BMI of 22.5 ±1.7 kg/m^2) attended the senior selection camp for the national netball team. Two of the nineteen senior player participants were from the junior netball team.

The fitness and physical training programmes that the junior and senior players followed varied according to the province, club and or university that they represented. Typical pre-season weekly training content would comprise of: four combined upper and lower

body strength gym sessions, two speed and agility sessions, four anaerobic focused running sessions, two aerobic training sessions and four core sessions. Typical in-season weekly training programme would consist of: two power gym sessions, one speed and agility session, one anaerobic focused running session, two aerobic running sessions, two tactical and team training sessions and two competitive games. The junior world cup and the national selection camp were held in-season, one month after the annual semi-professional netball league, a week after the local university tournament and a month before the international Quadrangular series which highlights that all players were at peak fitness.

3.3 Location

The national junior netball team were filmed and monitored during seven competitive matches throughout a nine-day international tournament, held in Botswana in July 2017. The matches were played against Australia, Barbados, New Zealand, Jamaica, Uganda, Zimbabwe and Singapore and all games were played indoors on wooden sprung floors. Additionally, three selection matches from a five-day national senior selection camp, held in Pretoria in July 2017, were filmed and monitored to include players from both teams playing against each other. All the selection games were played on synthetic flooring indoors.

3.4 Procedures

Before each game, the clocks on the two laptops that were capturing the video footage and the physiological data were synchronized to ensure the exact times were allocated to the two sets of data. This was achieved by setting the clocks to the exact same time to the second. Both data sets were downloaded on a daily basis and a backup was created for both the video data and the physiological data to ensure safety of the information.

3.4.1 Video Footage

The highest vantage point behind the goal line was chosen at each venue however, due to the different facilities at the world cup and the selection camp, the position of the cameras could not be standardized; One camera (Canon XA25 Professional HD

Camcorder; Canon, USA) was used to record on-the-ball play, so that skilled performance was captured at all times during a match. An additional static camera (Sony Handycam DCR-SR68/SR88; Sony, Japan) was used to record the full court throughout the match so that the movements of the players and umpires could be determined. Both cameras were started and stopped at exactly the same time at the beginning and end of each quarter, resulting therefore, with a total of eight 15 minutes video clips (different views) per game.

3.4.2 Technical and Tactical Performance Analysis

On completion of the tournament and selection camp, the video footage from both angles (on-the-ball play and full court) per quarter were combined into one movie using a digital analysis software programme (SportsCode Pro version 11.2.10; Hudl; USA) to create a more complete view of on court performance. A coding template consisting of the key performance indicators developed by the researcher and qualified by the national coach, was used to classify the events that occurred in each game.

Post-event analysis of the performance indicators was conducted by the researcher and was crosschecked independently by two experienced national coaches (Head Coach: Level 2 Netball Coaching Certificate, coaching at a national level since 2006 and Assistant Coach: Level 2 Netball Coaching Certificate, coaching at national level since 2015) to ensure a high degree of accuracy was attained for each different event. Each game was allocated a number and each KPI was logged and categorized according to playing level, i.e. junior (junior world cup players) or senior players (player's chosen to attend the selection trials for the national team). The actions of individual players were also incorporated into each instance in order to simplify the synchronization process with the heart rate data at a later stage.

The technical and tactical data (duration in possession, number of passes and location of possession lost) were categorized according to the performance level of the team to assess whether there were any differences between the two groups from an experience/age aspect.

3.4.3 Reliability

Reliability of the computerized system was evaluated using an inter-operator reliability study. The same 15 minute quarter was analysed with limited key performance indicators to code. Table 1 shows 100% accuracy between the two operators (Hughes and Franks, 2007) for all events except for duration in possession. The duration in possession found errors but they were less than 1%. The level of reliability achieved was deemed to be acceptable for the purpose of this study.

Table 3.1: Data collected by two independent observers using the computerized system

Observer 1	Event	Observer 2	% Difference
11	Goal	11	0
3	Missed Shot	3	0
6	Possession Lost	6	0
8	CP Unsuccessful	8	0
7	CP Converted	7	0
0	CP Converted: 1 Pass	0	0
0	CP Converted: 2 Passes	0	0
1	CP Converted: 3 Passes	1	0
0	CP Converted: 4 Passes	0	0
3	CP Converted: 5 Passes	3	0
1	CP Converted: 6 Passes	1	0
1	CP Converted: 7 Passes	1	0
0	CP Converted: 8 Passes	0	0
1	CP Converted: 9 Passes	1	0
2	CP Unsuccessful: 1 Pass	2	0
0	CP Unsuccessful: 2 Passes	0	0
0	CP Unsuccessful: 3 Pass	0	0
0	CP Unsuccessful: 4 Pass	0	0
2	CP Unsuccessful: 5 Pass	2	0
1	CP Unsuccessful: 6 Pass	1	0
1	CP Unsuccessful: 7 Pass	1	0
1	CP Unsuccessful: 8 Pass	1	0
1	CP Unsuccessful: 9 Pass	1	0
1	Possession Lost: Zone 1	1	0
3	Possession Lost: Zone 2	3	0
2	Possession Lost: Zone 3	2	0
2:09.1 min	Duration in possession for all converted CP movements	2:09.8 min	0.5%
01:48.8 min	Duration in possession for all unsuccessful CP movements	01:49.3 min	0.4%

3.4.4 Physiological Responses

Physiological monitoring devices (Zephyr™ BioHarness™; Zephyr Technology, Auckland, New Zealand) were positioned around the chests of all netball players before the warm up of the match by the team physiotherapist. Absolute heart rate (bpm) data were collected each second during the game and were transferred post-game from each device into an Excel spreadsheet. The timeline (in hh:mm:ss) of each player's physiological data recorded in one second epochs. Relative heart rate (percentage of heart rate maximum or %HRmax) for each netball player was calculated using the age-predicted maximal heart rate equation: HR_{max} = 208-(0.7 x age) in healthy adults (Tanaka et al., 2001). If a higher heart rate was recorded during the game, then it replaced the age-predicted maximal heart rate (Deutsch et al., 1998). Intensity zones were used to categorize the relative heart rate data: maximal (>95% HR_{max}), supra-threshold (85-95% HR_{max}), anaerobic threshold (75-84% HR_{max}) and sub-threshold (<75% HR_{max}) (Woolford and Angove, 1991).

3.4.5 Physiological monitoring devices: Zephyr™ BioHarness™

The BioHarness™ is a wearable device used to monitor and record physiological variables. A field based reliability and validity study of the Zephyr™ Bioharness™ was conducted by Johnstone et al. (2012) where heart rate, breathing frequency and accelerometry were tested by using two Bioharness™ devices which took measurements at the same time. Results for heart rate ($r = \sim 0.91$, $p < 0.01$) and accelerometry ($r > 0.97$, $p < 0.01$) suggested these variables are reliable. The outcome of the study was the Zephyr™ Bioharness™ is reliable and valid to test heart rate and accelerometry in a field-based setting (Johnstone et al. 2012).

3.5 Data Management

Analysis of the video was completed post tournament, to determine the following outcome variables from a centre pass: 1.) duration of every individual unit of possession recorded in seconds, 2.) the number of passes involved in each movement and 3.) the start and finish locations of movements while the team had possession of the ball.

Each unit of possession (or movement) was classified according to how the movement

ended, either; (1) Centre Pass (CP) converted where points were scored (i.e. Attacking team's centre passes which ended in a successful shot) or (2) CP unsuccessful where possession was lost (Attacking team's centre pass which ended in an error and possession reverted to the opposition – this included a missed shot as the ball could have gone over the backline and it would have then been an opposition throw in).

Mean relative heart rates were calculated by taking the sum of all the average $\%HR_{max}$ of all players involved in a movement divided by the total number of players involved. The movement started from the moment the ball left the centre's hand at the beginning of the centre pass until the ball left the hand of either 1) the shooter to score a goal or 2) a player lost possession of the ball. The specific heart rate that was recorded for goals scored, missed shots and possession losses was the relative heart rate at the exact time point when the ball left the player's hand.

All the technical match and physiological data were sorted in chronological order using Microsoft Excel to have a reference point for each set of data. The excel VLOOKUP function was used to match timelines of the relative heart rate (physiological) and video (technical) data (accurate to within 0.5s). Synchronizing the two sets of data determined the heart rate response of all the players involved over the complete duration of each movement or a specific point in time of an event.

Data was entered into a Microsoft Excel and Statistica (StatSoft, Inc; USA) were used for all statistical analysis. Statistical tests chosen were based on the type of data (continuous, discrete, ordinal or nominal), number of groups being analysed (1, 2 or 2 or more), what the hypothesis was testing for (correlation, variances, means or association) as well as the normality of the graph (Marshall, 2016).

3.5.1 Technical and Tactical Performance Indicators

All centre pass movements were analysed and split into two categories: 1) centre pass converted (centre passes ending in a goal) and centre pass unsuccessful *(*centre passes ending in possession being lost).

The duration of possession (measured in seconds) and the number of passes were

expressed as median (IQR) for each movement. The Shapiro Wilk Test was used and data was found to be not normality distributed. Therefore, centre pass converted and unsuccessful centre pass movements were compared according to duration of possession using one sample t-test and number of passes using the Kruskal-Wallis test, significance was observed at $p < 0.05$. The centre pass movements were represented as relative frequency data according to duration of possession. These data were split into 5 second time bins for ease of analysis and visual representation. The number of passes per movement were also represented graphically as frequency data.

The final location of the centre pass movements were subjectively classified according to the zone of play on the court where the ball ended, using the painted court lines (Appendix A). All movements began with the centre pass starting in zone 3. All centre passes that were converted ended in the attacking shooting circle, zone 1. However, possession losses differed according to which zone the movement ended in. The video analysis data relating to possession losses of unsuccessful centre pass movements has been represented as frequency data according to the end zone of the movement and analyzed for statistical significance using the Kruskal-Wallis test, significance was observed at $p < 0.05$.

All data of the three technical or tactical measures between the movements that ended in points scored or in a loss of possession were categorized according to the performance level of the team to determine whether there were any differences between the two groups. Relative frequency data of centre passes converted and unsuccessful centre passes were compared for duration of possession, number of passes and location of possession losses according to junior and senior teams. These were analyzed for statistical significance using Kruskal-Wallis tests with the significance observed at $p < 0.05$.

