TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY

by

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DECLARATION

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Michael Shaw

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SUMMARY

Introduction: *Netball is a high intensity team sport characterized by short bursts of movements coupled with less intense recovery periods. Understanding the physiological demands of the sport is essential for constructing sport-specific conditioning programmes.*

Objectives: *The purpose of this study was to profile the physical characteristics and physiological demands on elite u/19 female netball players during netball matches, in an attempt to assess the differences in those characteristics and demands for the various playing positions in netball.*

Methods: *Global Positioning System (GPS) data on a total of forty-four (44) elite junior netball players (u/19A) were collected and a total of sixteen netball matches were analysed for the study. Therefore, a total of hundred and forty (140) GPS data sets (player games) were analysed (equivalent to 560 (140 x 4) player quarters out of a total of 731 player quarters that were recorded). Minimax X4 Catapult GPS units as well as a Polar HR monitors and chest straps were used to determine the physiological demands of netball players. The following variables were recorded: Distances covered, player load, the maximal velocity during the match; and heart rate (HR) response.*

The various HR and GPS data variables were analysed using a linear mixed model with Playing Position as fixed effect, and the random effects Game, Team, Game x, Team interaction term, and Player. Fitting these random effects allowed for correlation between the observations in question due to multiple observations from the same game, team, and player. Based on this linear mixed model, the mean values of the variable for each playing position were estimated, together with their standard errors. Furthermore, the pairwise mean differences between playing positions were estimated, together with 95% confidence intervals (CIs) for the mean differences and P-values associated with the null-hypothesis of zero mean difference between the pair of playing positions in question.

Results*: The body weight, body fat percentage and height of u/19 female netball players vary according to playing position. The Goal Shooter (GS) (186 b/min) recorded significantly ($p<0.05$) lower mean maximum HR than all the other positions. The mean HR of the GS (162 b/min) and the Goal Defence (GD) (170 b/min) was significantly lower than the Centre (C),Goal Attack (GA) (180 b/min) and WA (178 b/min). The C presented with the highest mean maximum velocity ($5.23 m.s^{-1}$) whereas the GS recorded the lowest mean maximal velocity of $4.05 m.s^{-1}$. The C also covered significantly ($p<0.05$) more distance and presented with significantly ($p<0.05$) higher Player load (PL) than all the other positions, whereas the*

GS and the Goal Keeper (GK) presented with significantly ($p<0.05$) lower distance covered and PL. However, the GS and GK had a significantly higher PL per meter. The C covered 44% of its total distance between 0.2 – 3.6 $m.s^{-1}$ whereas the GK and GS covered 77% of their total distance between 0.2 – 3.6 $m.s^{-1}$. The GS and GK covered significantly ($p<0.005$) more distance in velocity band 1 than the C, GA, GD and Wing Attack (WA) and the Wing Defence (WD) travelled significantly ($p=0.007$) further than the C in velocity band 1. However, the GK and GS covered significantly ($p<0.05$) less distance than all the other positions in velocity band 2. The C travelled significantly ($p<0.05$) further than all the other positions in velocity band 3 and 4 and the GK travelled significantly ($p<0.05$) less in velocity band 4 than the other positions.

Conclusions: *The study revealed the differences in physical profile and physical demands of u/19 female netball players between the seven playing positions. These findings emphasize the difference in physical demand between the different positions as well as the different type of load placed on the different positions. Coaches and conditioning coaches must implement the findings of the study to develop sport-specific, and more importantly, position-specific conditioning programs.*

Key words: *Time motion analysis; Junior netball players, Physical profile; Physical demands*

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Abbreviations	Meaning
b/min	Beats per minute
C	Center
CI	Confidence intervals
CM	Centimetre
CV	Coefficient of Variation
GA	Goal Attack
GD	Goal Defence
GK	Goal Keeper
GPS	Global Positioning System
GS	Goal Shooter
HIR	High-intensity Running
HR	Heart Rate
IQR	Inter-quartile range
KG	Kilogram
KM	Kilometre
LIA	Low-intensity Activity
M	Meter
MIN	Minute
NSA	Netball South Africa
PL	Player Load
SE	Standard Error
SD	Standard Deviation
SPI	Sport Performance Indicator
TEM	Test Error Measurement
TMA	Time Motion Analysis
u/19	Under 19
WA	Wing Attack
WD	Wing Defence
W:R	Work to Rest Ratio

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

1.1 Introduction

Netball is an action packed team sport enjoyed worldwide within the commonwealth by players of all ages, from junior players to highly skilled elite athletes (Chandler *et al.,* 2014). South Africa have reportedly half a million secondary school players and 9 700 adult players coupled with a national netball league and the national netball team participates internationally on a regular basis (Venter, 2005). According to Williams *et al.* (2005) is Netball, a dynamic and physically demanding game, requires various explosive movement patterns such as short, fast sprint, quick stops and many changes in direction (Ryan, 2009).

Each sport has its own specific physiological demands that coaches need to consider when preparing for competition. These demands are determined by the rules and structure of the sport, as well as the skill and tactical ability of all players involved. In order to optimize performance, players and coaches must have an understanding of and must be able to cope with these sport specific requirements (Thomas *et al., 2016*). However, this is particularly difficult in team situations where it may not be possible to assess every athlete individually. Davidson *et al.* (2008), Barris *et al.* (2008) and Sweeting *et al.* (2014) agreed that traditional methods of assessing movement in netball such as manual video analysis are time consuming, cannot be done in real time and may be prone to human error when quantifying common short, high intensity movements. Many athletes strive for success in the sport they practise. The value of success has increased dramatically, providing a need for an industry of specialists capable of harnessing maximum potential. Athletes, trainers and coaches often need to invest a considerable amount of time researching the physiological demands of their sport while striving for success (Cronin *et al*., 2001). Netball is a sport that is primarily played indoors and therefore there is currently limited literature on the use of GPS within the sport (Yong *et al.,* 2015).

However, Davidson *et al.* (2008) also mentioned that the different positions in netball [Goal Shooter (GS), Goal Attack (GA), Wing Attack (WA), Center (C), Wing Defence (WD), Goal Defence (GD) and Goal Keeper (GK)] all have different technical and tactical demands, coupled with the relative small court size, are likely to influence movement patterns such as distance covered. The intermittent and multi-directional nature of netball also places a high demand on the physiological aspects like acceleration, deceleration, changes of direction, jumping and landing mechanics. Davidson *et al.* (2008) concluded that netball imposes also a footwork rule which further increases the complexity of the biomechanical demands, with players required to decelerate fully to a landing position with one step. Mothersole *et al*. (2013) in addition to Hewit *et al.* (2012) stated that these physiological demands of netball increase the risk of injury, particularly in female athletes (Hewit *et al.,* 2005). Coetzee *et al*. (2014) also acknowledge the high physical demands of netball and emphasises the increased risk of injury. Further, Langeveld *et al.* (2012) enumerate that the ankle and knee are the primary sites of injury in netball. Therefore, knowledge of the physiological demands of netball players as well as the demands of the different playing positions is important for performance enhancement as well as injury prevention.

Otago (1983) and Steele *et al*. (1991) stated that when planning training activities a coach must contemplate that training effects are specific to the type of exercise performed (specific adaptation to imposed demands) during the training programme specific to the muscle groups involved in netball. Therefore, technology such as semi-automated camera systems could provide accurate activity profile data for these types of movements (Randers *et al.,* 2010). However, they can be prohibitively expensive and according to Cormack *et al.* (2013) this has never been used in netball. Cormack *et al.* (2013) also stated that research related specifically to netball is scarce. This may be due to the lack of structure during match play (Ryan, 2009) and the unpredictable nature of netball game-play could be another reason for the absence of intervention research on netball match performance (Ryan, 2009).

Analysis of sport performance can be summarized as the actual investigation of performance during sport or during training (O'Donoghue, 2010). There is a range of methods of sport performance analysis available, extending from quantitative biomechanical analysis to qualitative analysis (O'Donoghue, 2010). Methods of performance analysis include video-based time motion analysis (TMA) and global positioning system (GPS) technology (Yong *et al.,* 2015). However, Carling *et al*. (2009) stated that GPS technology is preferred to video-based methods because player-movement can be tracked more than 100 times per second and data can be generated in real-time. Therefore, the data are more precise. Having an understanding of the physiological demands placed on athletes during competition is a foundational requirement for designing a sport specific exercise program (Miller *et al.,* 1994). O'Donoghue (2010) also emphasises the importance of performance analysis by stating that the main reason for performance analysis of sport is to create an understanding of the sport to assist decision making by those seeking to enhance sport performance. Fish *et al*. (2014) mentioned that technology of GPS tracking devises nowadays have an accelerometer function which provides a contemporary and innovative means of obtaining biomechanical data during a netball game. (Yong *et al.* (2015) concluded that various team sports use GPS technology to investigate and monitor performance during competition and/or training
However, numerous factors, for example the playing environment, the opponents' skill level and the closeness of the match, which all cause a variation in movements patters during a

game, could influence the physiological stress experienced by a player during a netball match (Steele *et al.,* 1991). Research also suggests that various performance indicators have been used to try to understand and measure the physiological demands of match play for many sports. These indicators include blood lactate concentration (Docherty *et al.,* 1988); (Abdelkrim *et al*., 2007), heart rate (HR) monitoring (Woolford *et al.,* 1991); (Krustrup *et al.,* 2005), or measuring time-motion variables (McInnes *et al.,* 1995); (King *et al.*, 2003). However physiological aspects such as anxiety prior to competition may also influence the results (Acevedo *et al.,* 1999).

Recent enhancements in technology has allowed for the quantification of physiological load during competition using a non-invasive method. Petersen *et al.* (2009) indicate that the Catapult minimax X4 performs extremely well during short sprints and changes of direction. The three-dimensional data collection, a function of the tri-axial accelerometers, enables data collectors to collect data at a high frequency during match-play which in turn provide a measurement of movement quality (Fish *et al.,* 2014). Furthermore Cormack *et al.* (2013) claims the minimax X4 to provide an innovative and useful tool for the assessment of the activity profiles in both lower and higher standards of netball. Since both Cormack *et al.* (2013) and Petersen *et al.* (2009) emphasize the possibility of this accelerometer's use when quantifying the load in a netball tournament the current study will also make use of the Catapult Minimax X4 to quantify and differentiate the physiological demands of netball playing positions.

To conclude, the physiological demands of Under 19 netball players are relatively unknown. Therefore, this study will investigate the physical demands of elite u/19 netball players during match play using a tri-axial accelerometer which enable data collectors to collect data at a high frequency during match-play which in turn provide a measurement of movement quality**.**

1.2 Problem statement

Currently there is no published literature on TMA of junior netball players using GPS technology. Research has instead classified player movements into categories based on the intensity of the movement. Furthermore, previous research that is available focussed on senior netball (Davidson et al., 2008); (Fox et al., 2013). However, the relatively small amount of research on netball physiology suggests that the game does have similarities to other intermittent sports. However there are some well-defined differences specifically in the movement patterns performed during a netball game. As a result these discrete set of specific movements in netball makes the use of TMA research and/or physiological data from other sports implausible when investigating netball. The use of an up-to-date, state of the art accelerometer and/or GPS may improve both reliability and specificity when quantifying the physiological profile of netball players (McCabe, 2014).

1.3 Aim of the study

The primary aim of this study is to investigate the physical characteristics and assess the physiological demands on elite u/19 netball players during competition using an accelerometer (Catapult Minimax X4) in an attempt to define the variability between positions and providing coaches with adequate data to produce individual training programmes, and recovery protocols.

1.4 Objectives of the study

The specific objectives of the study are:

1. To determine the total **player load (Load $^{TM}\cdot$min $^{-1}$ (au))** of elite u/19 female netball players as well as the player load of the different netball positions during match play,
2. To determine the **HR (beats per minute)** response of elite u/19 female netball players as well as the HR response of the different playing positions during match play,

   2.1 to further investigate the **Maximum HR (beats per minute)** of elite u/19 female netball players as well as the **maximum HR response of the different playing positions** during match play,

   2.2 and to determine the **Mean HR (beats per minute)** of elite u/19 female netball players as well as the **mean HR response of the different playing positions** during match play,

3. To determine the **total distance covered (km)** of elite u/19 female netball players and to investigate the **difference between the different positions**,
   3.1. To determine the **distance covered (km)** during the different player movement patterns as described by various researchers such as Fox *et al.*

(2013)**,** of elite u/19 female netball players and to investigate the **difference between the different positions**, **:**

3.1.1. **"Standing"** No locomotor activity **(0 - 0.1 m.s^{-1}),**

3.1.2. **Walking:** Strolling locomotor activity in either a forwards, backwards, or sideways direction **(0.2 – 1.7 m.s^{-1}),**

3.1.3. **Jogging:** Slow, non-purposeful running with no obvious acceleration **(1.8 – 3.6 m.s^{-1}),**

3.1.4. **Running:** A fast running action with distinct elongated strides, effort and purpose **(3.7 – 5.3 m.s^{-1}),**

3.1.5. **Sprinting:** Running with maximum effort or at maximum speed. **(>5.4 m.s^{-1}),"**

3.2. To investigate the **percentage of total distance covered** during the above mentioned player movement patterns by elite u/19 female netball players and to investigate the difference between the different positions

1.5 Motivation for the study

Knowledge of the physiological demands of athletes during competition is a fundamental requirement in order for conditioning coaches to construct a sport-specific conditioning programme (Miller *et al.,* 1994). There is a range of methods available to analyse sport performance which may be of great value when trying to understand the demands of any sport. These methods include older and more time consuming methods such as Video-based TMA to more technological advanced, but more expensive TMA methods such as GPS tracking devise (O'Donoghue, 2010). TMA information can be used by coaches and conditioning coaches to better prepare teams as well as individuals for competition in various sport such as netball. Netball is one of the most popular sports across the globe and research regarding the physical demands of the game, especially at u/19 level is lacking. Sweeting *et al.* (2017) also highlighted the lack of TMA research on netball players especially on junior level.

Therefore the current study focussed on TMA of elite u/19 female netball players in order to close the gap in research. Furthermore, the data for the current study was collected from two teams playing against each other during their respective league games and the result of each match was documented in an attempt to compare the data collected during the matches played to the outcome of the match.

1.6 Structure of the dissertation

Chapter One: Introduction and problem statement: The chapter is included herewith in accordance with the guidelines of the Free State University and problem statement.

Chapter Two: Literature review: This chapter will review previous literature which is relevant to the research aims stated in Section 1.2. An overview of the nature of netball and the rules of the game will be explained. This is followed by a discussion of the physical characteristics and the physiological demands of a netball match. Finally, TMA and literature relevant to inform sound methodological approaches. The chapter is included herewith in accordance with the guidelines of the Free State University.

Chapter Three: Research methodology: The chapter is included herewith in accordance with the guidelines of the Free State University.

Chapter Four: Results: The chapter is included herewith in accordance with the guidelines of the Free State University.

Chapter Five: Discussion

Chapter Six: Conclusion, limitations and future research.

Chapter Seven: Reflexion on the research project.

CHAPTER 2

LITERATURE REVIEW

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

2.1 Introduction

Netball is a popular sport across the globe. The game is predominantly a female team court sport played by more than 20 million people in over 80 countries (Cormack *et al.,* 2013). Understanding the physiological demands of athletes during competition is a fundamental requirement for constructing a sport-specific conditioning programme (Miller *et al.,* 1994). TMA not only provide important information on the game demands, but also highlights the differences between players in various positions (Davidson *et al.,* 2008). TMA involves the quantification of various movement patterns in terms of the speed, duration, and distance travelled during the course of a competitive match (Dobson *et al.*, 2007); Petersen *et al.,* 2009a:). This information can be used by coaches and conditioning coaches to better prepare teams as well as individuals for competition in various sport such as netball.

An essential requirement for designing a sport specific training programme is the understanding and knowledge of the physical demands placed on the players during match play (Miller *et al.,* 1994). As previously mentioned TMA research related specifically to u/19 netball are scarce. Netball is primarily played indoors, therefore the use of GPS technology within netball is very limited (Yong *et al.,* 2015). Sweeting *et al.* (2017) also highlighted the lack of TMA research on netball players especially on junior level. Thomas *et al.* (2016) added that research regarding the physical characteristics of netball players is also limited. This may be due to the lack of playing structure during match play (Ryan, 2009). Previous TMA research on netball focussed on senior level participation (Davidson *et al.,* 2008); (Fox *et al.,* 2013). Because netball is predominately played indoors, these studies focussed on TMA where player movements are categorized into categories based on the intensity of the movement by analysing video recordings of the match.

A netball team consists of seven different court positions, each with its own roles and court restrictions during the match. As a result of the positional court restrictions imposed in netball, each position has different roles which affect the demands of each playing position during match play (Chandler *et al.,* 2014). Numerous TMA studies were previously published on other sports such as basketball (Montgomery *et al.,* 2010), (Adbelkrim *et al.,* 2006), handball (Belka *et al.,* 2014) and soccer (Gabbett *et al.,* 2012). The relatively small amount of research done on the physiological demands of netball suggests that the game does have similarities to other intermittent sports. However the differences specifically in the movement patterns performed in netball such as shuffling are well defined and differentiated (McCabe, 2014). These movement patterns are listed and described in Table 2.2, Table 2.6 and Table 2.10.

The various court positions within the game with its differing roles, potentially have an influence on the skill and conditioning requirements of the different players (Davidson *et al.,* 2008). O'Donoghue (2010) also emphasises the importance of movement analysis in order to gain a better understanding of the physical demands of the sport, the tactical elements and finally an understanding of the risk associated within the sport. Various researchers have used TMA to determine the physical demands of a range of team sports (Table 2.1). TMA does not only include the analysis of just on the ball movement, but analysis of the entire game (O'Donoghue, (2010). This consequently allows for an accurate estimation of the energy systems involved in different sport. To conclude, Fox *et al.* (2013) emphasizes the importance of knowledge of the physical demands of sports for the implementation of sport specific conditioning programs to enhance performance. The aim of this chapter is to summarise the literature pertaining to the physiological demands of different positions in netball using GPS in order to establish the theoretical background for this study. Firstly, this review will provide an overview of the nature of netball and the rules of the game will be explained. Secondly, the major aspects of the physical demands of a netball match and lastly, TMA and literature relevant to inform sound methodological approaches. Literature in which TMA was applied and was used for this review is listed inn Table2.1.

Table 2.1 Research done on TMA on various sport codes

Author	Sport code
Ogden *et al.* (2010)	Touch rugby
Adnan *et al.* (2013)	Soccer referees
Spencer *et al.* (2005)	Hockey
Jenninngs *et al.* (2012)	Hockey
Homels *et al.* (2011)	Female Hockey
Macutkiewicz *et al.* (2011)	Female Hockey
King *et al.* (2011)	Gaelic football
Dwyer *et al.* (2012)	Female Soccer
Gabbett *et al.* (2012)	Female Soccer
Tumilty *et al*. (1993)	Soccer
Carling *et al.* (2012)	Soccer
Dallaway *et al.* (2013)	Soccer
Krustrup *et al.* (2005)	Soccer
Abdelkrin *et al.* (2006)	Basketball
Montgomery *et al.* (2010)	Basketball

Bishop *et al.* (2006)	Basketball
Duthie *et al.* (2005)	Rugby League
Twist *et al.* (2014)	Rugby League
Meir *et al.* (1993)	Rugby League
Johnstone *et al.* (2014)	Rugby League
Clarke *et al.* (2015)	Female Rugby
Deutsch *et al.* (1998)	Rugby Union
Kraak *et al.* (2011)	Rugby Union
Cunningham *et al.* (2016)	Rugby Union
Saurez-Arrones *et al.* (2012)	Rugby Union
Belka *et al.* (2014)	Handball
Coutts *et al.* (2010)	Australian Football
Aughey *et al.* (2010)	Australian Football
Farrow *et al.* (2008)	Australian Football
Steele *et al.* (1991)	Netball
Otago *et al.* (1991)	Netball
Davidson *et al.* (2008)	Netball
Fox *et al.* (2013)	Netball
Cormach *et al.* (2013)	Netball
McCabe (2014)	Netball
Fish *et al.* (2014)	Netball
Chandler *et al.* (2014)	Netball
Yong *et al.* (2015)	Netball
Thomas *et al.* (2016)	Netball
Sweeting *et al.* (2017)	Netball

2.2 Netball

2.2.1 Background

Netball is predominantly a female sport game played by seven players consisting of 4 x 15 minute quarters. Movement patterns in netball are characterized by high intensity, short bursts of movements coupled with less intense recovery periods (Venter, 2005). Short high intensity sprints of 2-3m at a time, jumping, pivoting and catching are the typical movements that occur during a netball match. Due to the fact that netball is a physically demanding game, players need to be well conditioned with the focus on high levels of endurance, strength, speed, power, agility and flexibility.

The seven different positions comprise of the center court players (C, WA, WD), the shooters (GA, GS) and the defenders (GK, GD). A netball court is divided into equal thirds and particular positions are only allowed to move in specific areas of the court. Therefore each position has unique physical demands (Bruce *et al.,* 2012). The aim is to score a goal by shooting the ball through a ring at the top of 3.05 m high pole. A goal can only be scored by a GS or a GA since these are the only two playing positions, along with the opponent's GD and GK, allowed in the goal circle. Whilst there are strict rules to ensure the game is played without contact, the most unique aspect of the game is that players are not permitted to run with the ball and must stop after one step and pass the ball within three seconds (Cormack *et al.,* 2013).

2.2.2 South African Netball Perspective

As seen from the 1995 Rugby World cup, South Africa is a country that is united through sport (Pillay *et al.,* 2012). Netball is proven to be very popular in South Africa with over a million players country wide including approximately half a million players between the age of 16 – 19 years who compete in various competitions as illustrated in Table 2.2.