3.5.2 Relative heart rates of players involved in centre pass movements

The relative heart rates of all players involved in the movements for centre passes converted and centre passes unsuccessful grouped per intensity zone and were tested for normality using the Shapiro Wilk Test. The data was found to be not normally distributed, therefore the Kruskal-Wallis test was used to compare the groups for

statistical significance, which was observed at $p < 0.05$. The mean relative (%) heart rates of all players involved in the movements have been expressed as mean ±SD and median and range.

3.5.3 Heart rates at specific events: Goals scored, missed shots and possession losses

The relative heart rate of the player, taken at the specific time the ball was released from the hand when a shot was taken or a possession was lost i.e. turnover during play or a missed shot when the ball went over the backline resulting in opposition throw in, was analyzed using the Kruskal-Wallis test. This test was chosen on the basis that the data was found to be not normally distributed using the Shapiro Wilk test. Statistical significance was set at $p < 0.05$. Heart rate records were classified based on the event that took place: 1) goal scored 2) missed shot and 3) possession lost.

The shots taken and goal success rate data, comprising of goals scored and missed shots, were combined and categorized according to the two shooting positions (goal shooter and goal attack) to find out the proportion of shots taken by each shooter and the intensity zones the shots were taken in and was analyzed using a one sample t-test and the Kruskal-Wallis test.

3.6 Ethical consideration

An information session was held with the potential participants (players). Information sheets were provided beforehand to inform potential participants about the study. Potential participants were given the opportunity to ask questions. Thereafter, the researchers invited the players to volunteer in this study. Players who volunteered were asked to sign an informed consent (Appendix B). Participants were aware that if they decided to withdraw at any time point during the study, they were free to do so without prejudice. There were no risks involved with this study as physiological data was monitored unobtrusively as per normal participation in a netball tournament. The researchers of this study state that all data gathered have been represented truthfully and were not falsified in any way. The researchers guarantee that all personal information of subjects who participated in this study will remain confidential. Results have remained anonymous. All data has been kept in a secure location. Ethics

clearance certificate received, HREC number: M170531 (Appendix C).

3.7 Pilot study

Preliminary data, both video footage and physiological responses, were collected before July 2017 during a practice match. The pilot study allowed assessment of the logistics associated with the project, especially the setting up and running of filming equipment and the Zephyr technology to test the data collection procedures. The pilot study video footage was analysed to develop the operational definitions (Hughes, 2004) but was not used in the sample for this study.

CHAPTER FOUR

4 RESULTS

4.1 Anthropometric

The anthropometric values for the subjects involved in this study consisted of age (years), weight (kg), height (m), body mass index (kg/m^2) and heart rate max (bpm). The junior netballers weighed more (74.8 ±9.9 vs. 70.8 ±7.6) and had a higher body mass index (23.7 ±1.5 vs. 22.1 ±1.2) than the seniors, although no significance was found ($p > 0.380$ and $p > 0.056$). These descriptive characteristics have been summarized in Table 4.1.

Table 4.1: Descriptive and anthropometric values for the junior and senior players

	Junior Players Mean ±SD (n=12)	**Senior Players Mean ±SD (n= 19)**	**(t-test, p-value)**
Age (years)	20.6 ±0.5*	26.8 ±3.5	0.001*
Weight (kg)	74.8 ±9.9	70.8 ±7.6	0.380
Height (m)	1.77 ±0.09	1.78 ±0.08	0.726
BMI (kg/m^2)	23.7 ±1.5	22.1 ±1.2	0.056
HR_{max} (bpm)	195.4 ±2.7	195.3 ±12.6	0.942

* Significantly younger than seniors

kg = kilogram, m = metres, BMI = body mass index, kg/m^2 = kilograms per metre square, HR_{max} = heart rate maximum in beats per minute

4.2 Technical and Tactical Performance Indicators

A total of 621 centre passes were analysed for Objective 1. Fifty-eight percent (n=358) were CP converted movements while the remaining 42% (n=263) were CP unsuccessful movements.

Table 4.2: The number of passes represented as median (IQR) and mean duration of possession for each centre pass movement

	Centre pass converted (n = 358)	**Centre pass unsuccessful (n = 263)**	**p-value**
Number of passes (Median (IQR)	5 (4-7)*	4 (2-6)	0.000
Duration (s) (Mean ±SD)	17.0 ±9.1*	10.1 ±8.1	0.001

*Significantly greater than unsuccessful centre passes ($p < 0.001$)

4.2.1 Duration of centre passes

The mean duration of possession recorded for a converted CP was 17.0 ±9.1s and 10.0 ±8.8s for unsuccessful CP movements (Table 4.2). A significant difference ($p < 0.001$) and a moderate effect size were found ($d = 0.7$) between the two CP movements categories. Thirty-two (32%) of the unsuccessful CP were under three seconds (3s) in length. The minimum duration the ball was kept in possession for all converted CP was five seconds (5s) as opposed to 0s for unsuccessful CP movements (Figure 4.1). The maximum duration of possession for converted CP and unsuccessful CP were 53s and 44s respectively.

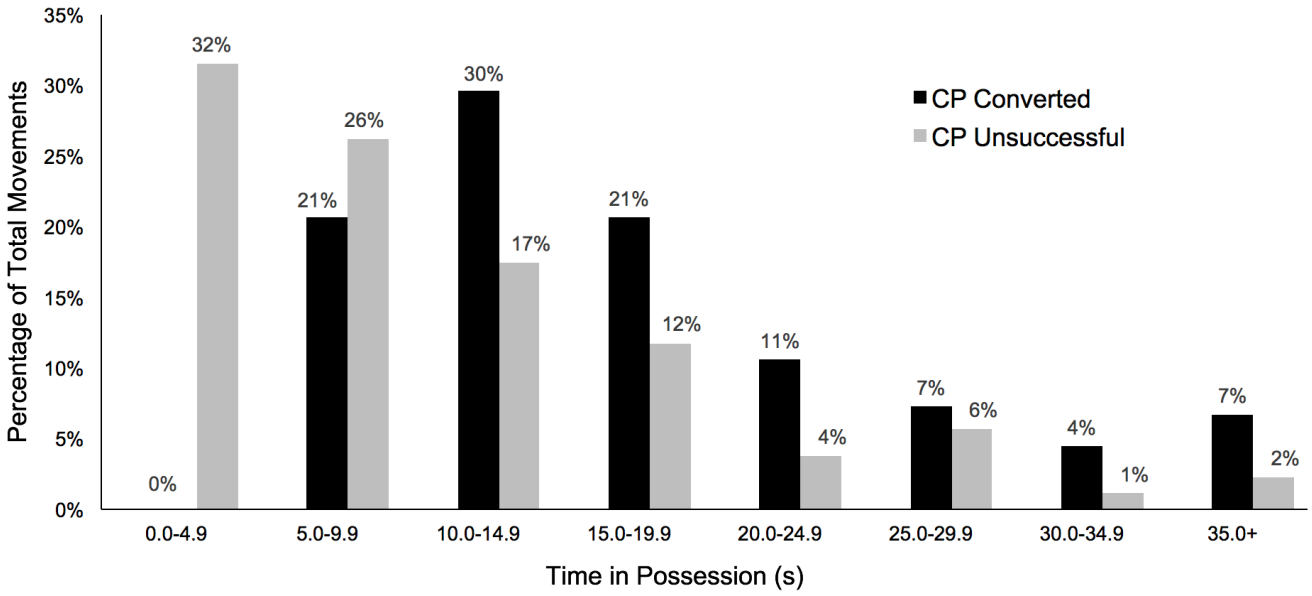


Figure 4.1: The relative frequency of the durations the ball was kept in possession for converted centre pass and unsuccessful centre pass movements

4.2.2 Number of passes

The 358 converted CP movements in this study displayed a median of 5 passes (IQR = 4-7) with a minimum number of 2 passes and a maximum of 14 passes. Of the 263 unsuccessful CP movements presented a median of 4 passes (IQR = 2-6) with a minimum number of 0 passes and a maximum of 13 passes (Figure 3). A significant difference ($p < 0.000$) was found between the two CP movements categories. The relative frequency range of the number of passes per movement recorded for each centre pass category established that a minimum of 2 passes must be successfully executed for a goal to be scored (Figure 4.2).

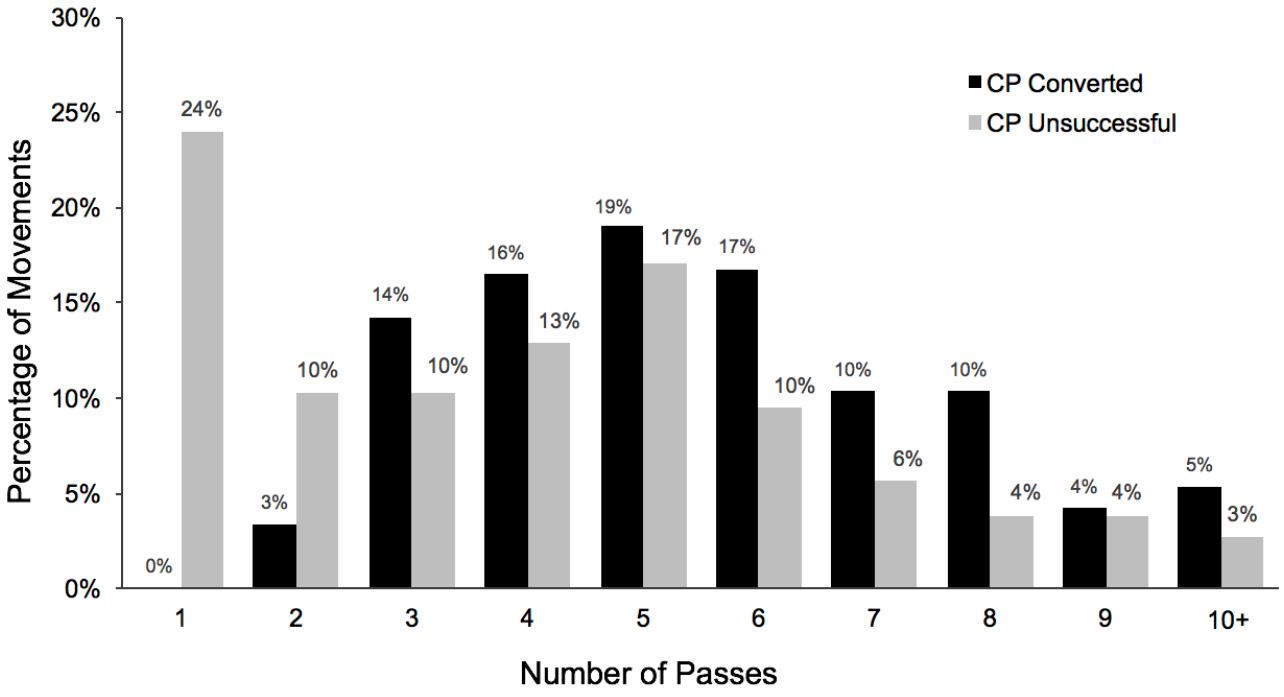


Figure 4.2: The relative frequency of the number of passes recorded for converted centre pass and unsuccessful centre pass movements.

4.2.3 Location of possession losses

Thirty-six percent of the possession losses (unsuccessful CP) occurred in zone 1 (attacking circle), 38% in zone 2 (attacking 3rd) and 25% in zone 3 (centre court) (Figure 4.3). No significant differences were found ($p = 0.066$) between any of the zones despite the visible difference between the middle and attacking thirds (Figure 4.3).

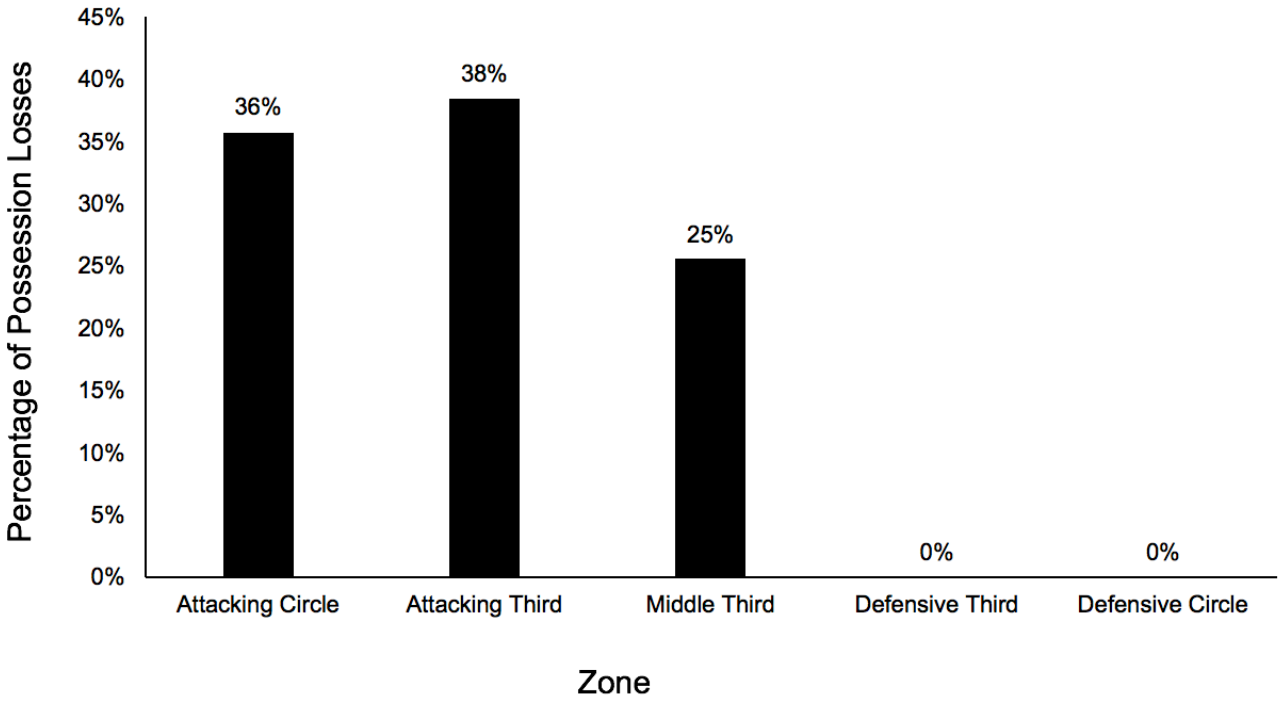


Figure 4.3: The relative percentage of possession losses per zone.

The technical and tactical data (duration in possession, number of passes and location of possession lost) were categorized according to the performance level of the team to assess whether there were any differences between the two groups from an experience/age aspect.

4.2.4 Experience and age effect on duration of centre passes

There was no significant difference noted between the age groups for the mean duration of possession for converted centre pass movements (junior (n=205) and senior (n=153, p = 0.13). However, it was noted that the senior players scored a goal from a greater proportion of centre passes in under 15 seconds than the junior team did (57% successful CP movements less 15s for the senior vs. 45% for the juniors) (Figure 4.4A). Similarly, the mean duration in possession for an unsuccessful CP was not significantly different between the junior and senior age groups (junior (n=133) and senior (n=127) and p = 0.1). The senior players had a greater propensity to lose possession from a centre pass within 15s than their junior counterparts (80% of unsuccessful CP movements compared to 70% for senior and junior age groups respectively) (Figure 4.4B).

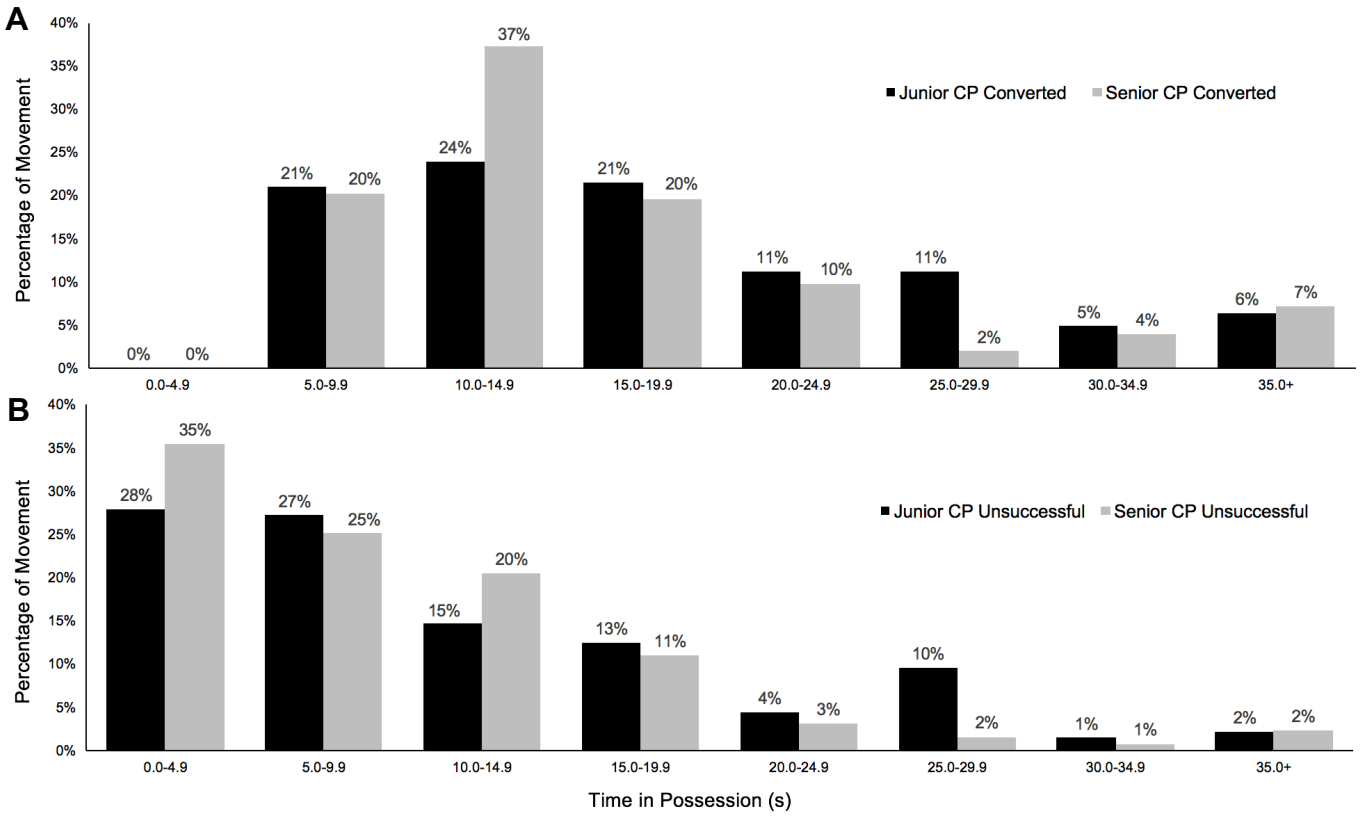


Figure 4.4: (A) The relative duration the ball was kept in possession per centre pass converted movement for junior and senior teams (B) The relative duration the ball was kept in possession per centre pass unsuccessful movements for senior and junior teams.

4.2.5 Experience and age effect on number of passes

No significant differences were found for the mean number of passes between junior converted CP and senior converted CP ($p > 0.35$). The junior and senior unsuccessful CP movements had similar distribution for the number of passes in movements where possession was lost ($p = 1$).

4.2.6 Experience and age effect on location of possession losses

There were visual differences between the junior and senior teams with regards to the zones where possession (unsuccessful CP) was lost with the junior teams tending to lose possession more frequently in the attacking third of the court whereas the seniors tended to lose the ball more often in their attacking circle (Figure 4.5). These differences were not however significant ($p > 0.75$)

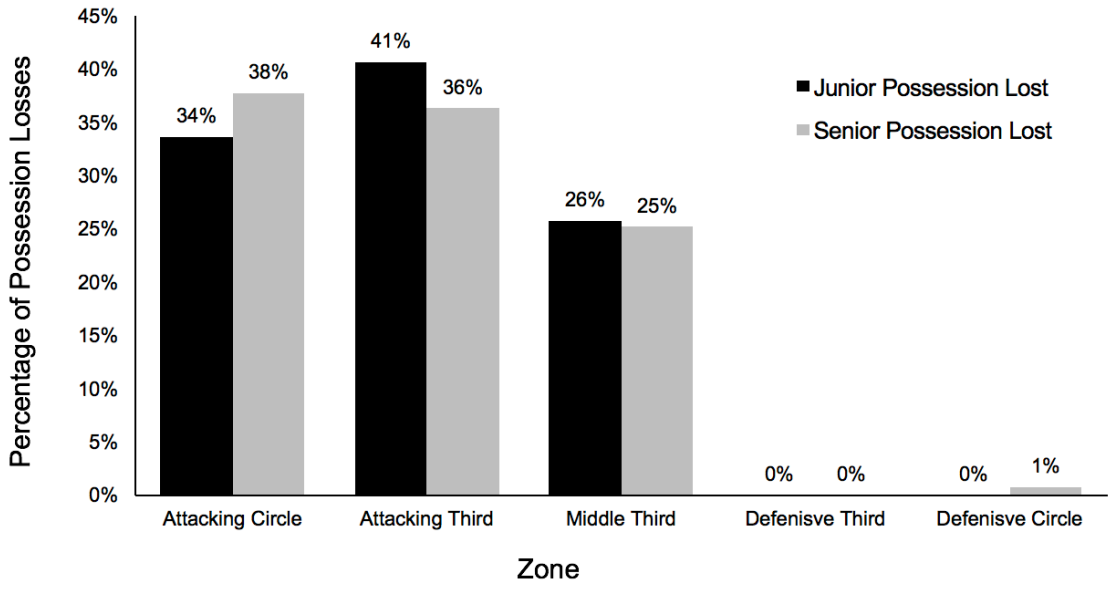


Figure 4.5: The number of possession losses per zone broken into junior and senior teams.