Table 2.2 School Netball Competitions worldwide

COPETITION	AGE GROUP	PARTICIPATION LEVEL
u/18 Schools tour to Fiji	u/18	International
All ages Tournament	All	Provincial
Secondary School Champs	u/14 – U19	School level
Fast 5	u/15 and u/18	School level
Kay Motsepe Schools Cup	u/15	School level
COSASSA Games	u/16	School level
u/15 Singapore Tournament	u/15	International
u/19 National Championship	u/19	Provincial

The national side, the Proteas, also compete with the best teams in the world annually (Venter, 2005) and managed to beat England during the 2017 SANZEA Quad series for the first time since 2013 and is currently 5th on the Netball World Rankings (Netball-sa.co.za. 2017). The South African Schools Netball structure consists of nine provinces each with its own districts (Figure 2.1)

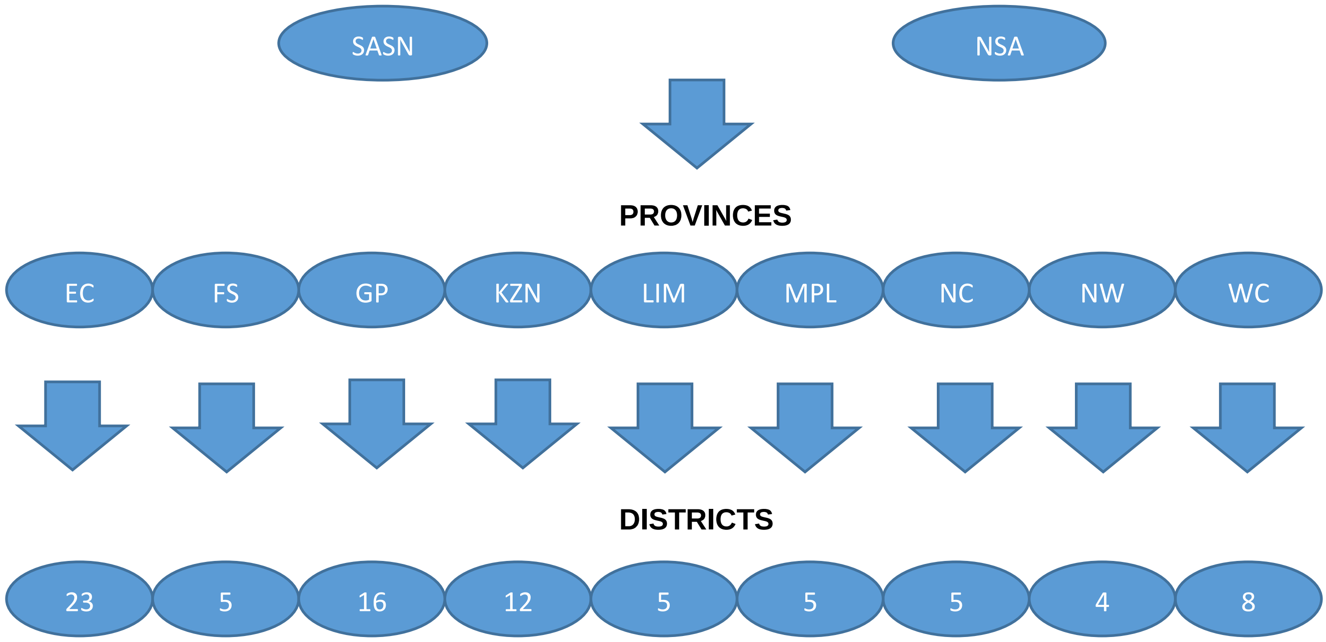

Figure 2.1: South African Schools Netball Structures (Saschoolsnetball.co.za, 2017).

2.2.3 Rules of netball

Willcox, (2011) stated some of the basic rules and common terminology used in netball as is presented in Table 2.3.

Table 2.3 Basic rules and actions performed in netball (Willcox, 2011)

Basic rules and actions performed in netball	Terminology and explanation
Offside	When a player goes into an area of the court that their position is not allowed into, the player is an offside position and the ball is turned over to the opposition.
Held ball	Upon receiving the ball a player only have three seconds to either pass the ball to another player or take a shot at goal to score a point. If a player is in possession of the ball for longer than three seconds the ball is turned over to the opposition.
Stepping	Once a player is in possession of the ball that player is not allowed to run. The "grounded foot" is the first foot that land on the ground after receiving the ball. The player is allowed to lift this foot of the ground, but they may not place it back onto the floor whilst in possession of the ball. This is called a step and will result in turned over ball.
Obstruction	Defending players must be at least 3 foot or 0.9m away from the player in possession of the ball and is measured from the "grounded foot" to the closest foot of the defending player. A penalty pass is awarded to the player with the ball if a player is called for obstruction. The player who was called for obstruction is "out of play" and must stand next to the player taking the penalty pass. If the penalty was awarded inside the shooting circle the player with the ball

	may either take the penalty pass or a shot at goal.
Contact	Physical contact (accidentally or deliberately) that interfere with an opponent's play is not allowed. A penalty pass or shot is awarded and the player called for contact is out of play.
Replay ball	A player is not allowed to play the ball again (pick it up) after losing control of it. A player is also not allowed to be the first to touch the ball again after passing it. The ball must be either touched by another player or hit the goal post. Therefore a shooter cannot catch the ball after an attempt at goal and the ball didn't hit the goal post or another player and a player is not allowed to bounce or pass to themselves.
Over a third	A ball is not allowed to travel through a playing third without being touched by at least one other player.
Centre passes	Play begins with a centre pass at the beginning of each quarter and after a goal has been scored. The first centre pass is decided with a coin toss, thereafter the centre passes alternate between the two teams after a goal is scored. The C must step into the circle with the ball. All other players must be behind the lines separating the court into the three playing thirds. Once the umpire blown the whistle the other players may enter the middle third and the ball may be passed ONLY within the middle third.
Feeding	A player passing the ball to a shooter within the shooting circle and within reasonable shooting range is referred to as "feeding".
Intercept	A clean gain of possession by the tea not

	currently in possession of the ball is referred to as an intercept and can be made by a clean catch of the ball by a defending player or by tipping the ball and then playing it themselves.
Tip	A deflection of the ball by a defending player. Possession of the ball will be determined by which team picks up the ball after a tip.

2.2.4 Playing positions and court layout

Table 2.4 Positions and court restrictions (Willcox, 2011)

Position	Court restrictions
Goal Shooter (GS)	Is allowed to shoot and can go anywhere in the attacking third.
Goal Attack (GA)	Is also allowed to shoot and can go anywhere in the attacking third and the middle third.
Wing Attack (WA)	Can go into the attacking third except into the goal circle, and also into the middle third.
Centre (C)	Can go anywhere on the court except the two goal circles.
Wing Defence (WD)	can go into the defensive third but not into the goal circle, and also into the middle third
Goal Defence (GD)	Can go into the defensive third except into the goal circle, and also into the middle third.
Goal Keeper (GK)	Can go anywhere in the defensive third

Netball courts are divided lengthwise into thirds which determine where players in particular positions can move. Situated at each end of the court are the semi-circular goal circles containing a goal post. Only the GS and GA are allowed to score a goal. The GK and GD of the opponents are also allowed to enter the goal circle in an attempt to prevent the GS and GA from scoring a goal. The small circle in the centre of the court is called the centre circle. Play is started from the centre circle at the beginning of each time period, and after each goal is scored (see Figure 2.2).

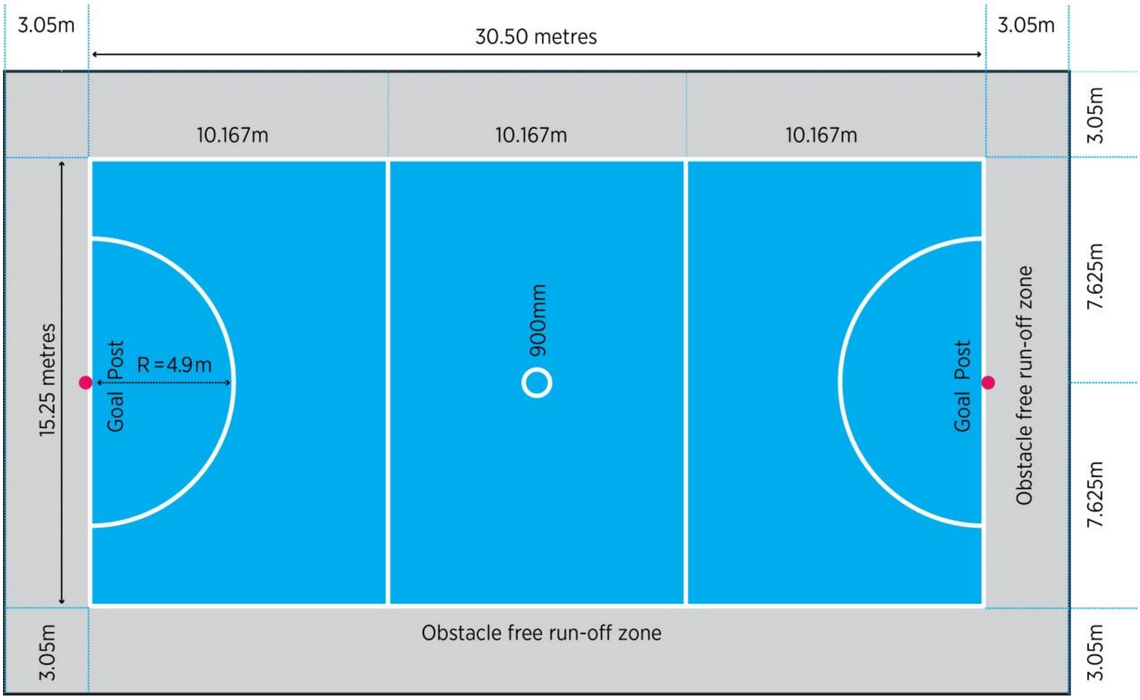

Figure 2.2: Diagram of a netball court (Dsr.wa.gov.au, 2018)

2.2.5 Physical characteristics of elite female netball players

For netball players to compete at the highest levels, players must be able to cope with the high physical demands of the game (Thomas *et al.,* 2016). Body composition profiling and somatotype evaluations have often been used to identify suitable sports for certain athletes as well as to identify potential talent as early as 1997 (Hopper, 1997). However, limited research is available regarding the height and body mass of female netball players. Netball players were previously reported to have a mean body mass of 61.4kg whereas the defenders (67kg) were found to be the heaviest followed by the shooters (63kg) and then the centre court players (63kg) (Chad *et al.,* 1991). Previous research on the Northern Irish Netball Team reported a mean (±SD) age and mass of 25.58 ± 3.99 years old and 72.3 ± 10.93 kg respectively (McCabe, 2014). Another study by Van Jaarsveld (2015) found the mean body mass of the participants to be 68.8 ± 6.0 kg. This correlated with Cormack *et al*. (2013) who investigated thirty-two (n=32) netball players and reported a mean (±SD) age and mass of 22.6 ± 4.4 years and 67.8 ± 8kg respectively. Thomas *et al*. (2016) also reported similar body mass values (69kg) for u/19 netball players.

Power-to-body weight plays an important role in any athlete who competes in sports that require explosive movements. As previously mentioned netball is described as an action packed sport that requires various explosive movement patterns such as short, fast sprint, quick stops and many changes in direction. Consequently, this increases the importance of power-to-body weight ratio in netball. Power-to-body weight can be increased by reducing body weight or by increasing power which will enhance overall performance. Although a decrease in body weight may lead to an increase in power-to-body weight, coaches and conditioning coaches must focus on decreasing body fat and not muscle mass or else power may be reduced (Chad *et al.,* 1991). Therefore the focus must shift from reducing body weight to rather reducing body fat in order to optimise an athlete's performance. Elite female netball players reportedly have a mean fat percentage of 19.8 ± 3.3% (Van Jaarsveld, 2015).

Netball player's height also plays an important role in performance and may be an advantage especially for positions within the shooting circle where players need to compete for rebounds, intercept passes and defend shots at goal. On the other hand, the centre court players are the link between the defenders and the shooters and utilize other skills such as agility and quickness. Chad *et al.* (1991) reported that shooters and defenders are considerable taller than the centre court players. Shooters and defenders were found to be 170cm and 174cm on average whereas centre court players only presented an average height of 165cm (Chad *et al.,* 1991). Research showed the mean height of netball players to be 175.00 ± 5.76 cm (McCabe, 2014). This correlates with Van Jaarsveld (2015) as well as Cormach *et al.* (2013) who reported player height to be 176 ± 5cm and 174.3 ± 6.6 cm respectively. Surprisingly, Thomas *et al*. (2016) reported a similar height (176cm) for u/19 netball players.

Somatotype components can be calculated using the Heath-Carter method and an individual can be classified as ectomorphic (linearity), mesomorphic (muscularity) or endomorphic (adiposity). Various authors agreed that somatotype differ from position to position in team sports. As reported in an article by Nicholas (1997) male rugby union players are shown to be primarily endo-mesomorphs. It is also observed that the forward positions are found to be more endo-mesomorphic than the backs. Additionally, Quarrie *et al.* (1996) also reported the forwards to be higher endo-mesomorpfic which could be related to a better performance on strength and power measures which is essential components when competing in scrums, rucks and mauls whereas the backs have a higher ecto-mesomorphic component. Nicholas (1997) also reported that female forward rugby players are heavier, taller and more mesomorphic than ectomorphic compared to the backline players. In addition these female rugby union players had higher mesomorphy and lower ectomorphy values compared to female hockey players.

Literature confirmed that elite female netball players do have different somatotypes for specific playing positions (Hopper, 1997). Hopper (1997) stated that the center court players have a more mesomorphic somatotype than the GA and GD positions. This could be due to the technical and physical demands placed on the center court players. These positions are the link between the attacking and defensive positions during a netball match and more explosive and short accelerations are required by the center court players. On the contrary, GD players are reported to have an ectomorphic somatotype. These players' higher linearity measures give them an advantage, as previously mentioned, with their defensive activities such as rebounding an attempted goal or jumping to catch or intercept a pass (Hopper, 1997). It becomes clear that somatotype profiling is considered to be an important component in determining an athlete's potential and suitability for a specific sport and a specific position.

Two hundred and forty (240) Netball players measured in 1988 at an All Australian National Netball Championship was found to have a mean body mass and height of 66kg and 173cm respectively (Hopper, 1997). Ferreira (2010) presented netball players to have a similar mean body mass, height and fat percentage of 68kg, 174cm and 27% respectively. More recently, Van Jaarsveld (2015) found the mean body mass of netball players to range between 62kg and 74kg. Interestingly, player height has gone up from an average of 173cm in 1988 (Hopper, 1997) to 174cm in 2010 Ferreira (2010) to an average of 176cm recorded by Van Jaarsveld (2015) in 2015.

Ferreira (2010) recorded a mean fat percentage for female netball players at 27%. It must be stated that Ferreira (2010) investigated players from the first, second, third and fourth league as well as the U19 A and B netball teams. Therefore player standard and conditioning could have influenced the results. In contrast, Van Jaarsveld (2015) investigated elite female netball players and found a mean fat percentage of 19.8%. To conclude the assumption could be made that player weight and fat percentage could be influenced by player standard as well as conditioning levels of the players.

To conclude, it becomes clear that different sports as well as different positions within the sports all have different requirements and therefore require specific individuals with specific body type and skills to complete the tasks required for that individual playing position.

2.3 Movement patterns of team sport participants

TMA of athletes provides conditioning coaches with knowledge of the demands of team sports in order to develop sport specific programs that enhance the physiological components of the specific sport and positions (Chandler *et al.,* 2014). Fox *et al.* (2013) emphasised the importance of understanding the different positional roles and demands of netball players. Fox *et al.* (2013) further stated that every player in a netball team has its own role to play within a match and that players are more often required to shadow an opposing player in order to execute her duties during a match.

TMA research on specifically netball has been published as early as 1983 (Otago, 1983). However, only a small amount of games were, analysed and analysis was done using the video footage that was intended for television purposes and not specifically for the use of TMA. Steele *et al.* (1991) also investigated the demands of netball players. Despite this study extending on earlier studies, the seven playing positions were grouped together. Therefore the research could not provide coaches with true specific playing positional demands. More recently, Fox. *et al* (2013) investigated the activity profiles of Australian female netball players and reported different activity profiles and work to rest ratios for each position and emphasised the importance of position specific training programmes. However, only a limited number of matches were analysed and the study focussed on senior level netball. Cormack *et al.* (2013) examined the differences of player load of different standards of netball. Although the gap between standard of play was eliminated, the positions were still grouped together. Therefore, the physical demands of all seven playing positions of under 19 netball players are still relatively unknown.

2.4 Time- motion analysis (TMA) to determine the different movement patterns of team sport participants

2.4.1 Methods of TMA in sport

There are a range of methods available to analyse sport performance which is of great value when trying to understand the demands of any sport (O'Donoghue, 2010). Several methods have been employed by researchers to monitor movement patterns in various sports including observation in the public domain of rugby league (Duthie *et al*., 2005) and rugby union (Deutsch *et al*., 1998), video recordings of football (Krustrup *et al.,* 2005), TMA using the Catapult system in gaelic football (King *et al.*, 2003) and filming of basketball games (Bishop *et al.*, 2006).

The use of an up-to-date, state of the art accelerometer and/or GPS may improve both reliability and specificity when quantifying the physiological profile of netball players (McCabe, 2014). TMA is proposed to be the most effective method of assessing the physical demands placed on athletes (Duthie *et al.,* 2005). This is in agreement with Meir *et al*. (1993) and Duthie *et al.* (2003a) that stated that TMA is effective and accurate in determining and quantifying player behaviour in a competitive sport environment.

2.4.1.1 Vision-Based TMA

Barris *et al.* (2008) described three different methods of vision-based motion analysis in sport. Firstly, Manual vision-based tracking systems or notational analysis, secondly, automated vision-based tracking systems and lastly the more expensive and sophisticated commercially available vision-based analysis systems which include systems like Dartfish™, Game Breaker™ and ProZone™. Manual video-based systems are often recommended to coaches as an inexpensive method of determining the physiological demands of sport and is the most widely used method of TMA (Spencer *et al*., 2005) as various research has been published in this regard (Spencer *et al*., 2005); (Bishop *et al.,* 2006) Notational analysis has been used in a range sports such as rugby, squash, badminton, basketball and netball (Barris *et al.,* 2008).

Historically, the process of notational analysis was carried out in different ways, from simple observations and written notes to more complex systems involving video recordings and computers (Barris *et al.,* 2008). Computerized movement tracking of squash players was introduced by Hughes *et al.* (1989). In 1995, Hughes *et al.* (1995) developed a more sophisticated notational analysis system to study elite tennis players where data were recorded on the court position of the players, time taken to play a shot and the type of activity. Video-based TMA most commonly uses one to seven cameras for field sports where most of the cameras are positioned on the halfway line, 5 to 30 meters from the side line and elevated to a height of 5 to 20 meters (Deutsch *et al.,* 1998); (Castagna *et al.,*(2004); (Da Silva *et al.,* (2008). Or, a less common approach can be followed where only two cameras are used (Spencer *et al*., 2005). The cameras are situated and focussed on opposite ends of each playing half with an overlap in the middle. This ensures recording of all the movements of the players during the duration of the game. It also provides the opportunity for all players to be analysed.

However, Duthie *et al.* (2003a) questioned the reliability of video-based TMA. The video recordings of ten rugby union players, that played Super rugby during 2001-2, were analysed by a single researcher on two different occasions 1 month apart. The test-retest reliability of the total time spent in movement categories was quantified as moderate to poor reliability (5.8-11% typical error measurement or TEM). The frequency of individual movements and the mean duration of individual movements had a good to poor reliability (4.3-13.6% TEM) and a moderate reliability (7.1-9.3% TEM) respectively. As seen in the abovementioned results, the conclusion could be made that the video-based TMA system is a moderately reliable measuring tool of movement patterns in Super rugby.

2.4.1.2 Automated Tracking Methods

Computerized semi-automated and automated tracking systems has recently been developed to track athletes during match play, however, these systems may be very expensive. Automated vision-based tracking systems do not require human operators to manually locate and record the position of the players or objects being tracked (Barris *et al.,* 2008). However, automated tracking systems also have limitations. One limitation is the inability to accurately track more than one player at a time. Players who are isolated on the playing area are very accurately tracked; however, problems with the tracking accuracy are often encountered in situations where multiple players cluster in the playing area (Barros *et al.,* 2007); (Muller *et al.,* 2004). Computerized video-based TMA are typically based on smooth movement patterns. In contrast, athletes that partake in sports such as netball and basketball often exhibit fast, agile and unpredicted movements and many changes in direction resulting in frequent collisions with each other and therefore limit the reliability of computerized video-based TMA for sports such as netball and basketball (Barris *et al.,* 2008). It must be mentioned that Pers *et al.* (2000) developed a computer vision-based tracking system that is capable of tracking multiple players at the same time. Three tracking methods were used namely: A: Tracking using the motion detection alone, B: Colour tracking alone and C: Combination of colour and template tracking. After counting the operator interventions required to maintain error-free tracking during a handball match it was concluded that method C was most suitable for use in automated player tracking. However**,** Pers *et al.* (2000) reported the errors associated with video-based player tracking. Movement of player’s extremities, quantization error, video tape noise, camera calibration errors and operator mistakes were identified as the most significant errors capable of influencing the tracking accuracy.

Lastly, commercially available vision-based analysis systems such as Dartfish™ and Game Breaker™ are designed to enhance performance by providing extrinsic feedback to athletes and coaches (Barris *et al.,* 2008). Game Breaker™ do not perform actual TMA but, create time-coded video clips to provide frame by frame feedback to athletes. However TRACKPERFORMANCE™ is a video-based tracking system that is capable of performing tracking in real-time. Operators must track player positions manually before the system can provide information such as distance covered velocity bands and work to rest ratios. TRACKPERFORMANCE™ is a video-based system and does not require athletes to wear any transmitting devices. Therefore tracking of opposing teams is also possible (Barris *et al.,* 2008). Similarly, ProZone™ is another video-based system proven to be a very reliable TMA system for analysing movement patterns of soccer players (Di Salvo *et al.,* 2006).

In conclusion, commercial video-based tracking systems clearly enhanced TMA in recent times, operating through high-speed digital video or cameras capable of detecting infra-red light. However, systems such as ProZone™ and TRACKPERFORMANCE™ require significant manual intervention to accurately track athlete performance.

2.4.1.3 Global Positioning System (GPS)

The use of small portable devices like GPS has become a popular method to determine the physiological demands of sport (Wisbey *et al.,* 2010). A GPS receiver receives signals from earth-orbiting satellites that produce constant coded signals at the speed of light. From this information a GPS can track an object (athlete) by calculating the displacement (change of position) of the object in real-time (Edgecomb *et al.*, 2006). One major advantage a GPS has over video-based tracking systems, is that the GPS data can be collected during or after the game and no time is needed to code different locomotor activities (Carling *et al*., 2005). Edgecombe *et al.* (2006) referred to The Sport Performance Indicator (SPI 10) that was developed by GPSports Systems Pty. Ltd. as an example of a GPS system used to record data on sport performance. Variables recorded by the system include time, distance covered, speed, position, altitude, direction and HR (depending if the athlete is wearing a heart rate monitor). The SPI 10 has a sampling rate of 1Hz which means data is recorded every second.