4.3 Heart rates of players involved in centre pass movements

562 centre passes were analysed to determine whether there was any relationship between %HR_{max} and success of the centre pass movement (Table 4.3).

Table 4.3: Mean and standard deviation of relative heart rates (%) for all movements.

	Centre pass converted Mean ±SD (n = 326)	**Centre pass unsuccessful Mean ±SD (n = 236)**	**p-value**
%HR_{max}	88.5 ±7.4	88.9 ±7.1	p = 1

There was no difference in the mean relative (%) heart rates of involved players for CP converted movements (88.5 ±7.4 %) and CP unsuccessful movements (88.9 ±7.1 %) ($p > 0.39$) (Table 4.3). The majority of the CP movements, converted (74%) and unsuccessful (74%) were performed between 85-95 %HR_{max} (Figure 4.6).

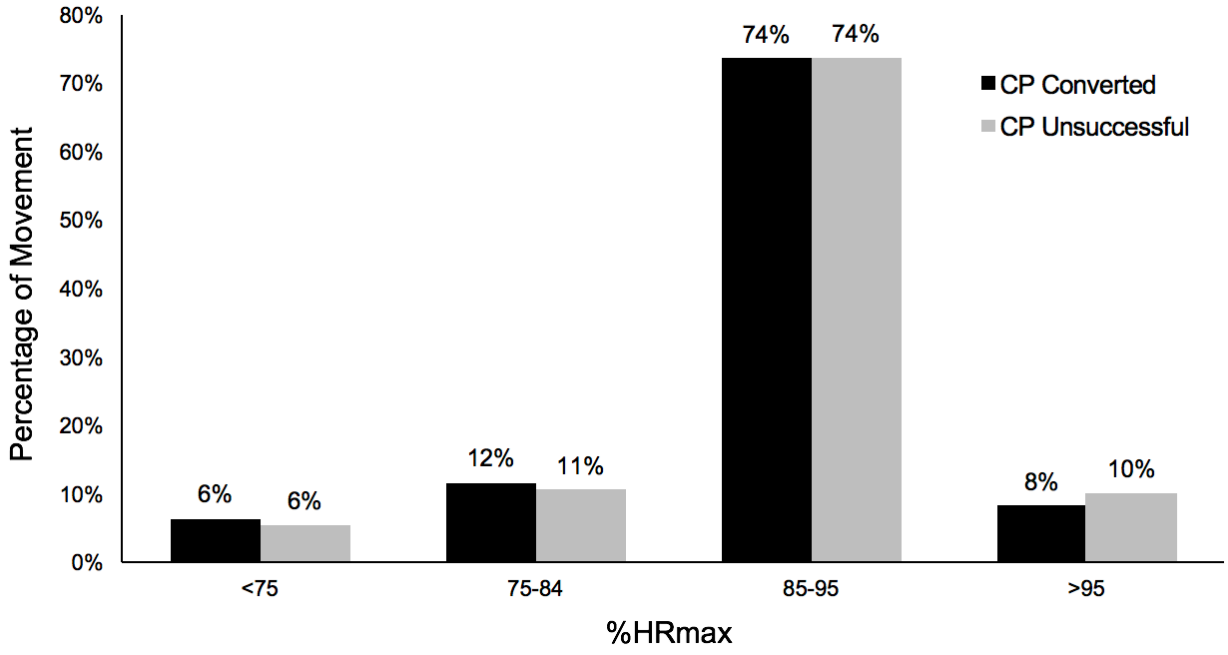


Figure 4.6: Centre pass success according to relative heart rate zones for all players involved in the specific movement.

4.4 Heart rates of individual players at specific events: Goals scored, missed shots and possession losses

No differences in mean relative heart rates were observed across all specific events (points scored = 87.5 ±9.4 %, missed shots = 87.1 ±9.7 %, and possession lost = 88.9 ±10.3%; p >0.15) (Table 4.4).

Table 4.4: The mean heart rates for the outcome of a specific event.

	Goal Scored	**Missed Shots**	**Possession Lost**	
	Mean ±SD.	**Mean ±SD**	**Mean ±SD**	**p-value**
	(n = 593)	**(n = 197)**	**(n = 184)**	
%HR_{max}	87.5 ±9.4	87.1 ±9.7	88.9 ±10.3	p > 0.15

At the 75-84% maximum heart rate there were fewer possession lost observations than for either of the shooting conditions (8% vs. 11% goals missed and 10% goals scored). The differences between the 3 groups were even more pronounced at 85-95% $HR_{max.}$ Shots, irrespective of outcome were on average 5% more frequently observed at this exercise intensity than compared to occasions when possession was lost (Figure 4.7).

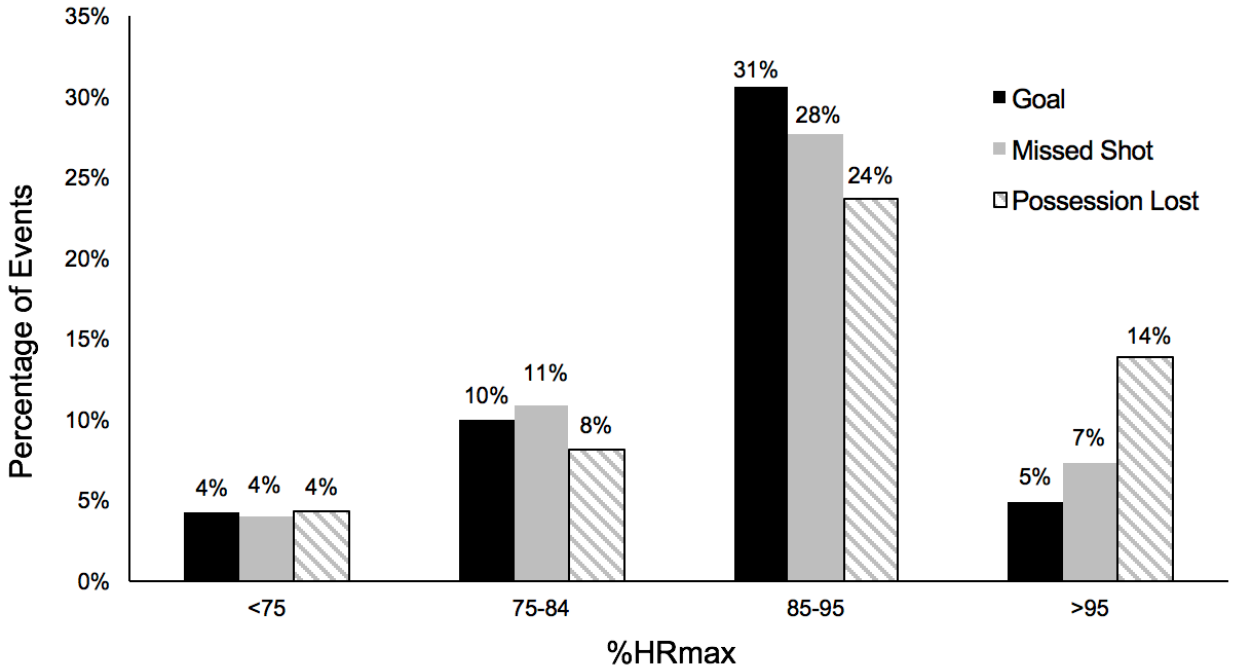


Figure 4.7: The percentage of heart rate maximum of a player at a specific event: Goal, missed shot and possession is lost.

The goals scored and missed shots data, were combined (n=790), and categorized according to which of the two shooting positions, namely goal shooter (n=536) and goal attack (n=254) made the shot. The ratio of shots made by the goal shooter vs. goal attack was 2.1:1. No significant difference was observed between the mean $\%HR_{max}$ for the two goal scoring positions when they were taking a shot at goal ($p > 0.03$). The relative distribution of the $\%HR_{max}$ data shows that while the majority of shots (60% for goal shooter and 59% for goal attack) were recorded in the 85-95% category the construct of the remaining 40% of shots were different between the 2 positions (Figure 4.8). The goal shooter showed a greater tendency to shoot goals when their relative HR_{max} was below 85% (37%) while the goal attack was observed taking shots more frequently (27%) in the >95% HR_{max} category (Figure 4.8).

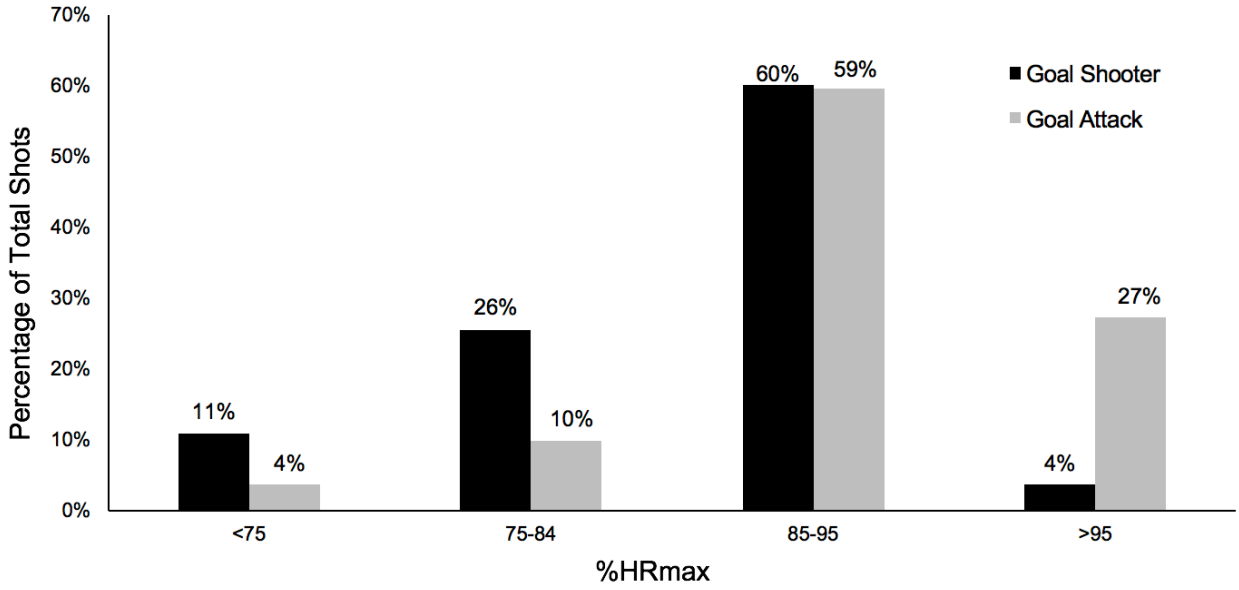


Figure 4.8: Success rate of shots taken by goal shooter versus goal attack in the different intensity zones.