A few disadvantages are associated with GPS in TMA. A clear view of the sky is essential for the SPI 10 system to receive data from the satellites, therefore it cannot be used indoors (Edgecomb *et al.*, 2006). The MinimaxX v4.0, Catapult Innovations, Melbourne, Australia system is another example of a GPS system used to measure sport performance (Cormack *et al.,* 2013). The Minimax X4 has a much higher sampling rate (10Hz) that records data ten times per second, but like the SPI 10, it cannot be used indoors (Johnston *et al.,* 2012). Athletes are required to wear a small receiver during competition which could limit the use of GPS in competitive sport and rules and regulations of certain team sports do not allow athletes to wear anything other than the apparel for the sport (Di Salvo *et al.,* 2006).

2.4.2 Validity and Reliability of TMA

When the validity and reliability of testing methods are not established, the results must be considered with caution. Most of the video-based TMA studies are based on subjective categorization of movement patterns, e.g. jogging and running (Tenga *et al.,* 2003). Therefore, the categorization of movement patterns is relying on the interpretation of the researcher (Lames *et al.,* 2007). It is therefore likely that the interpretation of the movement patterns may differ between different researchers, which may affect the reliability of the result.

O'Donogue (2010) investigated inter-observer reliability as well as intra-observer reliability where movements were categorized as high intensity and low intensity. The results showed significant systematic bias between observers regarding the percentage time spent performing high intensity activities ($p<0.01$). Observations between the different halves also revealed significant systematic bias where higher values were recorded during the first half ($p<0.05$).

Spencer *et al.* (2005) investigated movement patterns of international hockey players and reported Test Error Measurement (TEM) values of 5.9-10.2% and 5.7-9.8% for the frequency of movement patterns and the duration of the movement patterns respectively.

2.4.3 Limitations of TMA

Potential limitations in TMA studies could be that the small sample size of the matches analysed in some studies makes the results vulnerable (Davidson *et al.,* 2008). Secondly, Davidson *et al.* (2008) highlighted the importance of using the same observer for all the athletes. The methods to calculate distance using TMA could be limited as they require assumptions that the velocity of a player is constant throughout the movement (Duthie *et al.,* 2005).

Another limiting factor could be the differences in movement patterns of the different playing positions. Research has divided athletes into different positional groups based on the roles and rules of the different playing positions (Davidson *et al.,* 2008). However, this could limit the differences between each of the 7 different positions in netball leading to difficulty when prescribing individualized conditioning programmes. To conclude, in order to minimize the limitations of TMA it would be useful for researchers to increase the sample size and to investigate each individual playing position (Davidson *et al.,* 2008).

2.4.4 Applications of TMA

Fox *et al.* (2013) agreed with Martin *et al.* (2001) that TMA information may be very useful to conditioning coaches when developing conditioning programmes. Knowledge about the movement patterns, HR response, distance covered, velocity and accelerations may assist conditioning coaches when developing conditioning programmes that are sport and position specific. However, James *et al.* (2007) highlighted that TMA do have potential limitations regarding the validity and reliability of the measured data. These limitations include the unclear definitions of movement categories (James *et al.,* 2007). Davidson *et al.* (2008) suggested that in order to lessen the effect of these limitations, researchers should use clearer objective definitions for each movement category, increase the sample size and compare data recorded from different age groups and level of participation. This could also be a potential limitation however, the development of more sophisticated GPS based TMA systems have given researches the opportunity to do TMA studies that is less time consuming than video-based methods and this could lead to greater sample sizes in future studies (Di Salvo *et al.,* 2006). However, due to the high expense of these sophisticated GPS units, time consuming video-based TMA could still be used more frequently (Kraak, 2011). Coaches and conditioning coaches must be aware of the limitations of the different methods of TMA when reading literature on TMA (Petersen *et al,* 2009).

2.5 Heart Rate (HR) response to determine the intensity of team sport participants

2.5.1 Background of HR Recordings

The stethoscope was invented 200 years ago by Rene Laennec which made listening to the heart beat more accurate than placing your ear on the patients' chest (Achten *et al.,* 2003). However, it was still not possible to accurately monitor HR during exercise. The first electrocardiograph (ECG) was developed during the 20th century. Soon after a portable ECG (Holter-monitor) was developed, and it is able to record an individual's ECG for 24 hours by means of a continuous tape recording (Achten *et al.,* 2003). The first HR monitor was developed during the early 1980's consisting of a receiver (in the form of a watch-like monitor) and a transmitter (either disposable electrodes or an elastic electrode belt).

Thereafter, the use of HR for the monitoring of athletes has increased. Measurements became more objective as HR monitoring (objective) began to replace the subjective methods (perceived exertion) of performance monitoring. From then on HR monitors were developed with a larger internal memory and this makes it possible to store HR data from multiple exercise sessions which could be downloaded to a computer at a later stage (Achten *et al.,* 2003). More recently HR monitors have been developed with a calorie-counting feature and can even estimate the athlete's maximal oxygen uptake (VO_{2max}). HR variability (HRV), which is described as the variation in time between two consecutive heart beats, is another feature that recent HR monitors are equipped with (Achten *et al.,* 2003).

2.5.2 Factors Influencing HR

Monitoring HR during competition has proven to be useful to determine the physiological demands of an athlete during competition or training, however, the accuracy of HR monitoring may be influenced by certain factors (Kraak, 2011). Tumilty (1993) stated that factors such as physiological arousal and anxiety may influence HR. Apart from the small day-to-day variability of HR measurements Achten *et al.* (2003) also enumerate several physiological factors that may influence HR response to exercise. The first of these influential factors is cardiovascular drift. This term refer to the gradual decrease in stroke volume and the gradual increase of HR after the first few minutes of moderate intensity exercise. Cardiovascular drift is associated with numerous factors such as dehydration and heat stress.

According to Achten *et al.* (2003), hydration status is another factor that may influence HR. The research concluded that when athletes exercise in a dehydrated state without a raise core temperature, HR may increase up to 7.5%. The increased HR is positively correlated to the level of hydration.

It is reported that environmental factors such as temperature may also influence HR response (Achten *et al.,* 2003). Exercise in hot conditions is associated with higher HR recordings (as high as 10 beats per minute more) than exercise at the same intensity in cold temperatures (Achten *et al.,* 2003).

2.5.3 Reported HR Data in Sport

According to Achten *et al.* (2003) the first wireless HR devices were developed during the early 1980's. Thereafter the use of HR for the monitoring of athletes has increased. Measurements became more objective as HR monitoring (objective) began to replace the subjective methods (perceived exertion) of performance monitoring. In addition, it is also possible to do HR analysis in team sports by means of systems such as Team Polar (Polar Electro Oy, Kempele Finland) and Suunto Team Pack (Amer Sports Corporation, Mäkelänkatu 91, Helsinki, Finland). Various sports do not allow athletes to wear a watch-receiver during competition. However both of these systems make use of only a chest strap that has an internal memory to record HR during match play.

HR responses in intermittent sport such as soccer are reported to range from 152 – 186 beats per minute (b/min) (Krustrup *et al.,* 2005). Abdelkrim *et al.* (2007) also found mean HR values for basketball match play to be within a similar range to soccer players at 171b/min. This data is difficult to compare since it is not related to a proportion of maximal heart rate (HR_{max}). Krustrup *et al.* (2005) enlighten this information as well and documented that soccer players have a mean of 86% HR_{max}. Abdelkrim *et al.* (2007) reported a mean %HR_{max} of 91% for basketball players. This highlights the considerable physiological demands placed on basketball players during match play. The reason for difference in % HR_{max} between soccer and basketball could be the difference in court size and age of the subjects. Another contributing factor could be the standard of the subjects as Cormack *et al.* (2013) verified when they reported a greater PL in higher standard netball players compared to their lower standard counterparts in all positions.

Previous researchers have monitored HR to investigate the physiological demands of netball match play. Chandler *et al.* (2014) furthermore compared HR during match play to HR during training and reported a mean HR of 174 beats per minute (b/min) during a netball match for all playing positions. However Chandler *et al.* (2014) stated that the C and WA positions have a higher HR during match play (185 and 182 b/min respectively). Mean HR values seems to range from 156 – 185 b/min for netball players where the GA recorded the lowest mean HR (Chandler *et al.,* (2014). McCabe (2014) stated that the mean HR ranges from 152 – 178 b/min which is similar to the results of Chandler *et al.* (2014). During the study by

McCabe (2014) it was found that the GK recorded the lowest average HR and in contrast to Chandler *et al.* (2104) the GA in this case was reported to have the highest average HR. McCabe (2014) investigated twelve international netball players whereas Chandler *et al.,* (2014) investigated collegial-level netball players. As previously stated by Cormack *et al.* (2013) that the standard of participation could influence the PL, it could also be the reason for the different results found in the studies by McCabe (2014) and Chandler *et al.* (2014).

2.6 Physiological Demands of Netball Players

The physiological demands of intermittent sport such as netball are often more complex compared to the physiological demands of continuous sports like as running since intermittent sport places a unique demand on muscle metabolism (Bangsbo, 1994). Furthermore, due to the small court and the rules of netball, it could be argued that each of the different positions has its own physiological demands during match play (Woolford *et al.,* 1991). Cormack *et al.* (2013) stated that although movement patterns may be position specific, higher standard netball players are often required to maintain high exercise intensity irrespective of playing position. Davidson *et al.* (2008) investigated the physiological demands of only three different playing positions; thus the physiological demands of all the playing positions are poorly understood. A Poor understanding of the physiological demands of all playing positions could make the development of position specific conditioning programs very difficult (Chandler *et al*., (2014). Therefore the current study analysed all playing positions to provide a better understanding of the physiological demands of each player on court during match play.

An understanding of the demands of match play and the demands of specific playing positions in sports such as netball is important so that relevant training drills, that simulate game play, can be constructed (Yong *et al.,* 2015; Chandler *et al.,* 2014). Research suggest that TMA is becoming a popular method to determine the physical demands of various team sports such as basketball (Adbelkrim *et al.,* 2006), handball (Belka *et al.,* 2014) and netball (Chandler *et al.,* 2014). The little literature on TMA of specifically netball has primarily focused on methods where player movements are classified into categories based on the intensity of the movement (Yong *et al.,* 2015). These studies have mainly focused on senior level netball that is primarily played indoors, therefore TMA using GPS data on netball and more specifically at u/19 level is relatively unknown (Yong *et al.,* 2015). Analysis of sport create an understanding of the physical demands of the sport, and thereby empower coaches and condition coaches with knowledge to develop sport specific conditioning programs to enhance performance (Chandler *et al.,* 2014).

TMA using GPS technology is capable of generating data in real-time, therefore limit the time needed for coding and manual intervening (Yong *et al.,* 2015). Research have indicated that the C position are more active during match play, whereas the GK and GS positions are reportedly the least active playing positions (Fox *et al.,* 2013). Chandler *et al.* (2014) investigated the physical demands of netball players by using the Catapult Minimax S4 and measured the following variables:

- Time on court (min)
- Player load per minute (PL/min)
- Forward movement per minute
- Sideward movement per minute
- Vertical movement per minute

In addition, Yong *et al.* (2015) as well as Fox *et al.* (2013) tracked netball players, (Yong *et al.* (2015) using a 5Hz GSP unit in conjunction with the vision-based SportsCode Pro (Sportstec™ Limited, Warriewood, Australia) and Fox *et al.* (2013) using Datrfish) to determine the following variables:

- Distance per minute covered per quarter
- Distance covered per movement classification (Standing, Walking, Jogging, Running, Sprinting and Shuffling)
- Frequency of movement classification per quarter
- Duration of movement classification
- Work to Rest ratio (W:R)

The above mentioned movement classifications (Standing, Walking, Jogging, Running, Sprinting and Shuffling) are well established and have been used in a number of studies of netball : Otago (1983), Steele *et al.* (1992), Davidson *et al.* (2008) and Fox *et al.* (2013).

To conclude, using the Minimax X4 (Catapult Innovations), the current study used the same variables to determine the physical characteristics of under 19 netball players in the Free State region. The Minimax X4 has a coefficient of variation of <2% that proves the reliability of the accelerometer (Boyed *et al.,* 2011). Therefore, the current study made use of this accelerometer to determine the physiological and physical demands placed on netball players during match play.

2.6.1 Player load (PL) of netball players during match play

The recent development of small wearable devices has provided new opportunities for research in sport sciences, including research into the physical demands of sport (Montgomery *et al.,* 2010). Research adopted from basketball suggested that basketball players may execute approximately 50 explosive vertical jumps per game and may cover several kilometres during match play, including many high intensity movements, accelerations and decelerations in different directions (Montgomery *et al.,* 2010).

To determine physical activity of players, the Catapult Minimax X4 accelerometer unit measures accelerations in the frontal-, sagittal- and transverse axes of movement to determine a variable called player load (PL) (Gabbettt, 2012). In other words, Boyed *et al.* (2011) described PL as a variable developed and captured by the Catapult Minimax X4 during match play as a measure of physical activity by measuring the accumulation of accelerations in all 3 planes of movement (frontal, sagittal and transverse (Chandler *et al.,* 2014).

PL is calculated using the following formula (Boyed *et al.,* 2011):

$$PlayerLoad = \frac{\sqrt{((\mathrm{Ac1} - \mathrm{Ac1}{-}1)\ 2\ +\ (\mathrm{Ac2} - \mathrm{Ac2}{-}1)\ 2\ +\ (\mathrm{Ac3} - \mathrm{Ac3}{-}1)\ 2\ )}}{100}$$

where

Ac1 = Forward acceleration

Ac2 = Sideways acceleration

Ac3 = Vertical acceleration

The different accelerations are measured by the Catapult Minimax X4 (sampling at 100 Hz) during match play.

Montgomery *et al*. (2010) used the same formula to determine the physiological demands of basketball players. All the variables collected from the tri-axial accelerometer were divided by playing time to normalize the data. All body movements during the competition were expressed as accumulated load and expressed in arbitrary units (a.u.). The arbitrary units do have some advantage over other metrics such as velocity or distance covered, as the calculation takes into account whole body movements (Montgomery *et al*., 2010).

Boyd *et al.* (2011) for one stated that tri-axial accelerometers can profile the intensity of movements in multiple planes. Chandler *et al*. (2014) differentiated two variations of PL to determine physical demands namely (a) total PL and (b) PL in each axis (frontal, sagittal and transvers) to determine the physical demands of netball players. Chandler *et al*. (2014) also normalized all measurements for playing time and reported as arbitrary units Load $^{TM \cdot}$min $^{-1}$ (au) as Montgomery *et al*. (2010), Cormack *et al.* (2013), McCabe (2014) and Fish *et al.* (2014) previously did.

Table 2.5 Player load

Author		**Chandler *et al.* (2014)**	**Cormach *et al.* (2013)**			**McCabe (2014)**	**Fish *et al.* (2014)**	
Population		8 Collegiate female netball players	17 Higher and 17 Lower standard female netball players			12 Northern Irish netball players OVER a 5 day period	20 Collegiate female netball players	
	MEAN PL	6.6	10 – Higher standard 7 – Lower standard					
PL/Position (Load $^{TM \cdot}$min $^{-1}$ (au))	**GS**	3.5	The C had a 16% greater PL than the Shooters.			75.5	6.2	
	GA	6.7				122.38	9	
	WA	6.5				133.19	11	
	C	9.6				185.58	13.7	
	WD	5.1				147.25	10	
	GD	6.5				139.38	11	
	GK	3.4				103.35	8.5	
PL in different axis per position (Load $^{TM \cdot}$min $^{-1}$ (au))		**Forward**	**Side**	**Vertical**	The higher standard Shooters, C and Defenders had 11.1%, 11.6% and 10.7%great	**Forward**	**Side**	**Vertical**
	GS	1.4	1.5	2.3		1.7		2.7
	GA	2.4	2.7	4.7				

	WA	2.1	2.7	4.6	er vertical			
	C	3.8	3.4	6.8	contribution	3.4	3.9	6.4
	WD	1.8	2.2	3.4	than the			
	GD	2.2	2.5	4.3	lower			
	GK	1.5	1.4	2.3	standard players.			
PL / Position in different playing quarters (Load $^{TM \cdot}$min $^{-1}$ (au))	**Shooters**	Q1			9.7			
		Q2			9.6			
		Q3			10			
		Q4			8.2			
	Center	Q1			10.9			
		Q2			11.2			
		Q3			10.4			
		Q4			10.8			
	Defenders	**Q1**			10			
		Q2			9.9			
		Q3			10.3			
		Q4			9.2			

Literature indicates that PL would be greatest in the C position due to the court restrictions in netball (Davidson *et al.,* 2008). Numerous authors found the C position to be the most physical demanding position. Since the C has the greatest distance to cover, the load placed on the C should also be greater. Fish *et al.* (2014) further hypothesised that the biomechanical load of the different positions is influenced by the technical and tactical demand of each position. Davidson *et al.* (2008) agreed with Fish *et al.* (2014) that the C position exposed the greatest load during a match because of the greater distance that the C has to cover. Therefore this should correlate with the greater load placed on that individual player. Cormack *et al.* (2013) verify the greater load placed on the C when he reported that the C had a higher match Load™.min^{-1} than the GS. McCabe (2014) similarly associated the C with a greater demand as the C had a 38.33 Load $^{TM \cdot}$min $^{-1}$ (au) higher average PL than the WD position which, according to McCabe (2014) has the second highest PL. It should be mentioned that McCabe (2014) only tested 12 netball players during a five-day tournament.

After conducting a study on accelerometer load in different standards of netball, Cormack *et al.* (2013) reported a mean (±SD) PL of 10.0 ± 2.5 Load $^{TM \cdot}$min $^{-1}$ (au) for higher standard netball players. Additionally Chandler *et al*., (2014) reported a mean (±SD) PL of 6.1 (± 3.0-3.9 Load $^{TM \cdot}$min $^{-1}$ (au)). However, McCabe (2014) recorded an even higher PL during the five day tournament and reported a mean (±SD) PL of 129.52 ± 34.69 Load $^{TM.}$min $^{-1}$ (au) for the five days.

As previously mentioned, Chandler *et al*. (2014) further differentiated between PL in the different axis (frontal, sagittal and transverse) and found a mean (±SD) PL of 2.3 (2.1-2.5) Load $^{TM.}$min $^{-1}$ (au) for forward accelerations and 2.4 (2.2-2.6) Load $^{TM.}$min $^{-1}$ (au) and 4.2 (3.8-4.6) Load $^{TM.}$min $^{-1}$ (au) for the sideways and vertical accelerations respectively. Cormack *et al.* (2013) previously stated that a greater portion of the total PL of higher standard netball players is accumulated in the vertical plane. However, according to Hobara *et al.* (2010) it is possible that the PL accumulated in the vertical plane is reflected by the Load $^{TM.}$min $^{-1}$ (au) accumulated from the associated vertical displacement during running. Higher standard athletes run at higher intensities. Sprinting, acceleration and deceleration account for more rapid vertical displacement and therefore accumulate a greater contribution from the vertical vector (Jennings *et al.,* 2012). Nevertheless, Cormack *et al.* (2013) argued that it is possible that the rule in netball that forces a player to come to a complete stop within one step after taking possession of the ball has an impact on the individual contribution to Load $^{TM.}$min $^{-1}$ (au). It should also be mentioned that it is possible that activities such as jumping contribute to a portion of movement in the vertical plane as well as that the playing surface could also influence the Load $^{TM.}$min $^{-1}$ (au) and the individual vector contribution (Cormack *et al.,* (2013).

Chandler *et al*. (2014) also acknowledged a greater PL for the C. They reported a PL of 9.6 (8.8-10.5) Load $^{TM.}$min $^{-1}$ (au) for the C while the GD (6.7) had the second highest PL. The GK and GS recorded the lowest PL at only 3.5 (3.0-3.9) Load $^{TM.}$min $^{-1}$ (au) for the GK and 3.4 (3.1-3.6) Load $^{TM.}$min $^{-1}$ (au) for the GS. Furthermore, according to previous research it is apparent that the GS and GK have the lowest PL, suggesting that these positions have a lower physical demand during match play. Although PL shouldn't be measured only as distance covered it was reported that the GS and GK also performed less total distances as well as lower distances while performing jogging, running and sprinting activities (Steele 1990). Additionally, McCabe (2014) in agreement with Chandler *et al*. (2014) also acknowledged that the GS and GK have the lowest PL. The lower PL in these two positions may be because of the court restrictions with these players only allowed in one-third of the court. In contrast with the GS and GK the C position has the highest PL, suggesting the greatest physical demands during a netball match. Cormack *et al.* (2013) also shared this view as they found the C to have a significant higher activity profile than both the shooters and the defenders. This may also be linked to the court restrictions where the C has least court restrictions.

Chandler *et al.* (2014) agreed with Fish *et al.* (2014) and reported a higher PL in all planes of movement for the C position, suggesting that the C complete more multidirectional movements and may present with a higher physical demand than any other position during match play. Research regarding PL of specifically the WA and WD positions is limited as previous research categorized these positions as centre court players together with the C position. However, McCabe (2014) and Chandler *et al*. (2014) reported that the WA and WD have similar physical demands as well as the same court restrictions. It could be argued that the centre court players (C, WA, WD), who have fewer restrictions on court movement, correspond with the higher PL inflicted on them. On the other hand, the positions with the greatest court restrictions (GS, GK) correspond with the lowest PL (McCabe, 2014). However, Fish *et al.* (2014) reported PL of all the playing positions. In agreement with the above mentioned research, Fish *et al.* (2014) also reported that the C position is the most active playing position on the court with a PL of 13.7 Load $^{TM\cdot}$min $^{-1}$ (au), whereas the GS and GK are the least active position (6.2 and 8 Load $^{TM\cdot}$min $^{-1}$ (au) respectively).

Playing position also influence the PL in the different planes of movement. As previously mentioned Chandler *et al.* (2014) and Fish *et al.* (2014) reported that the C present with the highest PL in all planes of movement. PL in the sagittal plane (forward and backward accelerations) for the C position was found to vary between 3.4 Load $^{TM\cdot}$min $^{-1}$ (au) (Fish *et al.,* 2014) and 3.8 Load $^{TM\cdot}$min $^{-1}$ (au) (Chandler *et al*., (2014). The GK and GS displayed the lowest PL in the sagittal plane. Chandler *et al*. (2014) reported a PL of only 2.3 Load $^{TM\cdot}$min $^{-1}$ (au) for both the GS and GK position, whereas Fish *et al.* (2014) reported an even lower PL for the GS (1.7 Load $^{TM\cdot}$min $^{-1}$ (au).

Physical demands in the frontal plane (medio-lateral accelerations) seem to exhibit a similar pattern of position specific loading. The C position again displayed the highest PL in the frontal plane with measurements of 3.4 Load $^{TM\cdot}$min $^{-1}$ (au) and 3.9 Load $^{TM\cdot}$min $^{-1}$ (au) reported by Chandler *et al.* (2014) and Fish *et al.* (2014) respectively. Additionally the GS and GK also have the lowest PL in the frontal plane (Fish *et al.,* 2014). Chandler *et al.* (2014) reported a PL of only 1.4 and 1.5 Load $^{TM\cdot}$min $^{-1}$ (au) for the GS and GK positions.

The same pattern is reported for load in the transverse plane. This is accelerations in the vertical plane. As expected the C is reported to have the highest load in the transverse plane with PL reported to be as high as 6.8 Load $^{TM\cdot}$min $^{-1}$ (au) and again the GS and GK present with the lowest demand in the transverse plane of only 2.3 Load $^{TM\cdot}$min $^{-1}$ (au) (Chandler *et al.,*2014). Fish *et al.* (2014) supported this by reporting a PL of only 2.7 Load $^{TM\cdot}$min $^{-1}$ (au) for the GS position.

The WA and the C positions have similar technical and tactical demands. Although the WA can only access two thirds of the playing court, it has a fundamental role during attacking play for the team by incorporating rapid sprints and frequent changing of direction (Fish *et al.,* 2014). This could result in a higher accumulated PL. On the other hand, the GS and GK only have access to one third of the playing court, resulting in a shorter distance covered and therefore a lower PL (Fish *et al.,* 2014). Defensive players such as the GD and GK are reported to have a higher PL than their opposing attacking positions (GA and GS). (Fish *et al.,* 2014) suggested that the reasoning behind this could be coupled to the notational tactical demands of the specific position. Davidson *et al.* (2008) stated that the defender react to the movements of the attacking player. The defender will try to move around the attacking player to prevent the attacking player to receive the ball (Davidson *et al.,* 2008). However, according to Davidson *et al.* (2008) the GS cover a greater distance sprinting. This could also be technical as well as tactical as the GS sprint out to receive the ball in front of the defending player (Davidson *et al.,* 2008).

In conclusion, it is clear that research suggest that the C position is the most active player on court as they can operate in all tree thirds of the playing court. In agreement with Chandler *et al*. (2014) and Fish *et al.* (2014), Fox *et al.* (2013) concluded that the C and WA are the most active players in all the planes of movement. Player activity during match play will vary. A higher PL could be obtained by accumulating a greater distance covered, or by covering a shorter distance but at a higher intensity. It is also important to consider higher accelerations in the vertical plane by jumping up and down to compete for a rebound for example (Fish *et al*., 2014).

With this in mind, the differences in PL between the different playing positions need to be carefully considered when prescribing conditioning programs. Another factor that should be considered when quantifying physical demands of netball players is standard of play and difficulty of the match as suggested by study done by Cormack *et al.* (2013) that the PL (Load $^{TM\cdot}$min $^{-1}$ (au)) of higher standard netball matches is considerably higher than that of lower standard games. Lastly, Montgomery *et al*. (2010) and Chandler *et al*. (2014,) emphasised the importance to normalise accelerometer measurements for playing time. The tri-axial provides measurements in all 3 axes as Chandler *et al.* (2014) explained. That provides merit to the arbitrary units (Load $^{TM}\cdot$min $^{-1}$ (au)), as the calculation takes into account whole body movements.

As can be seen from previous research, the C position presented with a higher PL than all the other positions. The opposite can be said for the GS and GK positions, suggesting that the C is associated with a higher physical demand during a netball match and the GS and GK would have the lowest physical demand during match play. However, the current study will also investigate the difference in PL per meter between the different playing positions in attempt to more accurately define the physical demands of all the playing positions in netball.

2.6.2 Total distance covered by netball players during match play

Belka *et al.* (2014) remarked that the distance covered by athletes during competition is one of the most studied variables in the field of sport science. Aughey (2011) suggested a strong relationship between distance covered and Load $^{TM}\cdot$min $^{-1}$ (au) in elite Australian Football players. However, as Australian Football is played on a larger field than netball there is greater opportunity to accumulate distance. As previously mentioned, limited research has been done on the movement patterns and physiological demands of netball players. Previous literature often referred to total distance covered when performing TMA. In addition to total distance covered, the frequency, mean duration, total time and percentage time spend in activities are fundamental measurements in TMA (Duthie *et al.,* 2005).

Table 2.6 Distance covered

Author	Population	Total distance covered during a match (km)	Distance covered per playing position (km)						
			GS	**GA**	**WA**	**C**	**WD**	**GD**	**GK**
Liddle *et al.* (1996)	Badminton players	2							
Mohr *et al.* (2003)	High standard	8 – 12							

	soccer players						
Twist *et al.* (2014)	Elite rugby league players	5 – 8					
Cunningham *et al.* (2016)	40 International u/20 Rugby union players	5 – 6					
Coutts *et al.* (2010)	Elite Australian football players	12					
Scanlan *et al.* (2012)	State-level female basketball players	127 – 136 meters per minute					
Davidson *et al.* (2008)	6 English netball players.	4 - 8	4.2	These positions were not investigated	8	These positions were not investigated	4.2
Davidson *et al.* (2008)	6 English netball players.		GS covered 70 meters per minute		C covered 133 meters per minute	GK covered 71 meters per minute	
Yong *et al.* (2015)	22 Adolescent netball players 1 match of 6 quarters of 10min per quarter		35m per minute		37.7m per minute	36m per minute	

Total distance covered have been measured in various team sports and varies from 5-6km covered in under 19 rugby union (Cunningham *et al.,* 2016) to 5-8km covered in ruby league (Twist *et al.,* 2014) and 8-12km covered during a soccer match (Mohr *et al.,* 2003). Total distance covered by racquet sport athletes depends on the length of the game till victory is reached. Badminton players cover a mean total distance of 2km (Liddle *et al.,* 1996). The variation in total distance covered between the various sports may be reflected by the total playing time of a match as well as the size of the different playing courts or fields. Soccer is played for 90min and soccer players cover the largest distance. Rugby union, rugby league and soccer are all played on larger fields than sports like basketball, badminton and netball. There is limited research available on court-based athletes. Netball is played for 60min at senior level while an under 19 netball match only last 40min. Netball is played on a similar court surface area than basketball, therefore the total distance covered by netball players may be similar to that of basketball players (Ryan, 2009). However, playing time might have an influence on the distances covered at u/19 level. State-level female basketball players were reported to cover 127 – 136 meters per minute (Scanlan *et al.,* 2012).

Yong *et al.* (2015) studied the activity profiles of adolescent netball players. The positions were categorized as Defence (GD, GK), Midcourt (WA, C, WD) and Attack (GS, GA) and it was reported that the midcourt positions cover the greatest distance with attacking players covering the least amount of meters in adolescent netball. Davidson *et al.* (2008) on the other hand found the GK and GS to cover similar distances during a netball match (4283m ± 261m and 4210m ± 477m respectively) however, the GS covered a far greater distance while sprinting and the GK covered more distance shuffling. In addition, the C covers a far greater total distance (8km) than both the GS and GK who both travelled an average distance of 4.2km. Again, this difference could be described to the fact that the C has a greater distance to cover due to the areas on the court that the different positions are allowed to move. As previously described the C can move in all areas of the court accept for the shooting circle while the GK and GS are restricted to move in only one third of the court. Furthermore when the ball is in the opposite end of the court the GS or GK (depends on which team is in possession of the ball) will stand still until the ball reaches their side of the court. However, the C will follow the ball either on attack or as a defensive player. Otago, (1983), Steele *et al.* (1992) and Davidson *et al.* (2008) all classified movement patterns in the following categories.

Table 2.7 Classification of movement patterns according to Otago (1983), Steele *et al.* (1992) and Davidson *et al.* (2008)

Movement activity	**Definitions as defined by Otago (1983), Steele *et al.* (1992) and Davidson *et al.* (2008)**
"Standing	No locomotor activity
Walking	Strolling locomotor activity in either a forwards, backwards or sideways direction
Jogging	Slow running action where there is no specific goal and no obvious acceleration
Running	A fast running action with distinct elongated strides, effort and purpose
Sprinting	Running at maximum speed and full effort
Shuffling	A sideways movement of the body using a shuffling action of the feet"

Similarly and more recently, Fox *et al.* (2013) and Yong *et al.* (2015) also classified player movements as follows:

Table 2.8 Classification of movement patterns according to Fox *et al.* (2013) and Yong *et al.* (2015)

Movement activity	**Definitions as defined by Fox *et al.* (2013) and Yong *et al.* (2015)**
Walking	Strolling locomotor activity in either a forwards, backwards, or sideways direction
Jogging	Slow, non-purposeful running with no obvious acceleration
Shuffling	A sideways, backwards, or on-the-spot movement requiring effort and shuffling movement of the feet
Running	A fast running action with distinct elongated strides, effort and purpose
Sprinting	Running with maximum effort or at maximum speed

Davidson *et al.* (2008) in agreement with Steele *et al.* (1992) and Loughran *et al.* (1999) reported a significant difference in the distance covered while jogging and running between the C and GK and GS. The C jogged and ran 1756m ± 308m and 1758m ± 494m respectively while the GK and GS jogged a distance of only 195m ± 71m and 283m ± 160m respectively. While the GK and GS only ran 143m ± 37m and 362m ± 169m respectively. There were no significant difference in distance shuffling between the C and GK with 2025m ± 282m and 2037m ± 233m respectively. The C and GS are reported to sprint similar distances as Davidson *et al.* (2008) reported that the C sprint 555m ± 274m and the GS sprint 370m ± 233m. This could be because the GS more often sprint to move away from the defenders to receive the ball in a position that allow the player to take a shot at goal. According to Otago (1983) the GK spend significantly more time in a defensive positions which requires more shuffling movements.

As mentioned previously distance covered and Load ^{TM}·min $^{-1}$ (au) had a strong correlation in research done on Australian Football players (Aughey, 2011). This could be a reason why the PL of centre court players are higher as they cover more distance during netball match play (Davidson *et al.,* 2008). However, McCabe (2014) reported that the frequency of both accelerations and jumps are higher in other positions (GD and GA respectively). For example the GA has to sprint away from defenders to put themselves in a position to receive the ball. On the other hand GD must sprint and jump in attempt to intercept the ball when it passed around by the opposition.

2.6.3 Velocity and Acceleration thresholds during netball match play

Dwyer *et al.* (2012) investigated GPS data to determine velocity ranges of field sport athletes and stated that previous research classified locomotor activity in an attempt to simplify TMA results. The most common methods used to define locomotor activities are defined as a range of velocity thresholds, a mean velocity or as previously mentioned, subjective descriptions. However, researchers such as Aughey (2011) and Rampinini *et al.* (2009) further classified velocity bands as low-intensity running (LIR), moderate-intensity running (MIR) and high-intensity running (HIR). Suarez – Arrones *et al.* (2012a) and Coutts *et al.* (2010) to name a few furthermore classified movement patterns as absolute values (see Table 2.9). Consequently, comparing published research is problematic due to the various different definitions of velocity bands. Dwyer *et al.* (2012) furthermore, expressed his concern of what constitutes as a sprinting activity by stating that numerous sport scientists classified activities or efforts above a given threshold of 6 – 7 $m.s^{-1}$ are classified as a sprint.

However, Dwyer *et al.* (2012) enumerates that many maximal effort sport sprints start from a standing position and only last about 1-2 seconds. Although these activities are completed at maximal effort, the duration of these activities are too short to achieve the sprinting velocity threshold. Dwyer *et al.* (2012) reported that a sprint lasting only 1 second can cover up to 4.2 meters and sprints lasting 2 seconds could cover 7 meters. However these activities would not be classified as a sprint because the maximum velocities of these sprints were not greater than the traditional sprint velocity threshold of $5.6m.s^{-1}$. Therefore, Dwyer *et al.* (2012) investigated data sets of five different sports including male and female sports and acknowledged the traditional sprinting threshold of $5.6\ m.s^{-1}$, however recommended that a sprint should further be defined as: “any player movement that satisfies one or both of the following criteria: (a) The movement reaches or exceeds the sport specific sprint threshold velocity for at least 1 second and (b) the acceleration of the movement occurs in the highest 5% of accelerations in the associated velocity range. When the movement satisfies both criteria, it is counted as only 1 sprint.”

Unfortunately no previous research on TMA on netball has used absolute values for velocity bands. Research published on Australian Football by Farrow *et al.* (2008) classified moderate velocity as $2m.s^{-1}$ and high velocity as $4m.s^{-1}$. Farrow *et al.* (2008) additionally classified high accelerations as $>4m.s^{-2}$. In contrast, Aughey (2011) reported an acceleration of $2.78m.s^{-2}$ to be an appropriate threshold for maximum acceleration of Australian Football players. Aughey (2011) explained his theory of maximal acceleration of Australian Football players by evaluating accelerations of elite athletes in various sports codes. During the first second of a race an elite 100m sprinter accelerate at a rate of approximately $6m.s^{-2}$ and accelerate at about $2m.s^{-2}$ after the first second. Furthermore, Aughey (2011) reported a maximal acceleration from a standing start of $3m.s^{-2}$ for elite team sport athletes.

It is clear that there is no consistent definition for velocity bands, making comparisons between literatures very difficult. The confusion of the velocity thresholds also extend to the duration of movement activities such as a sprint. Carling *et al.* (2012) as well as Clarke *et al.* (2014) stated that a sprint must occur for longer than one second, however in other studies (Jennings *et al.,* 2012) no mention is made on the duration of a sprint.

Most of the available research on TMA of netball players used the traditional classification of locomotor activities. For this reason, to compare the results of the current study to previous research the current study made use of the velocity bands for female hockey players as defined by Dwyer *et al.* (2012) – Standing = $0\text{-}0.1m.s^{-1}$, Walking = $0.2\text{-}1.7m.s^{-1}$, Jogging = $1.8\text{-}3.6m.s^{-1}$, Running =$3.7\text{-}5.3\ m.s^{-1}$ and Sprinting = $>5.4m.s^{-1}$.

Table 2.9 Velocity zones

Author	Population	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5		Zone 6	
		Speed	Description	Speed	Description	Speed	Description	Speed	Description	Speed	Description	Speed	Description
Coutts *et al.* (2010)	Australian football players	0 – 0.7 km h^{-1}	Standing	0.7 - 7 km h^{-1}	Walking	7 – 14.4 km h^{-1}	Jogging	14.4 - 20 km h^{-1}	Running	20 - 23 km h^{-1}	Higher-speed running		
Aughey *et al.* (2010)	Australian football players	0.1 – 4.17 $m.s^{-1}$	Low-intensity									4.17 - 10 $m.s^{-1}$	High-intensity
Jennings *et al.* (2012)	Elite male hockey players	0.1 – 4.17 $m.s^{-1}$	Low-speed									>4.17 $m.s^{-1}$	High-speed
Farrow *et al.* (2008)	Australian football players	2 $m.s^{-1}$	Moderate velocity									4$m.s^{-1}$	High velocity
Johnston *et al.* (2013)	Sub-elite male rugby league players	0 – 4.72 $m.s^{-1}$	Low-speed									>4.75 $m.s^{-1}$	High-speed
Suarez – Arrones *et al.*	Rugby union	0.03 – 1.64 $m.s^{-1}$	Standing and walking	1.66 – 3.31 $m.s^{-1}$	Jogging	3.33 – 3.86 $m.s^{-1}$	Cruising	3.86 – 4.98 $m.s^{-1}$	Striding	5 – 5.53 $m.s^{-1}$	High intensity	>5.56 $m.s^{-1}$	Sprinting

(2012)													
Macutkiewicz *et al.* (2011)	Elite female hockey players	0 – 0.17 $m.s^{-1}$	Standing	0.19 – 1.67 $m.s^{-1}$	Walking	1.69 – 3.06 $m.s^{-1}$	Jogging	3.08 – 4.17 $m.s^{-1}$	Running	4.19 – 5.28 $m.s^{-1}$	Fast running	>5.28 $m.s^{-1}$	Sprinting
Carling *et al.* (2012)	Elite soccer players	<0.17 $m.s^{-1}$		1.94 – 1.97 $m.s^{-1}$		4 – 5.47 $m.s^{-1}$		>5.5 $m.s^{-1}$					
Clarke *et al.* (2015)	Female rugby union	<2 $m.s^{-1}$	Low-intensity	>3.5 $m.s^{-1}$	Moderate intensity					>5 $m.s^{-1}$	High-intensity		
Dwyer *et al.* (2012)	Male soccer	0 – 0.1 $m.s^{-1}$	Standing	0.2 - 2 $m.s^{-1}$	Walking	2.1 – 3.7 $m.s^{-1}$	Jogging	3.8 - 6 $m.s^{-1}$	Running	6.1 $m.s^{-1}$	Sprinting		
Dwyer *et al.* (2012)	Female soccer	0 – 0.1 $m.s^{-1}$	Standing	0.2 – 1.6 $m.s^{-1}$	Walking	1.7 – 3.3 $m.s^{-1}$	Jogging	3.4 – 5.3 $m.s^{-1}$	Running	5.4 $m.s^{-1}$	Sprinting		
Dwyer *et al.* (2012)	Male hockey	0 – 0.1 $m.s^{-1}$	Standing	0.2 – 1.7 $m.s^{-1}$	Walking	1.8 – 3.2 $m.s^{-1}$	Jogging	3.3 – 5.6 $m.s^{-1}$	Running	5.7 $m.s^{-1}$	Sprinting		
Dwyer *et al.* (2012)	Female hockey	0 – 0.1 $m.s^{-1}$	Standing	0.23 – 1.7 $m.s^{-1}$	Walking	1.8 – 3.6 $m.s^{-1}$	Jogging	3.7 – 5.3 $m.s^{-1}$	Running	5.4 $m.s^{-1}$	Sprinting		
Dwyer *et al.* (2012)	Australian football	0 – 0.1 $m.s^{-1}$	Standing	0.2 – 2.4 $m.s^{-1}$	Walking	2.5 – 3.5 $m.s^{-1}$	Jogging	3.6 – 5.6 $m.s^{-1}$	Running	5.7 $m.s^{-1}$	Sprinting		

2.6.4 Total high intensity distance covered by players during netball match play

The ability to accelerate and perform at a high-intensity is important for sport performance. In a study done by Beesley (2015) on amateur netball players, it was reported that netball players only spend 17% of the total playing time engaging in high-intensity activities such as running and shuffling and a staggering 36% and 25% of total playing time was spent standing and walking respectively. Total high intensity distance covered often distinguish positional groups and classify players as elite or sub-elite, as elite players often cover more distances at high intensities (Mohr *et al*., 2003). Fox *et al.* (2013) stated that activity profiles of international netball players suggest that players are constantly engaging in high intensity movement activities. As a result, Yong *et al.* (2015) also emphasizes the ability of netball players to perform repeated high intensity activities and resist fatigue. Research adopted from basketball suggested that basketball players may execute approximately 50 explosive vertical jumps per game and may cover several kilometres during match play, including many high intensity movements, accelerations and decelerations in different directions (Montgomery *et al.,* 2010). Davidson *et al*. (2008) highlighted the high intensity nature of a netball match and stated that players are frequently required to change activity throughout the match. Davidson *et al*. (2008) categorized high-intensity activities as sprinting, shuffling and running. However no mention on the exact velocity bands was made. In contrast, some researchers did quantify HIR as activities >3.9 $m.s^{-1}$ (Granatelli *et al.,* 2014), 4$m.s^{-1}$ (Farrow *et al.,* 2008) and 4.17 – 10 $m.s^{-1}$ (Aughey, 2011).

High-intensity running distance is a common method used to determine the demands of athletes in various sports. Aughey (2011) reported that HIR distance may be an indicator of fatigue and reflect that HIR distance decreased later in the game. Gabbett *et al.* (2012) investigated rugby league players and found that distances covered at high speed differs between the different playing positions, ranging from 235 – 583m on average and depending on playing position.

It is already noted that the C covers the greatest total distance and is linked to a higher PL than all the other positions in netball. With this in mind, Davidson *et al*. (2008) found the C (555m) to cover more distance at a high intensity (sprinting) than both the GK (69m) and the GS (370m). It must be mentioned that only tree positions (GS, C and GK) were part of the study. Fox *et al.* (2013) on the other hand investigated all the playing positions and found the WA to perform the most sprinting and running activities. The GK and GS positions cover similar total distances during match play, however the GS seems to cover more distance sprinting that the GK. On the other hand, it seems that the GK cover significantly more distance shuffling than the GS. This may be due to the different tactical and technical role of GS and the GK. The GS need to sprint away from the defending player to put themselves in a position to receive the ball without interference from the defending player. This may conclude in a higher sprinting distance covered by the GS compared to the defending positions. On the other hand, the GK need to shuffle around the attacking player to be in a position to contest for the ball.

Yong *et al.* (2015) who studied adolescent netball players reported that the attacking players covered the greatest high-intensity (sprinting) distance.

It should be mentioned, that Dwyer *et al.* (2012) used a different definition of a sprint. Therefore the distance covered at high intensity would also be influenced. Dwyer *et al.* (2012) revealed an increase of 40% in the total sprint distance covered.

2.6.5 Duration and frequency of each movement activity during netball match play

Fox *et al.* (2013) ranked the different playing positions by means of mean percentage of active time spent. As expected the C was ranked the most active position with 82% of the active time was spent on active activities. This was followed by the WA (76%), GD (75%), GA (75%) and WD (71%). Previous research found the GK and GS to be the least active positions on court with only 53% of the total playing time being classified as "active time" spend during the match. Although the GK is found to exhibit the second lowest percentage of active time spent during a match Fox *et al.* (2013) found this position to spend the greatest percentage of active time performing high intensity activities. In essence, this highlights the importance of individualized training programs as positions such as the GK need more emphasis on high intensity training activities.