A more detailed examination was conducted into the success rates of shots per position (Figure 4.9). No significant differences were found between the goal shooter's goals scored vs. missed shots ($p > 0.19$) (Figure 4.9A). Likewise, for the goal attack, no differences were found between goals scored and missed shots ($p > 0.39$) (Figure 4.9B).

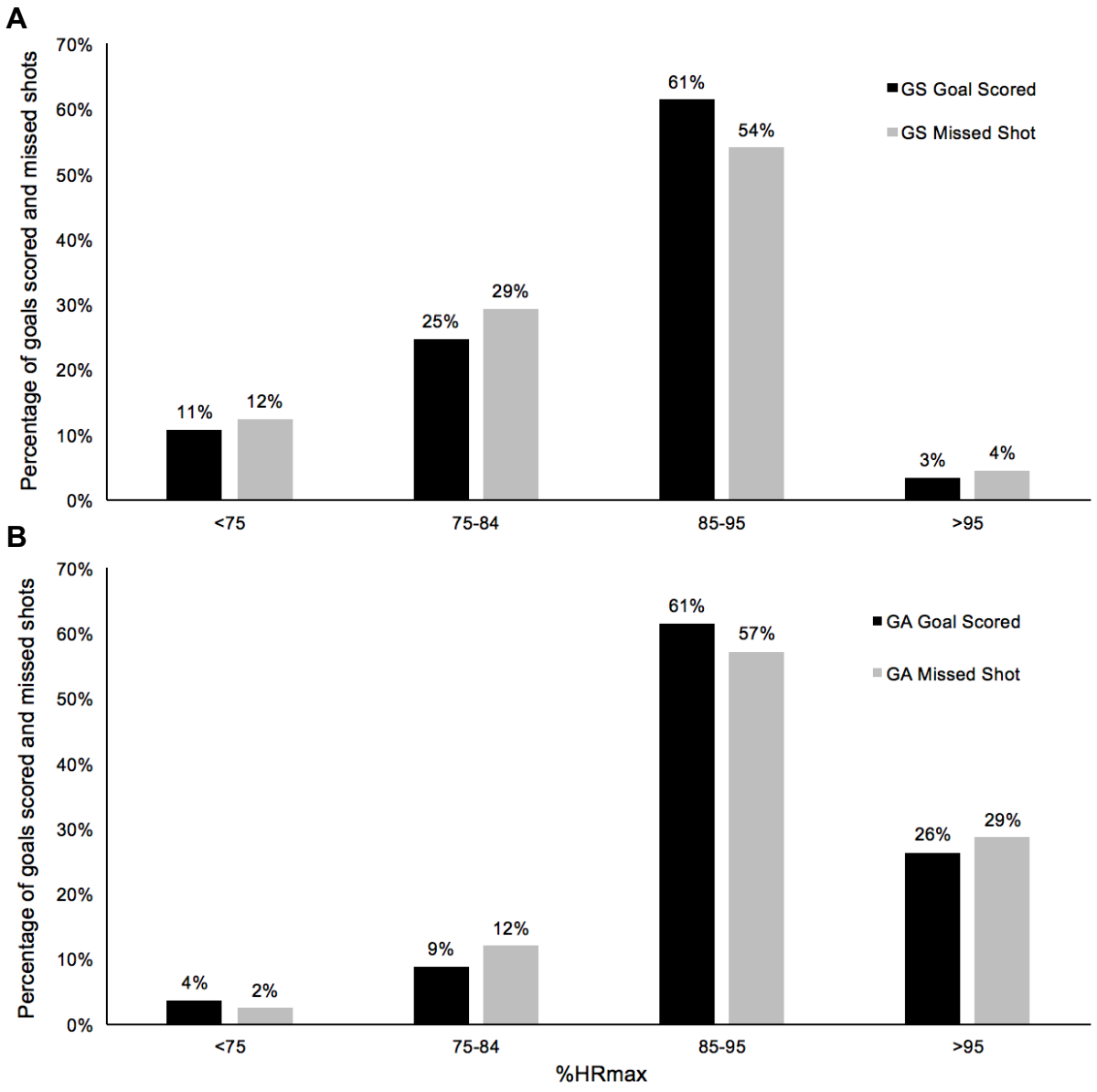


Figure 4.9: (A) Success rate of shots taken by the goal shooter in the different intensity zones (B) Success rate of shots taken by the goal attack in the different intensity zones.

CHAPTER FIVE

5 DISCUSSION

The aim of this study was to investigate if an association between technical and tactical performance indicators existed with the physiological responses of elite female netball players. The hypothesis was that physiological responses (heart rates) of netball players would have an association with the success of movements and technical performance. The main findings of this study were that converted centre pass (CP) movements were longer in duration of possession ($p < 0.001$) and consisted of more passes than unsuccessful CP movements ($p < 0.001$). The junior and senior teams had similar distributions for technical and tactical performance indicators, which meant there was no experience effect between the two senior and junior levels. No significance was found for the relative playing intensity of the different centre pass movements as they both occurred in the supra-threshold (85-95% HR_{max}) intensity zone irrespective of whether the outcome was a goal or a possession lost. The average relative heart rate of the individual players who were in possession of the ball when goals were scored, shots were missed and possessions lost, was also found to be in supra-threshold intensity zone again with no significance differences found between the three movement categories.

The data from this study of centre pass movements in elite netball games is similar to the findings of O'Donoghue's (2006) study on performance indicators for possession and shooting in international netball. This study found that on average a match consisted of 58% converted CP movements and averaged 45 goals per game. O'Donoghue (2006) study averaged 53% CP converted movements and 48.1 goals in world class vs. world class matches and 47.7.3% converted CP movements and 40.3 goals in international vs. international matches. O'Donoghue's (2006) study looked at junior elite players only whereas this study investigated both junior and senior matches, which could explain the slightly higher results. It is also possible that netball has evolved in the more than 10 years since O'Donoghue (2006) study and the greater number of centre passes and goals could be illustrative of this.

5.1 Technical and tactical performance indicators in centre pass movements

A significant difference existed between the duration of possession and number of passes in point scoring movements versus movements where possession was lost. Expressing these data according to the amount of time taken for an average pass to be made (mean movement duration / mean number of passes per movement) gave greater credence to these findings. The average time for each pass was calculated to be 3.0 seconds for converted centre pass movements versus 2.6s for unsuccessful ones. These findings are greater than those presented by Fox et al. (2013) who researched game demands of elite netball and established the average duration for time in possession when making a pass was between one and two seconds (2s). However, the actual time a player had possession of the ball before making a pass was not measured in the present study so there is no distinction between time in possession before a pass was made and the flight time of the ball to the receiving player. Furthermore, examination of the relative frequency distributions found that movements of two seconds or less were associated with unsuccessful centre pass movements suggesting rather that players should make better use of the 3s permitted to hold on to the ball before making a pass. These sentiments are supported in the netball coaching literature where the play from a centre pass is regarded as a set piece and requires planning and rehearsal to aid players in their selection of the best passing option (Plummer et al., 2014). The players are trained to develop better decision-making skills which might include delaying a pass for a fraction of a second longer to ensure that possession is maintained (Plummer et al., 2014).

This study found that the optimal number of passes to secure a goal from a centre pass was 5 and that the first 3 passes from the centre pass were the most important as there is a high chance of losing possession of the ball within those three passes. Plummer et al. (2014) indicated that it is the attackers' responsibility to ensure the ball is safely delivered to the shooters in the goal circle by ensuring that passes are completed and a turning over of the ball is avoided. Coaches should practice half court patterns of play (centre passes) with the team (without defence) during training sessions to ensure all players understand their role in the centre pass. Once these patterns of play have been understood by the forward line, defenders can be introduced to increase the attackers'

concentration and any weaknesses in the attacking play can be identified (Plummer et al., 2014).

Ensuring a minimum of five completed passes to secure a converted CP are supported by findings from a study looking at the differences between world class netball teams and international netball teams (Bateman 2006). Their study found that the world class teams were able to successfully convert a greater percentage of their centre passes into goals by having a higher pass completion rate than their international counterparts as the ball was transferred from the centre circle via the attacking circle into the goal.

A total of 63% of all possession losses occurred in middle or attacking 3rd of court, which, indicates that the ball never reached the shooting circle before being turned over by the opposition. These findings when combined with the duration of possession and passing data emphasize how important it is for the players to have discipline when passing the ball to the circle for a shot. The players should make use of the three seconds (3s) they have to make sure they have assessed which is the best passing option to enhance the team's attacking progress whilst still ensuring accurate and completed passes. When the attacking players are in possession of the ball in the attacking third of the court, attempting to get the ball into the circle, they are likely to experience a lot of pressure from the opposing defenders who are trying to turn the ball over (Plummer et al., 2014). In order to achieve effective attacking play, players should be able to catch and throw while moving, make good use of the court space when off the ball and be able to adapt to changes in playing speed to ensure favourable outcomes are achieved each time the team has possession of the ball. If these skills are not effectively executed then a bad pass could ensue, an opposition intercept could occur or a rule infringement could transpire all resulting in a possession loss (Plummer et al., 2014). The defending team places pressure on the attacking team, with the aim of forcing the attackers into making quick decisions whilst at the same time being ready to capitalize on any mistakes that occur. Clever defensive positioning will make passing angles smaller, close up space and decrease speed to the opposition (Plummer et al., 2014). The attacking players' ability to stay focused should be well trained especially when under pressure, remembering that balance and control is a priority when it comes to playing speed (Plummer et al., 2014).