Duthie *et al.* (2005) described data from TMA as the percentage of total time spent in different activity categories. This allows for better comparison between intermittent sports as it takes the difference in match duration into account (Ryan, 2009). Furthermore, many authors report that aerobic, low-intensity activity makes up varying proportions of the total match play duration in intermittent sports. Some of these authors include (Docherty *et al.,* 1988); (Meir *et al.,* 1993) and (Dawson *et al.,* 2004) which report low-intensity activity during match play at 85% in rugby union, 90% in rugby league and 94% in Australian rules football respectively. Ryan, (2009) stated that netball, as an intermittent sport, could have similar low-intensity effort proportions, however, the above mentioned sports are all played on a larger playing field than netball. Furthermore, the court restriction rules limit players to certain areas on the court. Duthie *et al.* (2005) recognized the activity differences between playing positions in rugby union. It would be likely that netball would have similar positional demands.

Literature reported that the C spend the least percentage of time standing still but the highest percentage of time jogging, running and sprinting, although, according to Davidson *et al.* (2008) only 2.4 percent of the total time is spent on sprinting. Fox *et al.* (2013) agreed with this statement as they reported a mean 3% of the active time spent on sprinting by the C. Fox *et al.* (2013) found the WA to be the position that sprints the most on court with 81 sprints per game and spending an average of 4.8 percent of the total time on sprinting. The GK seems to be the player which spends the least amount of time sprinting (0.2%); however this playing position seems to spend the most percentage of active time on shuffling (51%). Fox *et al.* (2013) found shuffling and walking to be the activities most frequently performed by all positions, but attacking activities such as jogging, running and sprinting are reportedly more frequently performed by positions involved in mid-court (GD, WD, C, WA and GA). On the other hand the GK and GS spend far less time jogging and running and more than doubled the time is spend on standing. Steele *et al.* (1992) shared this view and found that the GK and the GS recorded the least amount of game time walking, jogging and running, and the greatest percentage of time standing. This could be due to the fact that the GS and GK are restricted to one-third of the court and these players will only be actively in play when the ball reaches their side of the court. Fox *et al.* (2013) reported that the frequency of jumps was relatively consistent across all positions, with exception of the GS performing far less jumps. The mean duration of time spend standing is far greater in GK and GS, however it has been reported that the mean duration of shuffling of the GK (5.5s ± 0.3s) is higher than the C and GS (2.8s ± 0.5s and 2.8s ± 0.4s). The fact that the GK perform more shuffle movements than the C and GS may be because of the more defensive approach of the GK, which requires more shuffling movements.

Fox *et al.* (2013) emphasised that the overall frequency of work periods performed varied across court positions. As previously mentioned the C was reported to perform the most work periods followed by the GA, WA, WD, and GD. The GS and GK were reported to perform the least amount of work periods of all the playing positions. It is clear that literature

describe the C to be the position to perform the most number of work periods, however, Fox *et al.* (2013) found the duration of work periods performed by the defensive positions (GK, GD and WD) to be longer than the duration of the work periods of the other positions.
Fox *et al.* (2013) stated that the duration of majority of work periods performed by all the positions is less than four seconds per work period. Very few work periods, according to Fox *et al.* (2013), extends a duration of ten seconds. Work periods extending over ten seconds is most frequently performed by defensive players especially the GK and DG (Fox *et al.,* 2013). Davidson *et al.* (2008) reported that the C spend an average of 4s ± 0.4s during an event of walking, 2.0s ± 0.3s per event running and only 1.6s ± 0.3s on average per sprint. According to Davidson *et al.* (2008) the C walks an average of 298 times, jog an average of 251 times and sprint only an average of 49 times. The GK and GS walk an average of 236 and 243 times respectively. The GK and GS jog far less times than the C with only 38 and 52 times respectively. The GK and GS only perform 25 and 51 running activities on average compare to an average of 202 running activities done by a C during a match. With reference to the study done by Davidson *et al.* (2008) it is clear that the C cover a greater distance and at a higher intensity however only three positions were analysed. Compared to field hockey where players spent an average of 2.5 seconds per sprint (Spencer *et al.,* 2005) and according to Davidson *et al.* (2008), netball players only spend an average of 1.3 seconds per sprint. The shorter time spend while sprinting could be due to the smaller playing surface of a netball court.

Abdelkrim *et al*. (2007) stated that elite under 19-year-old basketball players perform on average 1050 movements during a basketball match. This results in a change of direction every 2 seconds which emphasise the intermittent nature of basketball. According to a study done by Davidson *et al.* (2008) on netball players, it was found that the C changes mode every 2.8 seconds, while the GS changes activity every 4.3 seconds and the GK every 5.2 seconds. However, Loughran *et al.* (1999) reported even more frequent changes in activity. They stated that the C changes from activity every 2.2 seconds, while the GK changes activity every 3.9 seconds. The difference may be because of different standards, skills and fitness levels of the participants used in the above mentioned studies as Davidson *et al.* (2008) used England Super League players and Loughran *et al.* (1999) used recreational club netball players in their study. Previous research also acknowledges the greater requirement for changing of direction in netball compared to other sports like Australian Football (Davidson *et al*., 2008). This may be due to the relative smaller court size that netball is played on. Yong *et al.* (2015) investigated the frequency and duration of movement activities of adolescent netball players. In comparison to the results of the study done by Fox *et al.* (2013), Yong *et al.* (2015) reported that adolescent players appear to carry out more high-intensity activities than elite netball players. It must be mentioned that the duration of the quarter in an adolescent netball match is (10 min) is much shorter to that of an elite netball match (15 min). Therefore the lower frequency of high-intensity activity of the elite players may be due to the superior understanding of the game and timing of their sprints. Elite players may do shuffle for longer durations, suggesting that they have a better understanding of how and when to create or deny space during match play (Yong *et al.,* 2015).

In conclusion, the increased physical demands placed on netball players are highlighted by the fact that players are exposed to a constant change direction and activity mode. With regard to time spend per work period; players tend to perform more high intensity activities with a short duration. The average duration of work periods varies from two to six seconds per activity with the most frequent work period duration performed by all positions is reported to be less than four seconds, validating the need for short, high intensity activities throughout the duration of the match (Fox *et al.,* 2013). It is therefore important to consider the demands of the different positions when designing conditioning programs as. The GK and GD are reported to be the two positions to perform more extended (longer than 10 seconds) activities. Players in these positions must be conditioned to also perform longer work activities during match play.

2.6.6 Total work and Work to Rest (W:R) ratio during netball match play

All locomotor activities (standing, walking, jogging, running, sprinting and shuffling) that occur during a match are classified as “work” or “rest” (Fox *et al.,* 2013). W:R ratio provide an objective method to quantify the physiological demands of an activity (Duthie *et al.,* 2003b). Bangsbo *et al.* (1994) reported a W:R ratio of 1:8 for football players and Bishop *et al.* (2006) reported a W:R ratio of 1:9 for basketball players. To calculate a work:rest profile Fox *et al.* (2013) classified work and rest activities using the following criteria:

Table 2.10 Classification of activities as Work or Rest periods

Period classification	Description
Work period	activities that involve active activities of running, shuffling, sprinting, jumping, off-ball guarding, guard and jump, rebound, defend and jump
Rest period	activities of rest such as a shot at goal, walking, slow jogging, guarding, defending, passing and catching

To clarify the above mentioned criteria of the work:rest ratio Fox *et al.* (2013) used the following definitions to classify game related activities.

Table 2.11 Classification of game related activities

Game related activity	Description
Goal	"Attempted shots at goal during match play – restricted to GS and GA positions"
Pass	"Passing of the ball from one player to another. May take place on court or from a sideline throw in"
Catch	"Receiving the ball from a pass"
Jump	"Upward displacement of the body other than for a rebound"
Rebound	"Upward displacement of the body in an attempt to catch the ball after an unsuccessful attempt at goal"
Guard	"Defending a player (outside of the goal circle) who is in possession of the ball"
Off-Ball Guard	"Defending a player who is not in possession of the ball"
Defend	"Defending a player who is in possession of the ball inside the goal circle; restricted to the positions of Goal Keeper and Goal Defence"

Match play physiological stress experienced by a netball player will be affected by numerous factors including the playing environment, the opponents' skill and the closeness of the match, which all cause variation in movements patterns (Steele *et al.*, 1991). Otago (1983) was one of the first researchers to investigate the activity patterns of netball players and revealed many differences between playing positions. Loughran *et al.* (1999) stated that 79.1% of players' activity during match play is spent on low-intensity activity. Therefore, the development of an efficient aerobic capacity is essential for netball. A work to rest (W:R) ratio of 1:3 was reported, but Otago (1983) only analysed a small amount of games. Moreover, data collection were restricted to television coverage which resulted in the fact that not all players could be tracked for the entire match and high intensity activity performed by players that were not close to the ball was difficult to be recorded. In a similar study done by Loughran *et al.* (1999) also revealed a W:R similar to Otago (1983) but additionally emphasised the high intensity nature of netball and the constant changes of activity and changes in direction during a netball match. However this study also had a few limitations including the fact that different observers were used and audio recordings were verbally coded. The participants were not elite netball players.

Steele *et al.* (1992) however carried out a more detailed study whereby players were tracked for the entire match and therefore the findings in their study were more representative of match play. However only four players per position were analysed and no details of the analysis were reported. The fact that Steele *et al.* (1991) found that drills executed during training did not meet the demands of the different playing positions during match play could highlight the need of knowledge of the physiological demands of netball as well as the importance to implement this into conditioning programs. Woolford *et al.* (1991) supported the statement made by Steele *et al.* (1991) when they found that HR observed during training did not reflect the same intensity as HR observed during National Title games or the lead up to the games. Therefore the current study will aim to provide conditioning coaches clear data regarding the physiological demands during netball match play and to provide an opportunity for coaches to accurately simulate the match play demands during training sessions.

Davidson *et al.* (2008) reported that the C performed considerably more total work than the GK and the GS. However, the GK also performed more total work than the GS. The C performed 19.7min of total work while the GK and GS performed a total work of 15min and 10min respectively. In addition, the C spends a greater amount of time in high intensity activities compared to GK and GS and reported a W:R of 1:1.9 for the C, 1:4.5 for the GS and 1:2.9 for the GK. However, Otago (1983) suggested that because of the more time spend in less intense activities like slow jogging, defending and guarding, than the other positions, the C do the least amount of work. This could be explained by the classification of work used in the Otago (1983) study. Although, the other center court positions (WA and WD) also have less movement restrictions on the court than the GK and GS, these positions were not considered in the study. A study by Davidson *et al.* (2008) reported a mean W:R ratio of 1:3.1 for all positions combined which is similar to previous findings by Otago (1983) and Loughran *et al.* (1999). McCabe (2014) reported that although the C had the greatest number of decelerations as well as the highest amount of changes in direction, the GA had the highest amount of jumps and the GD had the greatest number of accelerations.

The GK is reported to have a higher W:R ratio than GS which could be due to the greater frequency and time spend shuffling. The GK perform constant defensive work as the ball enters the defensive third of the court. This continues until a goal has been scored or the opposition attack has been stopped. Shuffling is a defensive movement pattern therefore explaining the higher W:R ratio compared to the GS. However, Davidson *et al.* (2008) suggested that the GS on the other hand spends more time sprinting than the GK. However, the total time spend sprinting by the GS is less than the combined time sprinting and shuffling by the GK. In comparison to basketball (Bishop *et al.,* 2006) and football (Bangsbo *et al.,* 1994) it appears that netball requires more high intensity activity. This may be due to the small court size.

According to Fox *et al.* (2013) a work:rest ratio of 1:5 is most frequently performed during match play. The nature of the game as well as the rules of netball may be influential factors on the lower (1:5) W:R ratio. It becomes clear that players are required to perform short, high intensity activities followed by a longer period of rest due to the ball moving to the other side of the court or moving to an area on the court restricted to a specific player due to the rules of the game. Therefore more focus should be placed on the anaerobic energy system which allows athletes to perform the required short, high intensity efforts during match play Fox *et al.* (2013). Due to the eccentric nature and the amount of decelerations during a netball match conditioning coaches should also consider increasing the amount of eccentric contractions done during conditioning sessions. Therefore training the muscle to cope with the physiological demands it incurs during performance. Additionally, minimising the amount of muscle damage and possibly preventing injury (Lindstedt *et al.,* 2001).

2.6.7 Total number of jumps, accelerations and decelerations performed by netball players during match play

Cormack *et al.* (2013) stated that distance covered may suggest higher exercise intensity, however the same variable could substantially underestimate movement intensity of playing positions characterised by short, high intensity activity like jumping, accelerating, decelerating, and changes of directions. These short bursts of high intensity activity may result in a relative small distance covered. Therefore PL must not only be characterised by total distance covered. The use of three dimensional accelerometers such as the Catapult minimax X4 allow for more accurate quantification of movement intensity that could be underestimated with earlier analysis methods.

It was previously mentioned that Cormack *et al.* (2013), stated that netball players accumulate a greater PL in the vertical plane. It was also mentioned that it could be possible that the greater vertical PL accumulated from the vertical displacement of running (Hobara *et al.,* (2010), however, it should also be mentioned that it could be possible that the greater vertical PL accumulated from activities such as jumping. Abdelkrim *et al*. (2007) stated that basketball players jump an average of 44 times during match play. Previous literature revealed the GS to perform the least amount of jumps (31) during a match. This is almost 20 jumps on average per match less than the GK who recorded the second least amount of jumps (Fox *et al.,* 2013). The WA is, according to Fox *et al.* (2013), the position to perform the greatest amount of jumps with a mean frequency of 67 jumps per match followed by the GA and GD with 55 and the C with 53 jumps on average during match play. In contrast McCabe (2014) enumerate that the GA performs the greatest amount of jumps and that the WA and the C perform the least amount of jumps. Although the centre court players perform less jumps as well as accelerations than other positions, it is still the position with the highest PL.

Compared to the GS, Fox *et al.* (2013) stated that the WA performs more than double the amount of jumps during a netball match. This correlates with the average frequency sprinting activities. The WA performs on average 81 sprinting activities whereas the GS only completes 51 (Fox *et al.,* 2013). Literature stated that Australian Football players perform an average of 96 maximal accelerations during a match (Aughey, 2011) and Basketball players sprint on average 55 times during a game (Abdelkrim *et al*., 2007). However, Australian Football is played on a much bigger pitch compared to a netball court. Interestingly Fox *et al.* (2013) also found the WA to perform the second most walking activities behind the GA with

302 and 311 respectively. The GK only walked 159 times on average which is far less than the GS who recorded the second least amount of walking activities. However the GK also recorded significant less sprinting and running activities as well as the second least amount of jogging which are higher intensity activities compared to walking. The centre court players (WD, C, WA) outscored the other positions with the higher intensity activities.

To conclude, Fox *et al.* (2013) suggested that although the centre court positions are involved in more periods of walking during match play, they also partake in more high intensity activities such as jogging, shuffling, running and sprinting. This suggests that the centre court players are more active and have a higher PL (as previously discussed) during match play. The court restriction rule in netball could be a reason for the higher number of sprints, jumps, running as well as walking activities recorded by the centre court players during an activity profile study conducted by Fox *et al.* (2013) on the Australian female netball team during international competition. McCabe (2014) reported that although the C does have the greatest amount of decelerations as well as the highest number of changes of direction, the number of both accelerations and jumps, as previously mentioned, are higher in other positions (GD an GA respectively). The differences in movement patterns in the different positions emphasize the necessity for position-specific conditioning and training programs. Centre court players, for example, need to engage in more acceleration, deceleration and changes of direction during match play compared to the GS and the GK. Individual skill training as well as position-specific agility drills may add great value to conditioning programs (Chandler *et al.,* 2014).

2.7 Summary

Various researches have previously investigated the nature and physical demands of netball (Otago, 1983); (Steele *et al.,* 1991); (Davidson *et al.,* 2008); (Fox *et al.,* 2013); (Cormack *et al.,* 2013); (Chandler *et al.,* 2014); (Yong *et al.,* 2015); (Thomas *et al.,* 2016), however, with the exception of one study, all of the researchers have grouped together the playing positions and the main focus has been on elite senior netball players. Therefore, the findings of most of these studies may be of too high standard for coaches and conditioning coaches at under 19 level. This creates a need for research on the demands of under 19 netball players. Cormack *et al.* (2013) investigated the difference in load of between lower standard and higher standard netball players. However, the study also grouped together the playing positions. As a result the physical demands of all the playing positions and more specifically under 19 level netball players are relatively unknown. The question must be asked: "Would TMA knowledge make any difference in performance and the outcome of the match?" Fox *et al.* (2013) for one highlighted the importance of sport specific training programmes for optimal athlete performance. As previously mentioned, it is critical to understand the demands of the specific sport to ensure a sport specific exercise program. To enumerate further on the subject conditioning coaches must also understand the different roles and demands of each and every different playing position. As proven in the literature review the demands of the different playing positions of netball differ from each other.

CHAPTER 3

RESEARCH METHODOLOGY

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

3.1 Study design

A quantitative, cross-sectional research design was conducted to determine the physiological demands of elite u/19 netball match play using GPS technology.

3.2 Participants

Sampling methods for research may be divided into two groups, namely sampling for quantitative research and sampling for qualitative research (Bowling, 2014). Methods for sampling can further be either random sampling or non-random sampling. Simple random sampling, unrestricted random sampling, cluster sampling, systematic sampling and stratified random sampling are all examples of random sampling.

When conducting research for the purpose of understanding phenomena, rather to apply findings on a wider population, the non-random sampling method is used. Polit *et al.* (1993) described convenient sampling as cohort of subjects that happen to be in the right place at the right time. The current study also made use of a convenient sampling method. After obtaining permission from Netball South Africa (Appendix B.2), the headmasters of all the schools that participate in the Bloemfontein u/19 A league and the South African Top Schools Championship (Appendix B.3), the head coaches of the u/19 netball teams in the Bloemfontein league as well as the head coach of the Mangaung Metro u/19 Netball Team (Appendix B.1), the study aimed to assess the physiological demands during netball match play in a cohort of elite u/19 netball players in the Bloemfontein, Free State region. The researcher aimed to monitor the physiological demands of two netball teams playing against each other during the Bloemfontein u/19 netball league as well as the National u/19 Netball tournament. The teams approached for participation in the study were:

- Jim Fouche High School u/19A Netball team
- Sentraal High School u/19A Netball team
- Oranje High School u/19A Netball team
- Eunice High School u/19A Netball team
- Fichardtpark High School u/19A Netball team
- Jacobsdal High School u/19A Netball Team
- Sand du Plesssis High School u/19A Netball Team
- Mangaung Metro u/19A Netball Team

However, not all these teams took part in the study. Due to the conflict of playing dates and times, Jacobsdal High School u/19A Netball Team could not be tested during the netball league and due to unforeseen financial difficulties; the Mangaung Metro Netball Team did not send a team to represent the region at the National u/19 Netball Championships. Therefore these two teams did not partake in the study. Furthermore, only two teams from Free State qualified for the South African Top Schools Championship. As a result, more GPS data on these two teams were collected. Only data from players that played all four quarters during the match in the same playing position were analysed. In the end, data were collected from players competing in the Bloemfontein u/19A netball league and the South African Top schools Championship during the 2017 netball season.

The Bloemfontein u/19A league consisted of 33 matches. Each team in the Bloemfontein u/19 league played every other team once. Every team therefore played five league games. Thereafter the four best placed teams on the log played one match in a semi-final round where after the two winners of the semi-finals competed in the final over one match. However, due to the availability of only 20 Catapult GPS units as well as a conflict in the time that the semi-finals were competed, therefore, the researcher could only analyse one of the two semi-finals. The researcher tested two teams that played against each other simultaneously and the result of each match was recorded. The teams that contested the final of the Bloemfontein u/19A league went on to compete in the National u/19 School Netball Tournament. These two teams each played another 5 matches during this tournament and every match played by these two teams were analysed and formed part of the study. Therefore, more data sets on these two teams formed part of the study. Teams did not have the same players in the same position for every match they played during the season. Therefore it could be argued that with 10 players per team and two teams competing in a match for a total of 7 matches played during the Bloemfontein U 19A league are equal to 70 netball players that were analysed during the Bloemfontein u/19A league alone. However although data on more matches were collected, the study only included matches where all the players participated in all four quarters. GPS data on a total of forty-four (44) netball players were collected and a total of sixteen netball matches were analysed for the study. A detailed explanation of the participants, the number of players that participated from the different schools, the number participants of which physical profile measurements were collected as well as the number of GPS data sets collected during the study will follow in the next chapter.

Before participation in the study each participant will be asked to read an information sheet (see Appendix A.1) and sign a consent form (see Appendix A.2).

3.2.1 Inclusion criteria

Study participants had to adhere to the following inclusion criteria:

1. Participants must be female.
2. Participants must be a u/19 netball player in the Bloemfontein A league or included in the 2017 Mangaung Metro u/19 netball team.
3. Participants must be cleared to play netball by the team doctor.
4. Participants must be free from injury.
5. Participants must be able and willing to give consent in English.

3.2.2 Exclusion criteria

If a potential participant displays any of the following criteria, the player will be excluded from the study:

1. Participants suffering from any illness.
2. Participants older than 19 years of age.
3. Participants that are under the age of 18 years of age and whose parent or guardian did not give consent to participate in the study.
4. Participants rehabilitating from injury.
5. Persons who are 19 years and younger but unwilling or unable to give consent in English.
6. Participants are free to withdraw at any time.

3.2.3 Withdrawal of study participants

Participants will be withdrawn from the study if they sustain an injury during a match which is used for data collection.

3.3 Data collection

A literature review is the first step of a research project to identify appropriate methodology for the study. Information is obtained from primary and secondary resources such as scholarly articles, scientific papers, journals, books and internet resources and was fully discussed in the previous chapter. All the data collected was handled with confidentiality. Confidentiality was maintained by means of allocating numbers to the participants to identify the participants during the study. All information recorded was stored with the researcher and raw data was stored in a safe in a locked office. After obtaining the raw data the data was processed and stored on a PC that is password protected. Data collection was done in two parts.

3.3.1 Part 1: Data collection process

This first part of data collection was done one week before the start of the Bloemfontein u/19 netball league. After obtaining permission from all the relevant authorities, the researcher and his assistant visited each participating school to start the data collection process. The participants' age, mass (kg), length (cm), playing position, team as well as anthropometric data was collected during this part of data collection. This part of data collection commenced at the participating schools on scheduled appointment. All the anthropometric measurements were done by the researcher and his assistant captured the data on the measurements collection form. All apparatus that were used in the data collection process was provided by the researcher and all measurements were taken in a private room at the schools to ensure confidentiality. The duration of this part took approximately one hour. The following apparatus were used during the first part of the data collection process:

- Pens
- Data collection form (Appendix C)
- Marsden Professional Physicians Scale
- Marsden Free Standing Height Measure
- Pressure calibrated Harpenden skinfold calliper

All equipment used was available at the Exercise and Sport sciences centre and the researcher could utilize the equipment free of charge for the duration of the data collection process.

3.3.2 Part 2: Data collection process

The second part of the data collection process commenced at the start of the Bloemfontein u/19A league. Data regarding the physiological demands of netball matches was collected during this part of the data collection process. Davidson *et al.* (2008) mentioned that future studies on the physiological demands of netball players should consider a method that minimises human error and provides rapid results. The above mentioned study made use of a filming protocol to collect data, but emphasizes that it is time consuming and distance calculation errors may occur. Therefore the current study made use of a commercially available GPS unit (Minimax X4, Catapult Innovations, Melbourne, Australia) as well as a Polar HR monitor and chest strap to determine the physiological demands of netball players.

Matches played during the 2017 u/19A Bloemfontein league were analysed to determine the physiological demands of u/19 netball players. The top two teams in the Bloemfontein league competed at the South African Top Schools Championship in Boksburg. The matches played at this tournament by the two teams that finished first and second on the log in the Bloemfontein league were also measured with the Catapult system and the data formed part of the current study. The study focussed on the physiological demands of each playing position in netball. Playing positions were classified as goal-keeper (GK), goal-defence (GD), wing-defence (WD), center (C), wing-attack (WA), goal-attack (GA), and goal-shooter (GS). Data on all players, including substitutes, were collected over each match that formed part of the study. Therefore, data collected could be individualized for every playing position. The GPS unit used includes a tri-axial accelerometer with extremely responsive motion sensors used to measure the frequency and magnitude of movement in three dimensions namely, anterior-posterior, mediolateral, and longitudinal (Krasnoff *et al*., 2008). The Catapult Minimax X4 units measures accelerations in the frontal-, sagittal- and transverse axes of movement to determine a variable called PL (Gabbettt *et al.* 2012) and has been proven highly reliable with a coefficient of variation of <2% (Boyd *et al.,* 2011). Chandler *et al*. (2014) used two variations of PL to determine physical demands namely total PL and PL in each axis (frontal, sagittal and transvers). The current study will report total PL and PL per meter.

The GPS units (worn by all the players during the match) were housed in a custom made harness that prevent unwanted movement and hold the units in place in the middle of the upper back. Therefore limiting any potential hindrance on performance. Participants received the HR monitor with its chest strap as well as the harness, which will host the accelerometer, prior to the warm up for the match. Thereafter the players went to the locker room to fit the harness and HR monitor themselves before putting on their netball dresses over the harness. Therefore the school uniform was not interrupted as the Catapult system was not visible. The GPS units were switched on by the researcher and as soon as the unit indicated that it is connected to the GPS signal it was fitted into the harness and situated between the shoulder blades. After every participant received a GPS unit, the teams commenced with their warm up and the match. The start and end time of each match was recorded. Therefore data recorded by the GPS unit during the warm up and in between the playing quarters could be easily cut and did not form part of the data used I the study. The researcher, additionally, recorded the time and details of all substitutes as well as injuries that occurred during the match. At the end of the match all the equipment (the GPS units, harnesses, HR monitors and chest straps) were collected by the researcher.

Thereafter the accelerometer data (Load TM.min -1 (au) from individual X-medio-lateral, Y-anterior/posterior, and Z-vertical vectors) was downloaded post-match using manufacturer specific software (OpenField 1.17.0 Build #30874 software). The following variables were recorded by the Minimax X4 during this study.

- Distances covered
    - Total distance covered
    - Mean differences between the different playing positions in distance covered during match play
- Player load (PL)
    - Total PL during match play
    - PL per meter
    - Mean differences between the different playing positions in total PL during match play
    - Mean differences between the different playing positions in PL per meter during match play
- The maximal velocity during the match
- HR response
    - Maximum HR
    - Mean HR response during match play
    - Mean differences between the different playing positions in HR response during match play

Each playing position was investigated individually and comparisons regarding the variables were made between the different playing positions.

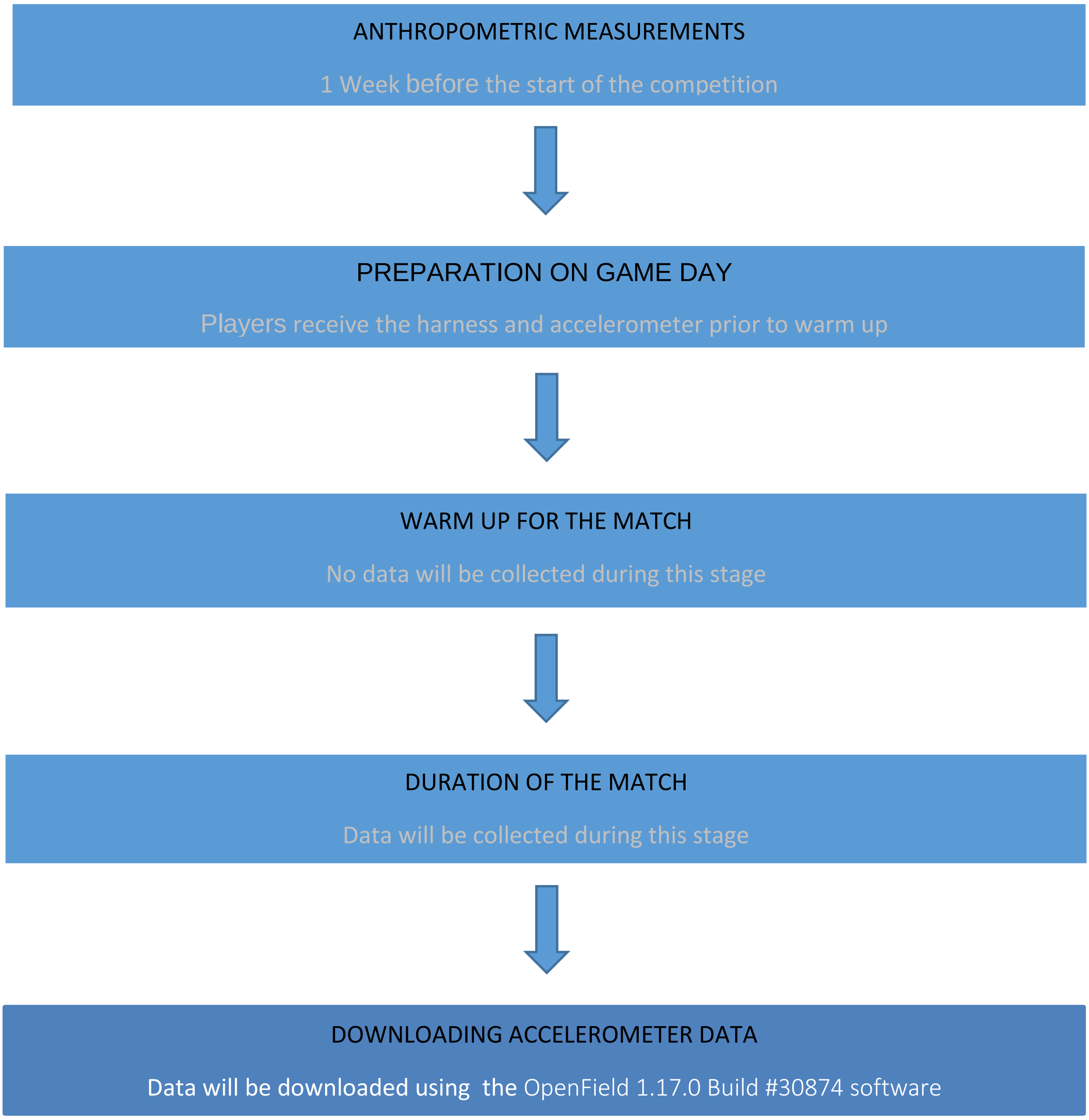

Figure 3.1: Schematic representation of the data collection process

3.3.3 Anthropometric measures

One week before the start of the Bloemfontein u/19A league, the following data were recorded:

1. Age
2. Playing position
3. Team representing
4. Body mass (kg to the nearest first decimal)
5. Length (cm)

The Heath and Carter anthropometrical assessment will be used (Carter,1982; Carter *et al.,* 1990; Marfell-Jones *et al*., 2006).

The participants were asked to fill in a data collection form (Appendix C) to determine the gender, age, playing position and the team that the participant is representing. Body mass and length were measured by the researcher using a Marsden Professional Physicians Scale and a Marsden Free Standing Height Measure respectively. Skinfold measurements were taken by a Level 1 Anthropometrist using the International Standards for Anthropometric assessment (Marfell-Jones *et al*., 2006) as guideline. The measurements were taken on the right side of the body in an upright standing position, with exception of the Medial Calf skinfold, which were taken in the sitting position (Carter *et al.,* 1990). The following six skinfold measurement were collected for calculation of estimated body fat percentage:

Table 3.1 Anthropometric measurements

Site of measurement	Explanation
Triceps	
Definition	The most posterior part of the Triceps when viewed from the side at the marked mid acromial-radial level.
Subject position	Anatomical position
Location	The Tricep skinfold site marked over the most posterior part of the Tricep muscle when viewed

	from the side at the marked mid acromial-radial level.
Subscapular	
Definition	The site 2 cm along a line running laterally and obliquely downward from the Subscapular landmark at a 45° angle.
Subject position	Standing relaxed with arms hanging by the sides
Location	Locate the point 2 cm from the Subscapular in a line 45° laterally downward.
Suprailiac	
Definition	The site at the center of the skinfold raised immediately above the marked Iliocristale
Subject position	The subject assumes a relaxed position with the left arm hanging by the side and the right arm abducted to the horizontal
Location	This skinfold is raised immediately superior to the iliac crest. Align the fingers of the left hand on the iliac crest landmark and exert pressure inwards so that the fingers roll over the iliac crest. Substitute the left thumb for these fingers and relocate the index finger a sufficient distance superior to the thumb so that this grasp becomes the skinfold to be measured. Mark the center of the raised skinfold. The fold runs slightly downwards anteriorly as determined by the natural fold of the skin.
Abdominal	
Definition	The site 5 cm to the right hand side of the omphalion (midpoint of the navel).
Subject position	The subject assumes a relaxed standing position with the arms hanging by the sides.
Location	This is a vertical fold raised 5 cm from the right hand side of the omphalion.

Anterior mid thigh	
Definition	The site at the mid-point of the distance between the Inguinal fold and the anterior surface of the patella on the midline of the thigh
Subject position	The subject assumes a seated position with the torso erect and the arms hanging by the sides. The knee of the right leg should be bent at a right angle.
Location	The measurer stands facing the right side of the seated subject on the lateral side of the thigh. The site is marked parallel to the long axis of the thigh at the mid-point of the distance between the Inguinal fold and the superior margin of the anterior surface of the patella (while the leg is bent). The Inguinal fold is the crease at the angle of the trunk and the thigh. If there is difficulty locating the fold the subject should flex the hip to make a fold. Place a small horizontal mark at the level of the mid-point between the two landmarks. Now draw a perpendicular line to intersect the horizontal line. This perpendicular line is located in the midline of the thigh. If a tape is used be sure to avoid following the curvature of the surface of the skin.
Medial calf	
Definition	The site on the most medial aspect of the calf at the level of the maximal girth.
Subject position	The subject assumes a relaxed standing position with the arms hanging by the sides. The subject’s feet should be separated with the weight evenly distributed.
Location	The level of the maximum girth is determined and marked with a small horizontal line on the

	medial aspect of the calf. The maximal girth is found by using the middle fingers to manipulate the position of the tape in a series of up or down measurements to determine the maximum girth. View the marked site from the front to locate the most medial point and mark this with an intersecting vertical line.

Care was taken to accurately locate the anatomical landmarks and associated skinfolds, as advised by Marfell-Jones *et al*. (2006). Anthropometric measurements will be collected using a pressure calibrated skinfold caliper and body fat percentages calculated using the Carter (1982) equation:

Body fat percentage = (sum of the 6 skinfolds X 0.1548) + 3.58.

3.4 Reliability of the Catapult Minimax X4 accelerometer

Accelerometers have been reported to have good reliability in the measurement of biomechanical load. The reliability of the Minimax X4 accelerometer prove to be acceptable both within and between devices under controlled laboratory conditions, and between devices during field testing and can be confidently utilized as a reliable tool to measure physical activity in team sports across multiple players and repeated bouts of activity. (Boyd *et al.,* 2011). Various team sport, including Australian football (Coutts *et al.,* 2010), Rugby codes (Deutsch *et al.,* 1998) and Hockey (Johnston *et al.,* 2014) have used various methods to determine the physical demands placed on athletes during training or competition. Methods to measure physical demands include HR monitoring, TMA analysis through video analysis and GPS monitoring. The shortcoming with these methods is that the validity of HR monitoring is questionable when activity is intermittent and at high intensity (Tarbizan *et al.,* 2002) such as netball. Video analysis is time consuming and one can only monitor one athlete at a time. Moreover, this method is also prone for human error and cannot be done in real time (Edgecomb *et al.,* 2006). Jennings *et al.* (2010) further stated that Global positioning system (GPS) TMA also present some issues and reported poor reliability and validity (coefficient of variation [*CV*] ≤34%) in measuring distance especially at high speeds over short distances.

On the other hand, tri-axial accelerometers measure movement in the anterior-posterior, mediolateral and longitudinal dimensions (Krasnoff *et al*., 2008). Johnston *et al.* (2012) agreed with Jennings *et al.* (2010) and Coutts *et al.* (2010) that the validity and interunit reliability of 1 Hz and 5 Hz GPS units decreased when measuring small distances and sharp change in direction at high speeds. However, Johnston *et al.* (2014) reported that 10 Hz and 15 Hz GPS units are valid and reliable measure instruments for measuring total distance covered and are more reliable measures of movement demands than 1 Hz and 5 Hz GPS units. Dispite a tendency to overestimate total distance covered, the 10 Hz GPS units provide a valid measure of total distance covered (<1% error). Therefore this study will use the Catapult Minimax X4 10Hz GPS unit to collect movement data during netball matches.

3.5 Pilot study

According to Mouton, (2014) a pilot study is the extensive collection of data to gain a comprehensive understanding of a single phenomenon on a particular group, social setting or event. In this study the researcher conducted a pilot study on two female netball players who did not meet to all the required inclusion criteria and therefore was excluded in the final group of participants for the study. One week prior to a match between two hostel netball teams (N=14) the participants were asked to complete the data collection form (Appendix C). Thereafter, using the Heath and Carter method (section 3.3.2), anthropometric data were recorded. Accelerometer measures were collected according to the process described before. Thereafter the data was downloaded from the accelerometers onto a computer and the results was analysed. The aim of the pilot study was to ensure the effectiveness of the data sheets, equipment, and protocols.

3.6 Methodological errors

The researcher attempted to minimized systematic methodological errors by using the same equipment (Catapult Minimax X4 accelerometer system, Marsden Professional Physicians Scale, Marsden Free Standing Height Measure, Pressure calibrated Harpenden skinfold caliper) for all the measurements that were taken. All the above mentioned equipment were calibrated as per manufacturer's specifications by the researcher. Furthermore, the same qualified Level 1 Anthropometrist (using the International Standards for Anthropometric assessment (Marfell-Jones *et al*., 2006) as guideline) was responsible to take all the anthropometric measurements. In addition the researcher made sure that each player was fitted with the correct size chest strap for the HR monitor as well as the correct size harness that will host the accelerometer.

Random methodological errors that could have occur include changes in weather on the different days that the matches will be played on. Rain or cloudy weather may interfere with the GPS signal of the Catapult system. The data may also be influenced by external factors that may lead to early fatigue such as games played in extreme hot conditions and the number of games played in the week. Furthermore, game plans may also differ from one match to the other and could have an effect on the results of the study.

It must be mentioned that four of the twenty GPS units broke down during the study which resulted that only 16 units were in a working condition over a period of one week. Data were collected from two teams playing each other. Therefore 14 units were actively participated in the match and the four broken units were allocated to players on the bench and none of those players participated in that particular match. Therefore the four broken units did not have any influence on the data collected.

3.7 Statistical Analysis

Descriptive Statistics

Descriptive statistics for the physical profile variables (weight, height, body fat percent, BMI) of the 42 players with such data are provided, separately by playing position, and overall. The physical profile variables are graphically presented using boxplots.

Furthermore, descriptive statistics for each variable are provided for the 140 player games, separately by playing position, and overall. Note that the sampling unit now is a player game, so that the summarized data is not independent: There are repeated observations for the same player (in different games), and repeated observations for the same game (from different players). For this reason, a standard deviation is not reported.

Statistical comparison of playing positions

The various variables were analysed using a linear mixed model with Playing Position as fixed effect, and the following random effects:

- Game
- Team
- Game x Team interaction term

- Player

The fitting of the above random effects allowed for correlation between the observations in question (presumably, repeat observations from the same game or team are correlated with each other; similarly repeated observations from the same player are correlated). Based on this linear mixed model, the mean values (of the variable) for each playing position were estimated, together with their standard errors. Furthermore, the pairwise mean differences between playing positions were estimated, together with 95% confidence intervals (CIs) for the mean differences and P-values associated with the null-hypothesis of zero mean difference between the pair of playing positions in question. The analysis was carried out using SAS procedure MIXED (see SAS, 2016).

3.8 Implementation of findings

The proposed TMA analysis research to establish the difference in physiological demands between the different netball playing positions can provide coaches and conditioning coaches with the information that can be used in planning conditioning programmes as well as information that could help with injury prevention. The completion of this study should provide adequate information, which may be utilised by high performance netball coaches and conditioning coaches in an attempt to generate both, training programmes and individualised recovery protocols in an attempt to optimise performance.

3.9 Ethical aspects

All studies with human participants involve some degree of risk (Marczyk *et al.,* 2005). The researcher must be aware that these risks present him or her with an ethical dilemma. Conducting research requires responsibility, honesty and integrity in order to protect the rights of the participants. To render the study ethical, the rights to self-determination, anonymity, confidentiality and informed consent was observed. The study was submitted and approved by the Health Sciences Research Ethics committee of the University of the Free State.

Written permission to conduct the research study was obtained from the following professional bodies:

- The Ethics committee of the Health Sciences Research Ethics committee of the University of the Free State;

- Netball South Africa (see Appendix B.2);
- Free State Department of Education (Appendix B.4) ;
- Participating coaches (Appendix B.1);
- Head masters of the participating schools (Appendix B.3);

All the data collected from the study was kept strictly confidential, and was only used for the purpose of this study. The schools and participants were not identifiable by name. The results of study will be presented through scientific forums and publications, but the particulars of the schools as well as the participants will not be revealed. Participation in the study was voluntarily. Participants received an information sheet where details on the study were explained. This Information sheet was signed by all participants as well as their parents or legal guardians. All documentation was available in English and Afrikaans (Appendix A. 1 to A.3, Appendix B.1 to B.6, Bylaag A.1 to A.3, Bylaag B.1 and B. 2)

As mentioned above, participating in the study was absolutely voluntary and refusal to take part did not lead to any penalty or loss of benefits the player is entitled to. Each participant had the right to withdraw from the study at any time. Informed, written consent was also obtained from all study participants (see Appendix A.2 and Bylaag A. 2). Participants that were under the age of 18 years when participating in the study completed the Informed consent form together with their parents or legal guardian. Furthermore, under aged participants had to complete a Child Assent form (Appendix A. 3 and Bylaag A.3). Basic elements of informed consent will include the following:

- A fair explanation of the procedures to be followed;
- A description of the value and benefits of their participation;
- An offer to answer any enquiries concerning the processes;
- An indication that the participant is free to withdraw consent and to discontinue participation on the project or activity at any time.
- The rights of the participant will be considered by the researcher;
- The right to privacy or non-participation;
- The right to remain anonymous;
- The right to confidentiality; and
- The right to expect experimenter responsibility.

It was made clear to all participants that they will not receive any financial compensation for their contribution in the study. However, all participants received feedback after every match played regarding their own performance during the match. In the case where the results of the study are published the participants will be informed beforehand. Every effort will be made to keep personal information confidential at all times and in all circumstances.

After receiving the Catapult harness, HR monitor and chest strap, the players fitted the harness themselves before putting on their netball dresses. The researcher was responsible to switch the GPS unit on before the start of the warm up for the match. As formerly mentioned the unit was fitted in the harness and situated between the shoulder blades. Many sport teams including various national netball teams use these accelerometers as part of their normal sportswear to monitor the players during training as well as during matches. The Catapult system is a very expensive piece of equipment; therefore not many sport teams and especially netball teams in South Africa had and will have the opportunity to be monitored by this system. As previously mentioned the units do not have any influence on the performance of the players and do not cause any risk of injury to the players. In the unfortunate invent of a player getting injured during a match, the normal protocol will be followed. At each match there will be medical assistance that is organized by the league organizers. This is compulsory for every league match in the Free State region.

CHAPTER 4

RESULTS

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

4.1 Introduction

The primary aim of this study was to profile the physical characteristics and assess the physiological demands on elite u/19 netball players during competition using an accelerometer (Catapult Minimax X4). GPS data will provide insight on (1) PL, (2) player load per meter, (3) HR response, (4) maximal velocity, (5) total distance covered and (6) distance covered in different velocity bands were collected from u/19 female netball players from six schools playing in the Bloemfontein u/19A netball league as well as two teams playing in the South African Top Schools Championship during the 2017 netball season.

This chapter will present the results from the study. Box plots provide a graphic illustration of the variable that is plotted. The box plots illustrate the range between the first to the third quartile of the data. In other words the box displays the central 50% of the data. The difference between the third and the first quartile is referred to as the inter-quartile range (IQR). The whiskers drawn from the box display the most extreme point that is less than or equal to 1.5 times the IQ). Values higher or lower than the 1.5 times the IQR are displayed by a "+" or a "o" sign. The interpretation and the discussion of the findings will follow in Chapter 5.

4.2 Demographic information of participants

4.2.1 Number of players and number of player games analysed

Forty-four (n=44) under 19 female netball players from 6 schools in Bloemfontein participated in the study. Physical measurements of participants were collected and are listed in the physical measurements descriptive statistics (Table 4.3) section. Physical profile data and their preferred playing position were collected from a total of forty-two (42) participants and are illustrated in Table 4.1. It must be mentioned that due to injuries and match tactics the players did not play in the same position throughout the season. For example, a player may have indicated that she preferred to play C, however due to an injury to another player she had to play WA for the entire season. Of the 42 participants, seven (7) players preferred to play C, another 7 preferred GA, 4 players preferred GD, 7 preferred GK, 5 preferred GS, 8 WA and 4 WD (Table 4.1). Furthermore, GPS data were collected from players from the same 6 schools several matches played during the u/19A Bloemfontein league as well as the South African Top Schools Championship in Boksburg during the 2017 netball season. The GPS data on the other hand were collected from the players that played in a specific position during the match.