5.2 The relationship between exercise intensity and movement success

The findings show that there was no difference in mean percentage of maximal heart rate between CP converted and CP unsuccessful movements. Therefore, despite the end result of each movement being fundamentally different, both movements' mean relative heart rates of all the involved players occurred in the supra-threshold intensity zone (85-95 %). The results reject the hypothesis that an association between physiological parameters of netball players exists between technical and tactical performance indicators relating to the success of movements. This is in contrast to studies done in laboratory-type settings where significant differences were found between intensity and technical skills (Gabbett, 2008; Royal et al., 2006; Lyons et al., 2006 and Smith et al., 2016).

Research studies on the physiological testing of athletes are usually conducted in a controlled environment, such as a laboratory-setting (Larsson, 2003). However, this study focused specifically on the influence of high heart rates on movement success in a competitive setting. The lack of significant findings could be due to the difference in experimental designs and procedures in lab- vs. competition-based settings (Lyons et al., 2006a) or a difference in cognitive and somatic anxiety of netball players before competitive match-play vs. a training session (Hale, 2004). It was suggested that pre-match anxiety could lead to a greater work-rate on-court facilitating better play or could negatively affect the players performance (Hale, 2004). Studies by Marcora et al. (2009) and Smith et al. (2016) have provided evidence that mental fatigue affects the player's ability to accurately assess their remaining energy levels and apportion them correctly to completing a task as opposed to cardiorespiratory and musculoenergetic mechanisms affecting the outcome. The competitive setting in this study could have been affected by cognitive and somatic anxiety, mental fatigue and the overriding determination to win.

A possible reason for the unsuccessful CP movements falling into the same intensity zone as CP converted could also be due to high-intensity training. O'Donoghue (2004) mentioned that if coaches understand the playing demands of their sport, repeated high-intensity training could help players cope with the intermittent nature of the sport, slow down the symptoms of fatigue, prevent fatigue-induced technical errors thus bettering

the chances of winning a match. It would seem logical to suggest that players at elite levels and in competitive settings can perform optimally despite high physical exertion levels. Therefore, confirming the insignificant association found between heart rate and movement success.

Another explanation for the lack of findings could be that heart rate alone might not be the most accurate indicator of stress intensity (Fernandez et al., 2006). Heart rate was found to be affected by other environmental influences such as dehydration and thermal stress (Fernandez et al., 2006).

A further justification for this result could be due to the defensive strategies implemented by the opposition team. The defensive techniques used are completely out of the attacking team's control, therefore the outcome of the movements cannot solely be tied to the attacking team's physiological responses. According to Woodlands (2006) the main contributing factors to effective defending are pressure, team support, depth and concentration, therefore relying on the attacking team to make a mistake and lose possession.

However, the findings of this study are consistent with many other mean relative heart rates recorded during competition of team sports: Irish club male Gaelic football (81 $\%HR_{max}$) (Florida-James and Reilly, 1995), Spanish female international basketball (94.6 $\%HR_{max}$) (Krustrup et al., 2005), Tunisian male elite basketball (91 $\%HR_{max}$) (Abdelkrim et al., 2007) and Spanish professional male futsal (90 $\%HR_{max}$) (Barbero-Alvarez et al., 2008).

The investigation of the heart-rate profile of elite netball match play by Kennedy et al. (2011) found that centre court players spent 82% of match-play above 85 $\%HR_{max}$, circle players spent 70% of match-play above 85 $\%HR_{max}$ whereas both circle and centre court players spent an average of 25% and 23% of game time between 95-100% of $\%HR_{max}$ respectively. These studies confirm why there were no differences in converted CP and unsuccessful CP movements.

5.3 The relationship between exercise intensity and a specific outcome

According to the results of the observed specific outcomes, all three events fell across the four intensity zones. However, majority (goals (31%), missed shots (28%) and possession lost (24%)) all occurred in the supra-threshold intensity zone (85-95% HR_{max}).

Previous laboratory-based studies have found that the effects of prior moderate and intense exercise on sports-related performance suggest a significant decline in skill execution ($p = 0.010$) and attention ($p = 0.030$) after high-intensity or intense exercise (Lyons, 2011). Russell et al. (2011) found that exercise affected shooting precision (timing effect: $p = 0.035$) with shots taken post fatigue-protocol were 25.5 $\pm$4.0% less accurate than shots taken before. No significant differences were found in this study between heart rate and the outcome of a shot taken or possession lost. These results reflect that the findings of this study objective are consistent with the previous objective's results showing that majority of time spent during competition was in the supra-threshold intensity zone.

A study performed by Roberts and O'Donoghue (2013) ascertained three factors that affected a successful netball shot: 1) the location in the semi-circle where the shot was attempted from, 2) the type of defensive strategy executed by the goal defence and goal keeper and 3) whether or not a contact or obstruction rule infringement was made by the opposition's defensive players against one of the shooters. Although none of these factors were investigated in this study it can be assumed that heart rate cannot solely influence the success of a shot. Plummer (2014) confirms that shooting for goal does not happen by chance but is rather a skill that is well sequenced and practiced on a daily basis in order to gain accuracy.

Shooters need to take time to ensure they are well balanced and all the necessary body parts are in alignment with the post before attempting the shot. This is supported by Fox et al. (2013) who found that the shooting positions (goal shooter and goal attack) hold onto the ball a lot longer before taking a shot in comparison to the other positions when passing during play. The reason for this was suggested that the shooter maximize

duration of possession to ensure optimal accuracy for the shot.

The goal shooter takes double the amount of shots in comparison to the goal attack during a competitive match. This study found that the goal shooter averaged 79% success rate whereas the goal attack had a success rate of 67%. These results are confirmed by a study conducted by Evans (2008) who found that the goal shooter has more shot attempts with a 75.5% overall success rate during a match in comparison to the goal attack.

The majority of both the goal shooter's and the goal attack's shots are taken in the 85-95% HR_{max} zone. Overall, the goal shooter tends to take shots in the lower HR zones in comparison to the goal attack who often takes shots when in the highest HR zone (maximal). This could be an indication of the roles each shooting position plays. The goal shooter is only allowed in one third of the court with the main focus of scoring goals. The goal attack plays over two thirds of the court and is responsible for attacking and bringing the ball down the court, feeding the ball into the circle, assisting the goal shooter in taking shots as well as playing a defensive role (Hickey and Navin, 2007). Bateman (2006) study confirms the highest volume of work is by the goal attack as this is the position that passes the ball the most apart from the centre who begins each centre pass.

6 Study Limitations

While this dissertation has addressed the main objectives of this research study, there are a number of limitations to be aware of.

In order to determine relative heart rate, an age predicted formula was used to calculate maximal heart. Possibly a better method of determining maximal heart rate would have been during a maximal exercise test. However, due to the national representation of the players involved in this study, the players live and train in different regions of South Africa, it was therefore not possible to conduct such tests before data collection began.

There is the chance that the fitness and training variations of the junior and senior players could have impacted the results of this study. Again, determining fitness levels was out of the researcher's control due to the participants living in different areas of the country and following different training programmes based on their club or university team.

The collection of this data occurred during an international tournament and national selection camp, therefore certain technical issues that occurred on court regarding the wearable devices were out of the researchers control. This affected the number of movements that could be used.

Another way to measure physiological responses or levels of exertion accurately would have been through blood lactate testing, however this was not feasible in the international tournament setting.

The study only analysed attacking centre pass movements, therefore limiting the number of performance indicators that could have been investigated. Opposition centre passes and the outcome of turnovers were not taken into consideration.

This study only investigated play from an attacking centre pass perspective and revolved around the players in the middle third, the attacking third and circle. The defenders therefore, were not analyzed as they were not involved in the centre pass movements.

In order to fully understand the workloads of netball players, the whole game needs to be analysed so that the sequencing of events can provide a context from which work to rest ratios can be calculated.

Although there are a number of limitations, this does open up opportunities for future research studies. As minimal research has been undertaken to bring the physiological responses in competition-based netball together with performance analysis of key performance indicators, there are many areas of the game that have potential to be investigated further.

CHAPTER SIX

7 CONCLUSION

Three research objectives were identified at the beginning of this dissertation as the key areas driving the investigation. Each of these objectives were addressed individually and collectively over the course of the project and in the process of answering the research questions several insights into the technical, tactical and physiological demands of netball were made.

There is a difference in duration of possession and number of passes that occur when a centre pass successfully results in a goal being scored. The coaches and strength and conditioning trainers should utilize this knowledge when they are designing and implementing training sessions that focus on play from centre passes.

Knowing that the minimum duration of a converted centre pass is 5s, the average duration is 17s and the maximum duration is 53s, the minimum, average and maximum number of passes for a converted CP is 2, 5.6 and 14 respectively and the average relative heart rate for a converted CP is 88.5 $\pm$7.4%. Drills can be devised where players have to pass the ball from the centre circle to the shooting circle and score a goal in short (5s made up of 2 passes), medium (17s made up of 5-6 passes) and long (53s made up of 14 passes) bouts of play ensuring that the playing tempo is at relative heart rate intensity of 88.5 %HR_{max}.

Each player needs to know what their specific role is during the centre pass and be able to effectively perform this under the pressure demands of real match play. Patience, balance, good execution of basic skills and good decision-making will ensure a goal is scored off the movement.

No difference was found for the mean heart rate of players between successful and unsuccessful CP movements therefore, the researcher fails to reject the null hypothesis and cannot accept the alternative hypothesis.

Due to the highly uncontrollable environment of the competition-based settings of this study, further studies should investigate the influencing factors of mental fatigue, defensive strategies, “inter-player communication”, training programmes and other physiological responses (not only heart rate) on centre pass movement outcomes.

8 PRACTICAL APPLICATIONS

The results presented in this dissertation add a little more insight into previous netball literature and there are a number of practical applications to take out of this study.

Players should concentrate on the first two passes from a centre pass movement to ensure progression to the goal circle is possible. They should make use of the three-second rule to its full potential (without violating the rule) to ensure the best possible pass has been decided upon.

The team should work at an intensity to get the ball to the circle without over expending energy unnecessarily as possession is lost more frequently in the higher intensity zones. Coaches should teach players to use the time when the ball is out of play to recover so that they are effective for the full length of time they are on court. Training intensity and match demands should be measured and monitored in order to construct training programmes that simulate real competition demands.

9 REFERENCES

Abbiss, C.R. and Laursen, P.B., 2007. Is part of the mystery surrounding fatigue complicated by context? *Journal of science and medicine in sport*, *10*(5), pp.277-279.

Abbott, A., 2006. *The success rate of restarts and turnover ball in netball and the influence of fitness* (Doctoral dissertation, University of Wales Institute Cardiff).