A total of sixteen (16) matches were analysed. Although the HR and GPS data were collected from a total of forty-four (44) players, some of the players played more than one match and therefore, were tested more than once. A total of hundred and forty (140) HR and GPS data sets (player matches) were analysed, thus data on a total of 560 (140 x 4) player quarters were available and analysed. As mentioned previously, only data from players that participated in all four quarters were analysed, therefore the number of player games available for the various playing positions differs. In total, eighteen (18) players that participated in the study played C, 23 played GA, 18 played GD, the GK position was represented by 17 players, GS consisted of 27 players and 19 and 18 players played WA and WD respectively (Table 4.2).

Table 4.1 Physical profiles: Number of participants per school in the preferred playing position

School	Playing Position							
	C	GA	GD	GK	GS	WA	WD	Total per school
Sand du Plessis	1	2	1	1	1	1	1	8
Sentraal	1	1	0	2	1	2	1	8
Jim Fouche	2	0	0	1	1	1	1	6
Eunice	1	1	1	0	0	1	0	4
Fichardtpark	1	1	1	1	1	2	0	7
Oranje	1	2	1	2	1	1	1	9
Total per position	7	7	4	7	5	8	4	42

Table 4.2 GPS data: Number of participants per school in the different playing position.

School	Playing Position							
	C	GA	GD	GK	GS	WA	WD	Total per school
Sand du Plessis	1	0	1	1	1	0	1	5
Sentraal	8	10	7	8	12	9	6	60
Jim Fouche	5	7	3	4	6	5	5	35
Eunice	2	3	2	2	3	2	2	16
Fichardtpark	0	0	1	0	1	0	1	3
Oranje	2	3	4	2	4	3	3	21
Total per position	18	23	18	17	27	19	18	140

4.2.2 Physical profile of the participants

Box plots illustrate the distributions of the variables body weight, body height (Figure 4.1), body fat percentage and BMI for the different playing positions (Figure 4.2). Detailed descriptive statistics for these variables are presented in Table 4.3.

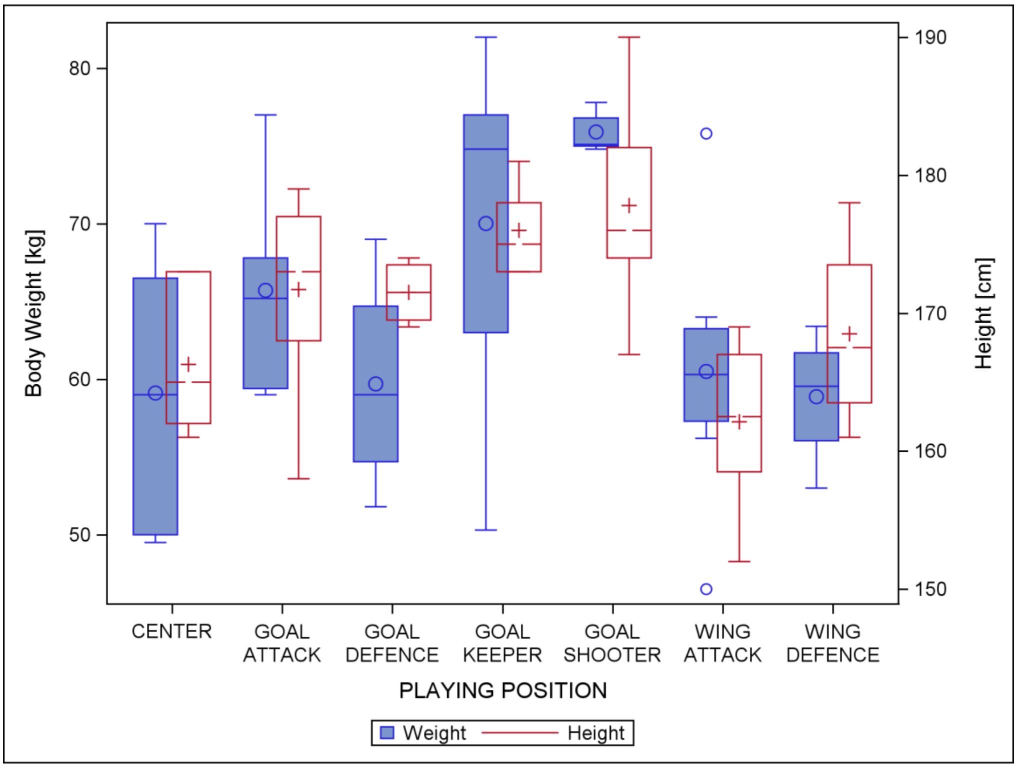

Figure 4.1: Box plot: Body weight and height of under 19 female netball players (n=42 players)

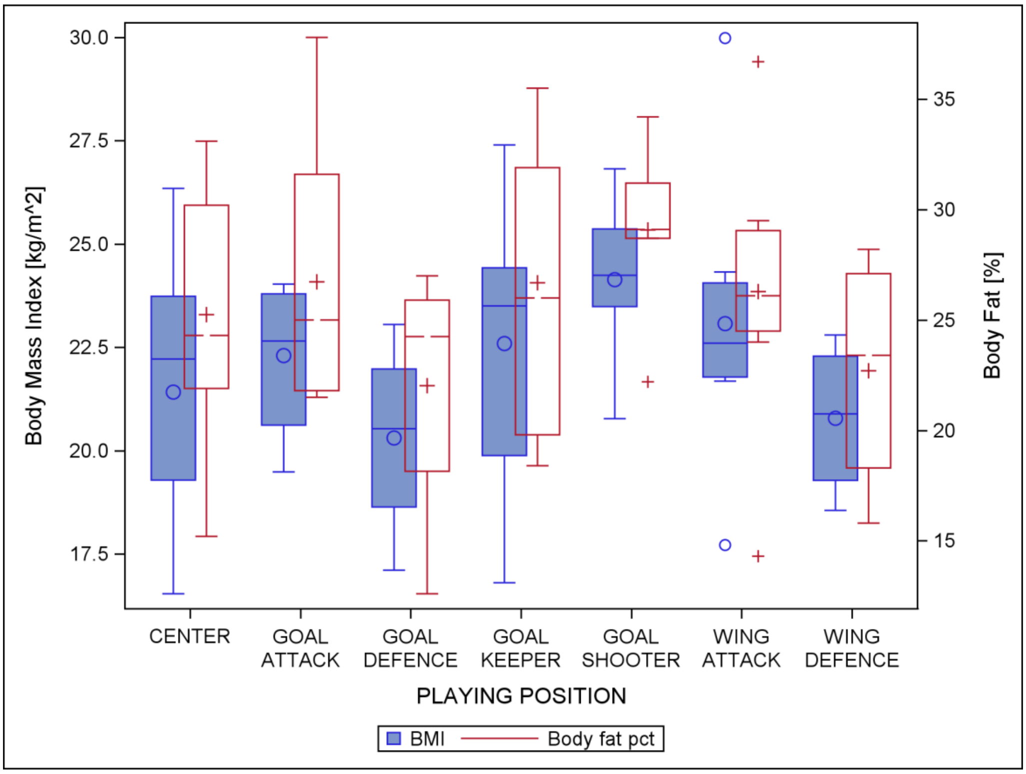

Figure 4.2 Box plot: BMI and body fat percentage of under 19 female netball players (n=42 players)

As can be seen from Figure 4.1, the body weight of u/19 female netball players varies according to playing position, that is, the GS and GK are heavier than players in the other playing positions: For both GS and GK, the lower quartile of body weight is approximately equal to, or above the upper quartile of body weight for the other playing positions. The mean body weight of GS and GK was 75.9kg and 70.0 kg, respectively, for GA 65.7 kg, whereas the players in the C, GD and WD positions had mean weights of about 60 kg (59.1 kg, 59.7 kg and 58.9 kg, respectively).

Similarly, Figure 4.1 suggests that players in the GK and GS positions tend to be somewhat taller than players from the other positions. The mean height of GK and GS was 176.0 cm and 177.8 cm, respectively, while the centre court players (C, WA, and WD) were considerably shorter on average (mean height of 166.3 cm, 162.1 cm and 168.5 cm), whereas GA and GD were of intermediate height on average (171.7 and 171.5 cam, respectively).

Figure 4.2 illustrates the body fat percentage of the u/19 female netball players. The GD and WD positions were found to be the positions with the lowest body fat percentage, with GS, GK and GA having the highest body fat percentage. The mean body fat percentage of the GK was 29.1%, while the GD (22%) and the WD (22.7%) had the lowest mean body fat percentage. The C and WA had similar body fat percentage of 25% and 26% respectively. As can be seen in Figure 4.2, the relative distributions of BMI for the various playing positions correlated well with the distributions of body fat percentage.

Table 4.3 Physical profile of under 19 female netball players: Descriptive statistics

Variable	Statistic	Playing Position							
		C	GA	GD	GK	GS	WA	WD	All
Weight [kg]	**N**	7	7	4	7	5	8	4	42
	Mean	59.1	65.7	59.7	70.0	75.9	60.5	58.9	64.3
	SD	8.58	6.05	7.16	10.64	1.33	8.20	4.33	9.17
	Min	49.5	59.0	51.8	50.3	74.8	46.5	53.0	46.5
	Q1	50.0	59.4	54.7	63.0	75.0	57.3	56.1	59.0
	Median	59.0	65.2	59.0	74.8	75.1	60.3	59.6	63.7
	Q3	66.5	67.8	64.7	77.0	76.8	63.3	61.7	74.8
	Max	70.0	77.0	69.0	82.0	77.8	75.8	63.4	82.0
Height [cm]	**N**	7	7	4	7	5	8	4	42
	Mean	166.3	171.7	171.5	176.0	177.8	162.1	168.5	170.1
	SD	4.99	6.97	2.38	3.06	8.67	5.69	7.14	7.62
	Min	161.0	158.0	169.0	173.0	167.0	152.0	161.0	152.0
	Q1	162.0	168.0	169.5	173.0	174.0	158.5	163.5	165.0
	Median	165.0	173.0	171.5	175.0	176.0	162.5	167.5	171.5
	Q3	173.0	177.0	173.5	178.0	182.0	167.0	173.5	174.0
	Max	173.0	179.0	174.0	181.0	190.0	169.0	178.0	190.0

Variable	Statistic	Playing Position							
		C	GA	GD	GK	GS	WA	WD	All
Body fat [%]	**N**	7	7	4	7	5	8	4	42
	Mean	25.2	26.7	22.0	26.7	29.1	26.3	22.7	25.8
	SD	5.88	6.04	6.43	6.22	4.42	6.27	5.55	5.83
	Min	15.2	21.5	12.6	18.4	22.2	14.3	15.8	12.6
	Q1	21.9	21.8	18.2	19.8	28.7	24.5	18.3	22.2
	Median	24.3	25.0	24.3	26.0	29.1	26.1	23.4	25.9
	Q3	30.2	31.6	25.9	31.9	31.2	29.1	27.1	29.5
	Max	33.1	37.8	27.0	35.5	34.2	36.7	28.2	37.8
BMI	**N**	7	7	4	7	5	8	4	42
	Mean	21.4	22.3	20.3	22.6	24.1	23.1	20.8	22.2
	SD	3.27	1.75	2.46	3.39	2.26	3.44	1.88	2.87
	Min	16.5	19.5	17.1	16.8	20.8	17.7	18.6	16.5
	Q1	19.3	20.6	18.6	19.9	23.5	21.8	19.3	20.2
	Median	22.2	22.7	20.5	23.5	24.2	22.6	20.9	22.5
	Q3	23.7	23.8	22.0	24.4	25.4	24.1	22.3	23.8
	Max	26.3	24.0	23.1	27.4	26.8	30.0	22.8	30.0

Note: N: Number of players; SD: Standard Deviation

4.3 Heart rate (HR) response

The boxplots in Figure 4.3 display the distributions of maximum HR and of mean HR for the different playing positions. Descriptive statistics for these variables are presented in Table 4.4.

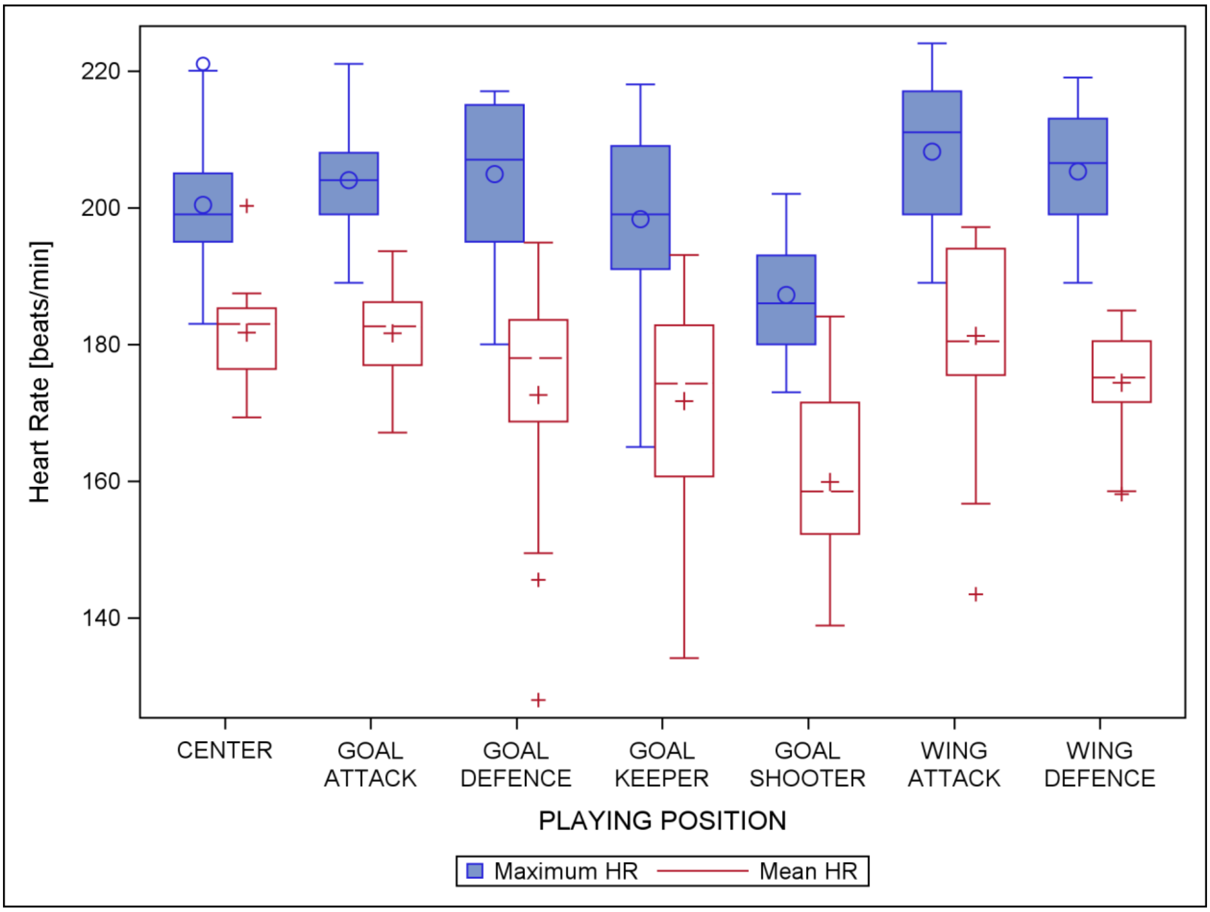

Figure 4.3 Box plot: HR response of u/19 female netball players (n=140 player games)

The boxplots suggest that the GS had a lower maximum as well as lower mean HR than all the other positions: The upper quartile of the maximum HR for GS is approximately equal to, or lower, than the lower quartiles for the other playing positions. The same can be said for mean HR, except that the distributions of mean HR for the GS and the GK overlap somewhat. The IQR of maximum HR and of mean HR of the other positions overlap, which suggests that there are no clinically significant differences in maximum and mean HR between C, GA, GD, WA and WD.

The GA, C and the WA presented with the highest mean HR (182 b/min) while the GS (n=27) recorded the lowest mean HR of only 160 b/min.

The results of the statistical comparison of the different playing positions with regard to maximum HR and mean HR are presented in Tables 4.3 and 4.4, respectively. The mean maximum HR of the GS is statistically significantly ($p<0.05$) lower than the mean maximum HR of all other playing positions, mean differences ranging from 13 to 20 b/min. Surprisingly, the mean maximum HR of the WD is significantly ($p=0.0498$) higher than that of the C. Similarly, the mean HR of the GS is significantly ($p<0.05$) lower than that of all other positions except for the GD, the mean differences ranging from 8 to 18 b/min. The mean HR recorded for the WA is also significantly ($p=0.0472$) higher than that of the GD. Furthermore, the C and the GA also recorded significantly higher mean HRs than the GD.

Table 4.4 Heart rate response: Descriptive statistics

Variable	Statistic	Playing Position							
		C	GA	GD	GK	GS	WA	WD	ALL
Maximum HR (b/min)	N	18	23	18	17	27	19	18	140
	Mean	200.4	204.0	204.9	198.3	187.2	208.2	205.3	200.5
	Min	183.0	189.0	180.0	165.0	173.0	189.0	189.0	165.0
	Q1	195.0	199.0	195.0	191.0	180.0	199.0	199.0	191.5
	Median	199.0	204.0	207.0	199.0	186.0	211.0	206.5	201.0
	Q3	205.0	208.0	215.0	209.0	193.0	217.0	213.0	209.5
	Max	221.0	221.0	217.0	218.0	202.0	224.0	219.0	224.0
Mean HR (b/min)	N	18	23	18	17	27	19	18	140
	Mean	181.7	181.6	172.6	171.7	159.9	181.2	174.4	174.1
	Min	169.3	167.1	128.0	134.1	138.9	143.5	158.1	128.0
	Q1	176.4	177.0	168.7	160.7	152.3	175.5	171.6	167.4
	Median	183.0	182.6	178.0	174.3	158.5	180.4	175.1	176.7
	Q3	185.3	186.2	183.6	182.8	171.5	194.0	180.5	184.1
	Max	200.2	193.6	194.9	193.1	184.1	197.1	184.9	200.2

Note: N: Number of players

Table 4.5 Maximum Heart Rate: Mean differences between playing positions

Playing Position	Statistic	Comparison with Playing Position						
		C	GA	GD	GK	GS	WA	WD
	Mean	199	205.7	205.2	200.5	186	205	205.5
	SE	(2.7)	(2.8)	(2.7)	(3.1)	(3.3)	(2.9)	(2.7)
C	**Difference**	-	-6.74	-6.17	-1.52	13.02	-5.95	-6.53
	P-value	-	0.0580	0.0883	0.7040	**0.0020**	0.0584	**0.0498**
GA	**Difference**		-	0.57	5.22	19.76	0.79	0.21
	P-value		-	0.8776	0.2035	**<0.0001**	0.8317	0.9543
GD	**Difference**			-	4.65	19.19	0.22	-0.36
	P-value			-	0.1512	**<0.0001**	0.9522	0.9187
GK	**Difference**				-	14.54	-4.43	-5.01
	P-value				-	**0.00156**	0.2827	0.2099
GS	**Difference**					-	-18.97	-19.55
	P-value					-	**<0.0001**	**<0.0001**
WA	**Difference**						-	-0.59
	P-value						-	0.8434

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

Table 4.6 Mean Heart Rate: Mean differences between playing positions

Playing Position	Statistic	Comparison with Playing Position						
		C	GA	GD	GK	GS	WA	WD
	Mean	180.03	180.01	169.82	174.95	161.67	178.10	174.45
	SE	(3.1456)	(3.2369)	(3.1986)	(3.7518)	(3.9856)	(3.2856)	(3.1837)
C	**Difference**	-	0.02	10.21	5.08	18.37	1.93	5.58
	P-value	-	0.9950	**0.0114**	0.2694	**0.0002**	0.5393	0.1052
GA	**Difference**		-	10.19	5.06	18.34	1.91	5.55
	P-value		-	**0.0139**	0.2825	**<.0001**	0.6374	0.1576
GD	**Difference**			-	-5.13	8.15	-8.28	-4.64
	P-value			-	0.1259	0.0955	**0.0472**	0.2352
GK	**Difference**				-	13.28	-3.15	0.50
	P-value				-	**0.0138**	0.5020	0.9128
GS	**Difference**					-	-16.44	-12.79
	P-value					-	**0.0010**	**0.0094**
WA	**Difference**						-	3.65
	P-value						-	0.2180

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

4.4 Velocity

The boxplots in Figure 4.4 display the distributions of maximum velocity for the different playing positions. Descriptive statistics for these variables are presented in Table 4.7.