Abdelkrim, N.B., El Fazaa, S. and El Ati, J., 2007. Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British journal of sports medicine*, *41*(2), pp.69-75.

Achten, J. and Jeukendrup, A.E., 2003. Heart rate monitoring. *Sports medicine*, *33*(7), pp.517-538.

ActiveSG n.d., *Bettering your netball positional play*, viewed 30 November 2017, from https://www.myactivesg.com/sports/netball/training-method/develop-your-game/bettering-your-netball-positional-play.

Araya, J.A. and Larkin, P., 2013. Key performance variables between the top 10 and bottom 10 teams in the English Premier League 2012/13 season. *Human Movement, Health and Coach Education (HMHCE)*, *2*, pp.17-29.

Åstrand, P.O., Rodahl, K. Dahl, H.A. and Strømme, S.B., 2003. *Textbook of work physiology: physiological bases of exercise*. Human Kinetics. pp.282

Bangsbo, J., Iaia, F.M. and Krustrup, P., 2007. Metabolic response and fatigue in soccer. *International journal of sports physiology and performance*, *2*(2), pp.111-127.

Barbero-Alvarez, J.C., Soto, V.M., Barbero-Alvarez, V. and Granda-Vera, J., 2008. Match analysis and heart rate of futsal players during competition. *Journal of sports sciences*, *26*(1), pp.63-73.

Bateman, J., 2006. *An analysis of the patterns of play from the centre and back-line pass of world class and interntional netball teams* (B.Sc. Hons dissertation, University of Wales Institute Cardiff).

Beesley, K., 2015. *A Comparative Physical Demands Analysis of Playing Positions in Amateur Netball Teams* (B.Sc. Hons dissertation, Cardiff Metropolitan University).

Bergeron, M.F., Armstrong, L.E. and Maresh, C.M., 1995. Fluid and electrolyte losses during tennis in the heat. *Clinics in sports medicine*, *14*(1), pp.23-32.

Boyle, P.M., Mahoney, C.A. and Wallace, W.F., 1994. The competitive demands of elite male field hockey. *The journal of sports medicine and physical fitness*, *34*(3), pp.235-241.

Broome, L., 2011. *A comparison into the difference in the way in which netball teams gain possession between super league netball and university level netball* (Doctoral dissertation, University of Wales).

Bruce, L., Farrow, D., Raynor, A. and May, E., 2009. Notation analysis of skill expertise differences in netball. *International Journal of Performance Analysis in Sport*, *9*(2), pp.245-254.

Chandler, P.T., Pinder, S.J., Curran, J.D. and Gabbett, T.J., 2014. Physical demands of training and competition in collegiate netball players. *The Journal of Strength & Conditioning Research*, *28*(10), pp.2732-2737.

Coelho, D.B., Coelho, L.G.M., Morandi, R.F., Ferreira Junior, J.B., Marins, J.C.B., Prado, L.S., Soares, D.D. and Silami-Garcia, E., 2012. Effect of player substitutions on the intensity of second-half soccer match play. *Revista Brasileira de Cineantropometria & Desempenho Humano*, *14*(2), pp.183-191.

Crouch, H. ed., 1992. *The netball coaching manual*. A. & C. Black.

Csataljay, G., O'Donoghue, P., Hughes, M. and Dancs, H., 2009. Performance indicators that distinguish winning and losing teams in basketball. *International Journal of Performance Analysis in Sport*, *9*(1), pp.60-66.

Davidson, A. and Trewartha, G., 2008. Understanding the physiological demands of netball: A time-motion investigation. *International Journal of Performance Analysis in Sport*, *8*(3), pp.1-17.

Davis, L. and Davis, D., 2006. *Netball*. Macmillan Education AU.

Deutsch, M.U., Maw, G.J., Jenkins, D. and Reaburn, P., 1998. Heart rate, blood lactate and kinematic data of elite colts (under-19) rugby union players during competition. *Journal of sports sciences*, *16*(6), pp.561-570.

Edwards, K., 2004. *Analysis of technical effectiveness of elite netball passing and shooting between winning and losing teams* (Doctoral dissertation, Cardiff Metropolitan University).

Edwards, K. and O'Donoghue, P.G., 2004. Technical effectiveness of shooting and passing of winning and losing teams in international netball competition. *Performance Analysis of Sport*, *6*, pp.15-21.

Elliott, B. and Smith, J., 1983. The relationship of selected biomechanic and anthropometric measures to accuracy in netball shooting. *Journal of Human Movement Studies*, *9*(1), pp.171-187.

Eshman, C., 2017. *Centre passes in focus*. Suncorp Super Netball, viewed 4 October 2017, from https://supernetball.com.au/2017/03/24/centre-passes-focus/

Evans, L., 2008. *Notational analysis of international netball* (Doctoral dissertation, University of Wales Institute Cardiff).

Fernandez, J., Mendez-Villanueva, A. and Pluim, B.M., 2006. Intensity of tennis match

play. *British journal of sports medicine*, *40*(5), pp.387-391.
Florida-James, G. and Reilly, T., 1995. The physiological demands of Gaelic football. *British Journal of Sports Medicine*, *29*(1), pp.41-45.

Fox, A., Spittle, M., Otago, L. and Saunders, N., 2013. Activity profiles of the Australian female netball team players during international competition: Implications for training practice. *Journal of sports sciences*, *31*(14), pp.1588-1595.

Franks, I. and Hughes, M. eds., 2004. *Notational analysis of sport: Systems for better coaching and performance in sport*. Routledge.

Fuller, C.W., Taylor, A. and Molloy, M.G., 2010. Epidemiological study of injuries in international rugby sevens. *Clinical Journal of Sport Medicine*, *20*(3), pp.179-184.

Gabbett, T.J., 2008. Influence of fatigue on tackling technique in rugby league players. *The Journal of Strength & Conditioning Research*, *22*(2), pp.625-632.

Garganta, J., 2009. Trends of tactical performance analysis in team sports: bridging the gap between research, training and competition. *Revista Portuguesa de Ciências do Desporto*, *9*(1), pp.81-89.

Gasston, V., 2004. Performance analysis during elite netball tournaments: experiences and recommendations. *Performance Analysis of Sport VI*, pp.8-14.

Hale, S., 2004. Work-rate of Welsh national league players in training matches and competitive matches. *Performance Analysis of Sport*, *6*.

Halson, S.L., 2014. Monitoring training load to understand fatigue in athletes. *Sports Medicine*, *44*(2), pp.139-147.

Hickey, J., 2007. *Understanding Netball*. Coachwise 1st4sport.

Higham, D.G., Pyne, D.B., Anson, J.M. and Eddy, A., 2012. Movement patterns in rugby sevens: effects of tournament level, fatigue and substitute players. *Journal of Science and Medicine in Sport*, *15*(3), pp.277-282.

Hughes, M., 2004. Performance analysis–a 2004 perspective. *International journal of performance analysis in sport*, *4*(1), pp.103-109.

Hughes, M.D. and Bartlett, R.M., 2002. The use of performance indicators in performance analysis. *Journal of sports sciences*, *20*(10), pp.739-754.

Hughes, M. and Franks, I.M. eds., 2004. *Notational analysis of sport: Systems for better coaching and performance in sport*. Psychology Press.

Hughes, M. and Franks, I., 2007. *The essentials of performance analysis: an introduction*. Routledge.

International Netball Federation 2017, *The Rules of Netball*, viewed 27 March 2017, from http://netball.org/game/the-rules-of-netball

James, N., Taylor, J. and Stanley, S., 2007. Reliability procedures for categorical data in performance analysis. *International Journal of Performance Analysis in Sport*, *7*(1), pp.1-11.

Johnstone, J.A., Ford, P.A., Hughes, G., Watson, T., Mitchell, A.C. and Garrett, A.T., 2012. Field based reliability and validity of the BioHarness™ multivariable monitoring device. *Journal of sports science & medicine*, *11*(4), p.643.

Kennedy, B., Appleby, B. and Piggott, B., 2011. An investigation of the heart-rate profile of elite netball match play. *Journal of Science and Medicine in Sport*, *14*, p.e94.

Kift, S., 2012. *The effect of score-line on netball performance* (Doctoral dissertation, University of Wales Institute Cardiff).

Krustrup, P., Mohr, M., Ellingsgaard, H. and Bangsbo, J., 2005. Physical demands during an elite female soccer game: importance of training status. *Medicine & Science in Sports & Exercise*, *37*(7), pp.1242-1248.

Larsson, P., 2003. Global positioning system and sport-specific testing. *Sports medicine*, *33*(15), pp.1093-1101.

Li, R.T., Kling, S.R., Salata, M.J., Cupp, S.A., Sheehan, J. and Voos, J.E., 2016. Wearable performance devices in sports medicine. *Sports health*, *8*(1), pp.74-78.

Lyons, M., 2011. *The effects of prior moderate and intense exercise on sports-related performance* (Doctoral dissertation, Coventry University).

Lyons, M., Al-Nakeeb, Y. and Nevill, A., 2006a. The impact of moderate and high intensity total body fatigue on passing accuracy in expert and novice basketball players. *Journal of sports science & medicine*, *5*(2), p.215.

Lyons, M., Al-Nakeeb, Y. and Nevill, A., 2006b. Performance of soccer passing skills under moderate and high-intensity localized muscle fatigue. *Journal of Strength and Conditioning Research*, *20*(1), p.197.

Lythe, J., 2008. *The physical demands of elite men's field hockey and the effects of differing substitution methods on the physical and technical outputs of strikers during match play* (Doctoral dissertation, Auckland University of Technology).

Macmillan Dictionary n.d., *Unforced error (noun) definition and synonyms*, viewed 4 December 2017, from https://www.macmillandictionary.com/dictionary/british/unforced-error

Main, L., 2011. *Error rates of british super league netball teams when playing different qualities of opposition* (University of Wales Institute Cardiff).

Marcora, S.M., Staiano, W. and Manning, V., 2009. Mental fatigue impairs physical performance in humans. *Journal of applied physiology*, *106*(3), pp.857-864.

Marshall, E., 2016. *The Statistics Tutor's Quick Guide to Commonly Used Statistical Tests*, viewed 6 June 2018, from http://www.statstutor.ac.uk/resources/uploaded/tutorsquickguidetostatistics.pdf.

Millar, E., 2012. *Error rate comparison in super league netball teams when playing against teams of the same and different qualities* (Doctoral dissertation, University of Wales Institute Cardiff).

Miller, S.A. and Bartlett, R.M., 1994. Notational analysis of the physical demands of basketball. *J Sports Sci*, *12*(2), p.181.

Noakes, T.D., 2000. Physiological models to understand exercise fatigue and the adaptations that predict or enhance athletic performance. *Scandinavian journal of medicine & science in sports*, *10*(3), pp.123-145.

Novas, A.M.P., Rowbottom, D.G. and Jenkins, D.G., 2003. A practical method of estimating energy expenditure during tennis play. *Journal of Science and Medicine in Sport*, *6*(1), pp.40-50.

O'Donoghue, P.G., 2004. Activity profile of senior netball competition. *Performance Analysis of Sport VI*, pp.28-34.

O'Donoghue, P.G., 2006. Performance indicators for possession and shooting in international netball. *Performance Analysis of Sport*, *7*(23), pp.459-467.

O'Donoghue, P., 2009. *Research methods for sports performance analysis*. Routledge.

O'Donoghue, P.G. and Longville, J., 2004. Reliability testing and the use of statistics in performance analysis support: a case study from an international netball tournament. *Performance Analysis of Sport*, *6*, pp.1-7.

O'Donoghue, P., Mayes, A., Edwards, K.M. and Garland, J., 2008. Performance norms for British national super league netball. *International Journal of Sports Science & Coaching*, *3*(4), pp.501-511.

Paget, N., 2015. *Performance analysis of high performance netball umpires for match-play and fitness demands* (Doctoral dissertation, Auckland University of Technology).

Palmer, C., Hughes, M. and Borrie, A., 1994. Centre pass patterns of play of successful and non-successful international netball teams. *Journal of Sports Science*, *12*(2), p.181.

Phillips, A., 2011. Possession Changes in Different Performance Levels of Netball.

Platanou, T. and Geladas, N., 2006. The influence of game duration and playing position on intensity of exercise during match-play in elite water polo players. *Journal of Sports Sciences*, *24*(11), pp.1173-1181.

Plummer, N., McIntosh, J., Broomhead, L. and Willering, Y., 2014. *INF - Foundation Coaching Manual*. Powerpoint presentation, viewed 8 October 2017, from https://www.slideshare.net/MuyyGladstone/coaching-manual-netball

Richards, P., Collins, D. and Mascarenhas, D.R., 2012. Developing rapid high-pressure team decision-making skills. The integration of slow deliberate reflective learning within the competitive performance environment: A case study of elite netball. *Reflective Practice*, *13*(3), pp.407-424.

Roberts, C. and O'Donoghue, P., 2013. Momentum in netball shooting. *Peters, DM, & O'Donoghue, P. Performance analysis of sport IX. London: Taylor and Francis*, pp.136-142.

Royal, K.A., Farrow, D., Mujika, I., Halson, S.L., Pyne, D. and Abernethy, B., 2006. The effects of fatigue on decision making and shooting skill performance in water polo players. *Journal of Sports Sciences*, *24*(8), pp.807-815.

Russell, M., Benton, D. and Kingsley, M., 2011. The effects of fatigue on soccer skills performed during a soccer match simulation. *International journal of sports physiology and performance*, *6*(2), pp.221-233.

Sampaio, J., Ibáñez, S., Lorenzo, A., 2013. Routledge Handbook of Sports Performance Analysis. Routledge.

Scanlan, A.T., Kean, C.O., Humphries, B.J. and Dalbo, V.J., 2015. Physiological and Fatigue Responses Associated with Male and Mixed-Gender Ultimate Frisbee Game Play. *The Journal of Strength & Conditioning Research*, *29*(9), pp.2600-2607.

Shakespear, W. and Caldow, M., 2009a. *Netball 2nd Edition: Steps to Success*. Human Kinetics.

Shakespear, W. and Caldow, M., 2009b. Netball steps to success-No. 1 Sports Instruction Series (2 nd Eds). *Human Kinetics, United States of America*.

Shepherd, A.P., Terpolilli, B.M. and Steinke, J.M., 2007. A hand-held device to measure oxygen uptake: performance characteristics, patient selection and the propagation of its measurement error into fick cardiac output determinations. *Journal of Invasive Cardiology*, *19*(3), p.113.

Smith, M.R., Coutts, A.J., Merlini, M., Deprez, D., Lenoir, M. and Marcora, S.M., 2016. Mental fatigue impairs soccer-specific physical and technical performance. *Medicine & Science in Sports & Exercise*, *48*(2), pp.267-276.

Tanaka, H., Monahan, K.D. and Seals, D.R., 2001. Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), pp.153-156.

Taylor, K., Chapman, D., Cronin, J., Newton, M.J. and Gill, N., 2012. Fatigue monitoring in high performance sport: a survey of current trends. *J Aust Strength Cond*, *20*(1), pp.12-23.

Therminarias, A., Dansou, P., Chirpaz-Oddou, M.F., Gharib, C. and Quirion, A., 1991. Hormonal and metabolic changes during a strenuous tennis match. Effect of ageing. *International journal of sports medicine*, *12*(01), pp.10-16.

Uygur, M., 2009. *Fatigue does not affect the kinematics of free throw shooting in basketballL* (Doctoral dissertation, Middle East Technical University).

van Rooyen, K.M., Lombard, C. and Noakes, D.T., 2008. Playing demands of sevens rugby during the 2005 Rugby World Cup Sevens tournament. *International Journal of Performance Analysis in Sport*, *8*(2), pp.114-123.

van Rooyen, K.M. and Noakes, D.T., 2006a. An Analysis of the movements, both duration and field location, of 4 teams in the 2003 Rugby World Cup. *International Journal of Performance Analysis in Sport*, *6*(1), pp.40-56.

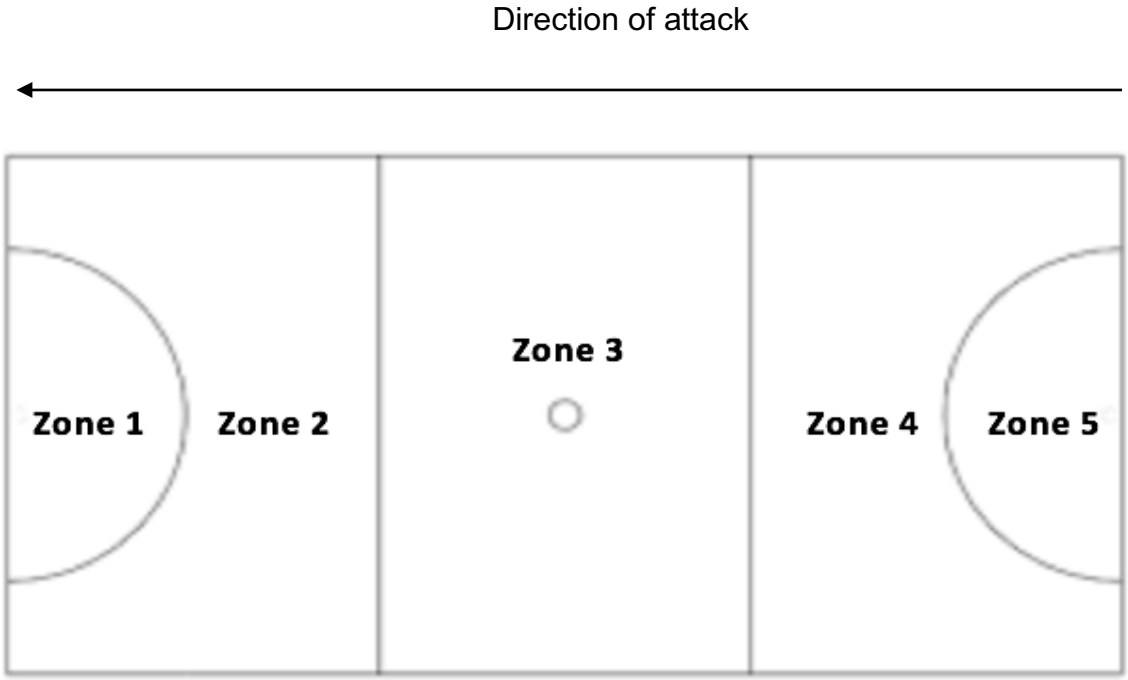
van Rooyen, K.M. and Noakes, D.T., 2006b. Movement time as a predictor of success in the 2003 Rugby World Cup Tournament. *International journal of Performance analysis in Sport*, *6*(1), pp.30-39.

Woodlands, J., 2006. *The netball handbook*. Human Kinetics.

Woolford, S. and Angove, M., 1991. A comparison of training techniques and game intensities for national level netball players. *Sports Coach*, *14*(4), pp.18-21.

10 APPENDICES

Appendix A - Zones on court to depict start zone and end zones for each movement.



Appendix B – Informed Consent

Study: The association between technical and tactical performance indicators and the physiological responses of elite female netball players.

Dear Participant,

The aim of this research is to investigate whether there is an association between technical and tactical performance indicators, regarding possession lost and goals scored, and physiological responses of elite female netball 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:

Mrs Christy Mullender, 084 741 8888, cristymullender@gmail.com
Mr Marc Booysen, 082 495 7691, Marc.Booysen@wits.ac.za
Dr Michele van Rooyen, 082 678 1161, michele.vanrooyen@gmail.com

Please return the completed form to the researcher Mrs Christy Mullender 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 netball career as all data will be coded and kept confidential. The intention of the study is to improve the understanding of elite netball 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 whether there is an association between technical and tactical performance indicators, regarding possession lost and goals scored, and physiological responses of elite female netball 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 - Ethics clearance certificate

R14/49 Ms Christy Mullender

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M170531

NAME: (Principal Investigator)	Ms Christy Mullender
DEPARTMENT:	Centre for Exercise Science and Sports Medicine Netball World Youth World Cup - Gaborone, Botswana
PROJECT TITLE:	The Association of Technical and Tactical Perfomance Indicators with the Physiological Responses of Elite Female Netball Players
DATE CONSIDERED:	26/05/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Mr Marc Booysen and Dr Michelle van Rooyen
APPROVED BY:	Professor P. Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	03/07/2017

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 floor, Senate House/3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially review May and will therefore be due in the month of May each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix D – Turn It In Report

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ORIGINALITY REPORT

13%	9%	5%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of Witwatersrand Student Paper	2%
2	Submitted to University of Wales Institute, Cardiff Student Paper	1%
3	researchspace.auckland.ac.nz Internet Source	1%
4	www.ncbi.nlm.nih.gov Internet Source	<1%
5	Tim J Gabbett. "Influence of Fatigue on Tackling Technique in Rugby League Players :", The Journal of Strength and Conditioning Research, 03/2008 Publication	<1%
6	Submitted to Chester College of Higher Education Student Paper	<1%
7	repositoryaut.lconz.ac.nz Internet Source	<1%