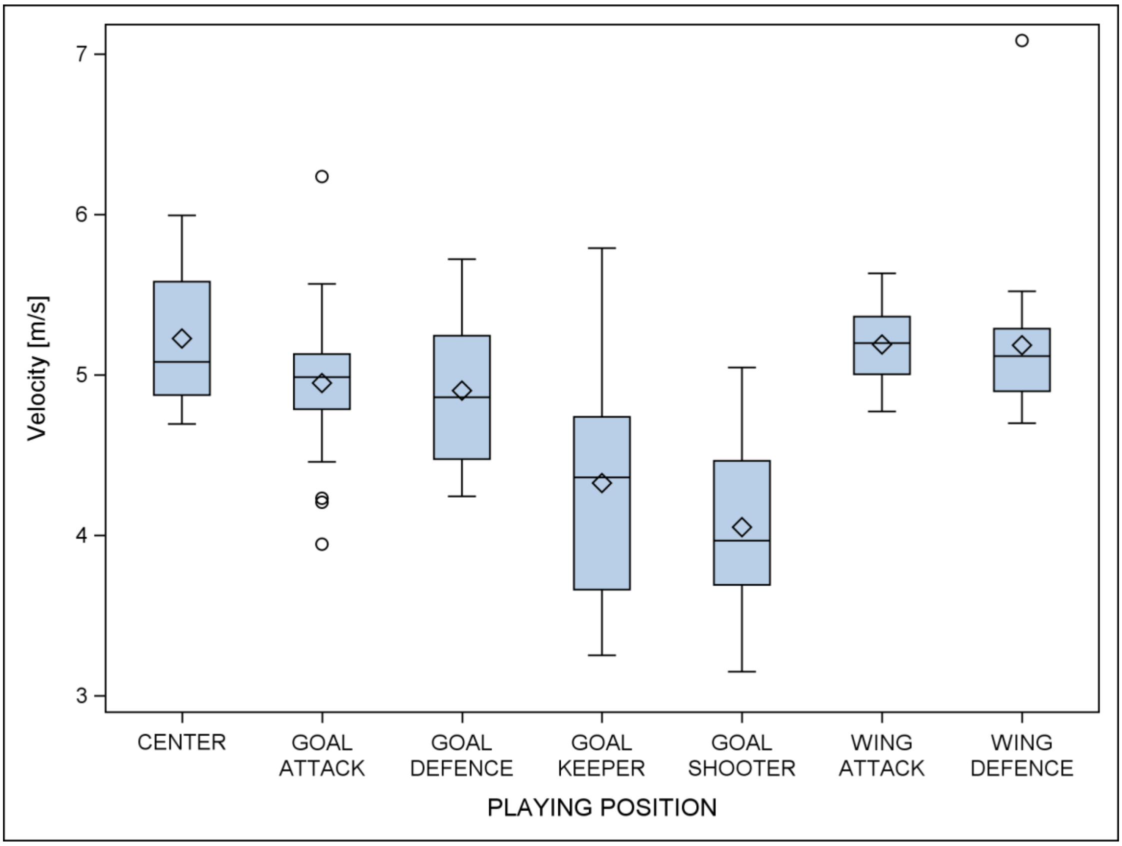

Figure 4.4 Box plot: Maximum velocity (n=140 player games)

The boxplots suggests that the GS and GK had a lower maximum velocity than all the other positions. The upper quartile for GS and GK is approximately equal to, or lower, than the lower quartiles for the other playing positions. The IQR of the other positions overlap, which suggests that there are no clinically significant differences in maximum velocity between the C, GA, GD, WA and WD. Although the statistics for the WD and GA suggest that the values are clustered around the same central value, one must take note the outliers in the data for the GA and WD.

The C presented with the highest mean maximum velocity (5.23m.s^{-1}) and the GS recorded the lowest mean maximal velocity of 4.05m.s^{-1}. The mean maximal velocity of all the participants was 4.79 m.s^{-1}.

Table 4.7 Maximum Velocity

	Playing Position						
Statistic	**C**	**GA**	**GD**	**GK**	**GS**	**WA**	**WD**
N	18	23	18	17	27	19	18
Mean	5.22	4.90	4.87	4.38	4.11	5.19	5.17
SE	(0.1275)	(0.1314)	(0.1298)	(0.1387)	(0.1308)	(0.1348)	(0.1324)

Mean: Least squares mean from mixed model analysis. **N:** Number of player games

4.5 Distance covered

4.5.1 Total distance covered

The boxplots in Figure 4.5 display the distributions of the total distance covered by the different playing positions. Descriptive statistics for these variables are presented in Table 4.8. The results of the statistical comparison of the different playing positions with regard to distance covered are presented in Tables 4.7.

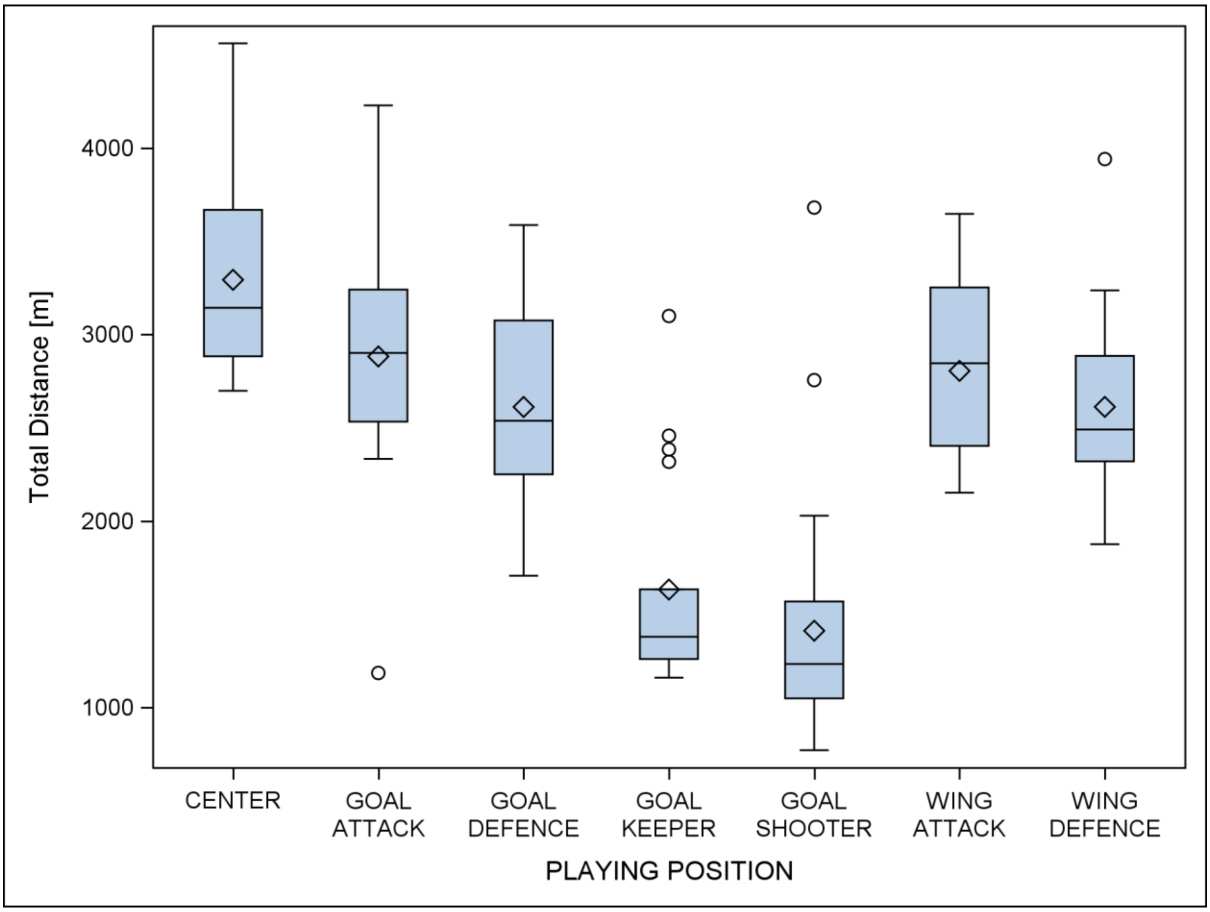

Figure 4.5 Box plot: Total distance covered (n=140 player games)

The boxplot suggests that the GS and GK covered similar distances, far less than the other positions. The upper quartile of the GS and GK is far lower than the lower quartile of all other positions. The mean distance covered by the C is approximately equal to, or higher than the upper quartile of all the other positions, which suggests that the C cover significantly more distance than all the other positions. The IQR of the GK and GS positions is more clustered around a central point than the other positions, suggesting that the data from these two positions is in agreement with each other.

The C presented with the highest distance covered with a mean of 3293.6m, followed by the GA who covered 2882.5m on average and the WA with a mean of 2805.1m covered during match play. On the contrary the GS and GK covered the least amount of meters during match play with a mean of 1632.4m and 1411.6m respectively. The C covered significantly more distance than all the other positions ($p<0.05$), mean differences ranging from 396.8m to 1515.3m. Furthermore, the difference in distance covered by the GS and the GK was significantly less ($p<0.05$) than all the other positions (C, WA, WD, GA and GD). The mean differences between the GS and the C, WA, WD and GD range from 756.3 to 1475.9m and the mean differences between the GK and the C, WA, WD and GD ranged from 795.6 to 1515.3m. The difference in distance covered between the GS and the GK was not significant (Table 4.9).

Table 4.8 also illustrate that most of the total distance covered is covered between 0.2 – 3.6 $m.s^{-1}$ (velocity band 2 and velocity band 3). The C covered a mean of 1361.30m and 1448.86m in velocity band 2 and velocity band 3 respectively. That is 41% of the total distance covered in velocity band 2 and 43% of the total distance covered in velocity band 3. The GK as well as the GS on the other hand, covered 77% of the total distance covered in velocity band 2. The C covered the most meters in velocity band 4 with 455.73m, which is 14% of the mean total distance covered by the C.

The results of the statistical comparison of the different playing positions with regard to distances covered in the different velocity bands (movement classifications) will follow in the next section.

Table 4.8 Total Distance: Descriptive statistics

Variable	Statistic	Playing Position							
		C	GA	GD	GK	GS	WA	WD	All
Total Distance	N	18	23	18	17	27	19	18	140
	Mean	3293.6	2882.5	2611.5	1632.4	1411.6	2805.1	2612.1	2419.8
	Min	2698.4	1184.8	1706.5	1159.9	770.8	2151.9	1875.5	770.8
	Q1	2883.3	2532.8	2250.5	1259.8	1048.7	2403.0	2320.0	1644.3
	Median	3143.5	2901.4	2537.6	1379.1	1233.2	2846.2	2490.8	2498.5
	Q3	3669.0	3241.3	3075.5	1633.5	1568.5	3252.5	2885.8	3071.2
	Max	4561.9	4229.1	3587.4	3099.5	3681.2	3647.3	3941.2	4561.9
Velocity Band 1	N	18	23	18	17	27	19	18	140
	Mean	17.07	18.13	18.39	32.58	32.55	21.66	24.73	23.89
	Min	8.81	10.69	10.46	14.18	12.38	10.67	14.77	8.81
	Q1	11.86	15.20	12.85	24.21	23.35	16.78	18.60	16.54
	Median	14.10	18.03	17.54	26.77	30.18	18.03	23.64	20.22
	Q3	17.88	19.99	20.78	32.36	41.02	27.59	28.71	27.99
	Max	43.87	31.37	41.54	73.50	60.35	51.81	46.52	73.50
Velocity Band 2	N	18	23	18	17	27	19	18	140
	Mean	1361.30	1441.81	1458.09	1227.80	1060.51	1402.81	1477.99	1333.39
	Min	1103.18	794.82	1037.40	917.57	558.52	1017.35	986.97	558.52
	Q1	1178.89	1274.31	1243.48	1029.80	832.35	1251.13	1255.40	1133.14
	Median	1290.96	1391.53	1442.07	1130.86	1023.42	1435.43	1477.42	1313.91
	Q3	1457.40	1589.41	1593.25	1268.59	1228.02	1540.43	1567.01	1535.48
	Max	2189.71	1962.70	2061.54	2106.79	1736.24	1820.99	2234.73	2234.73

Variable	Statistic	Playing Position							
		C	GA	GD	GK	GS	WA	WD	All
Velocity Band 3	N	18	23	18	17	27	19	18	140
	Mean	1448.86	1127.55	946.81	326.77	272.06	1060.06	893.51	844.15
	Min	1028.98	348.47	541.10	96.77	83.87	729.25	583.16	83.87
	Q1	1237.32	916.57	761.05	155.78	148.31	839.57	711.50	300.74
	Median	1343.27	1103.64	919.19	231.94	194.19	1069.33	839.73	895.78
	Q3	1672.29	1303.08	1160.53	354.27	254.31	1208.15	989.16	1226.68
	Max	1967.49	1679.49	1300.24	860.24	1689.11	1451.78	1346.49	1967.49
Velocity Band 4	N	18	23	18	17	27	19	18	140
	Mean	455.73	284.22	179.03	37.17	39.20	309.79	206.48	208.97
	Min	292.23	17.72	35.63	0.00	0.00	156.99	112.21	0.00
	Q1	377.30	225.85	127.99	7.81	6.91	238.40	132.46	32.36
	Median	462.27	266.48	158.25	17.08	17.57	302.88	175.05	188.54
	Q3	484.34	332.43	233.50	27.04	31.69	366.94	274.66	332.39
	Max	649.09	598.82	363.07	201.50	467.27	481.63	396.11	649.09

N: Number of player games

Table 4.9 Total Distance covered [m]: Mean differences between playing positions

Playing Position	Statistic	Comparison with Playing Position						
		C	GA	GD	GK	GS	WA	WD
	Mean	3276.3	2694.3	2602.6	1761.1	1800.4	2879.6	2556.7
	SE	154.4	156.8	155.9	168.1	172.1	159	157.3
C	**Difference**	-	582	673.7	1515.3	1475.9	396.8	719.7
	P-value	-	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.0013**	**<.0001**
GA	**Difference**		-	91.7	933.3	893.9	-185.2	137.7
	P-value		-	0.5316	**<.0001**	**<.0001**	0.2179	0.3437
GD	**Difference**			-	841.6	802.2	-276.9	45.9
	P-value			-	**<.0001**	**<.0001**	0.0641	0.7406
GK	**Difference**				-	-39.4	-1118.5	-795.6
	P-value				-	0.8244	**<.0001**	**<.0001**
GS	**Difference**					-	-1079.2	-756.3
	P-value					-	**<.0001**	**<.0001**
WA	**Difference**						-	322.9
	P-value						-	**0.0055**

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects

4.5.2 Distance covered according to different movement classifications

The boxplots in Figures 4.6 and 4.7 display the distributions of distance covered in the different velocity bands (movement classifications) for the different playing positions. Descriptive statistics for these variables are presented in Tables 4.8. The results of the statistical comparison of the different playing positions are presented in Tables 4.9, 4.10, 4.11 and 4.12.

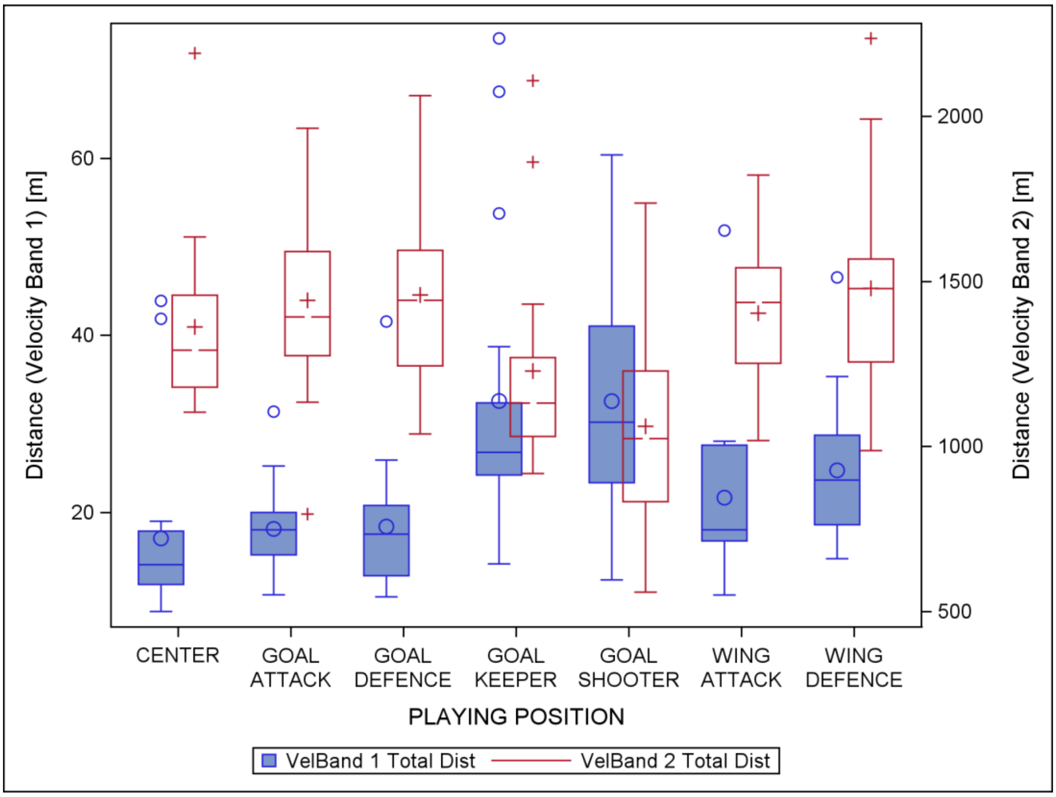

Figure 4.6 Box plot: Distance covered in Velocity band 1 and Velocity band 2 (n=140 player games)

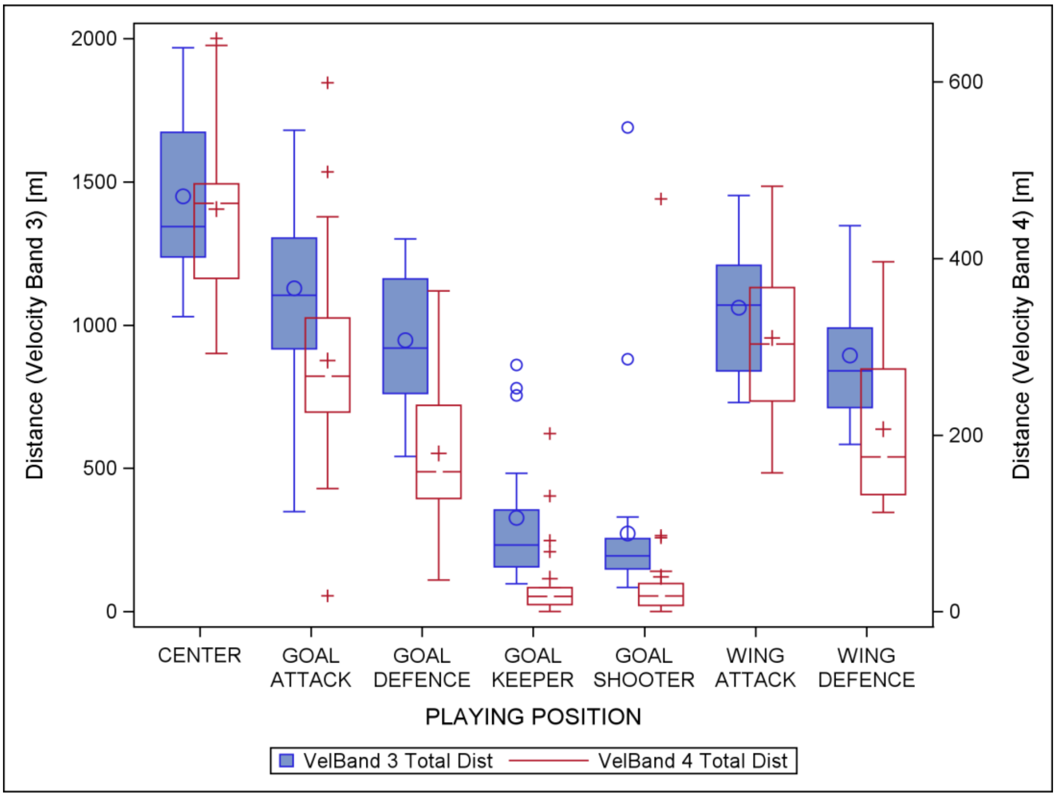

Figure 4.7 Box plot: Distance covered in Velocity band 3 and Velocity band 4 (n=140 player games)

The boxplots in Figure 4.6 and 4.7 show definite differences between distances covered by the different positions in the different velocity bands. It is evident that the box plots seen in these two figures are much smaller than the box plots for example HR (Figure 4.3), suggesting that distance covered are more position specific than for example HR.

The lower quartile of the distance covered in velocity band 1 by the GS and GK are approximately equal to, or higher, than the upper quartiles for the all the other playing positions except for the WD, which suggest that the GS and GK positions cover significantly more distance in velocity band 1 than all the positions except for the WD. The opposite can be said for mean distance covered in velocity band 2. The upper quartile of the distance covered in velocity band 2 by the GS and GK are approximately equal to, or lower, than the lower quartiles for the other playing positions. The IQR of velocity band 2 of the other positions overlap, which suggests that there are no clinically significant differences in distance covered in these two velocity bands between C, GA, GD, WA and WD.

Table 4.10 present the descriptive statistics for the distance covered in the different velocity bands. The C covered the least amount of meters in velocity band 1 - Standing (20.6m) while the GK and GS recorded the greatest distance in velocity band 1 with 33.2m and 34.8m respectively. Conversely, the C covered more meters than any other position in velocity band 3 (1418.9m) and velocity band 4 (467.9m), whereas the GK only covered 387.3m in velocity band 3 and only 68.3m in velocity band 4, which was the lowest of all positions. Surprisingly, no scores were recorded for velocity band 5 by any of the playing positions.

The results of the statistical comparison of the different playing positions with regard to distance covered in velocity band 1 and 2 are presented in Tables 4.9 and 4.10, respectively. The mean distance covered in velocity band 1 by the GS was significantly ($p<0.005$) higher than the C, GA, GD and WA, mean differences ranging between 10.17 to 14.24m. Similarly, the mean distance covered in velocity band 1 by the GK was significantly ($p<0.005$) higher than the C, GA, GD and WA, mean differences ranging between 8.55 to 12.62m. Surprisingly, the WD also travelled significantly ($p=0.007$) further than the C in velocity band 1 with a mean difference of 7.8m. Table 4.12 shows that the GK and GS covered significantly ($p<0.05$) less distance than all the other positions in velocity band 2, mean differences ranging from 143 to 363m. The GK also travelled significantly ($p=0.0277$) further than the GS with a mean difference of 136m.

Furthermore, the boxplots in Figure 4.7 suggests even more significant differences in distance covered in velocity bands 3 and 4 between the playing positions. The upper quartiles of the GS and GK for velocity band 3 and 4 are significantly lower than the lower quartiles of all the other positions. The IQR for velocity band 3 of the GA, GD WA and WD overlap, which suggests that there are no clinically significant differences in distance covered in velocity band 3 between these positions. Tables 4.11 and 4.12 present the results of the statistical comparison of the different playing positions with regard to distance covered in velocity band 3 and 4. The C travelled statistically significantly ($p<0.05$) further than all the other positions in velocity band 3, mean differences ranging from 330.8 to 1031.6m (Table 4.13). Furthermore, the distance covered by the GS and GK in velocity band 3 were significantly ($p<0.05$) lower than all the other positions, mean differences ranging from 410 to 1031.6m. The difference between the GS and GK was not significant. Surprisingly, the distance covered by the WA was also statistically significantly ($p= .0086$) higher than the distance covered by the WD in velocity band 3. The same can be said for velocity band 4 where the C covered significantly ($p<0.05$) more distance than all the other positions, mean differences ranging from 171.1 and 399.6m. Similarly, the distance covered by the WA was significantly ($p<0.05$) higher than all the other positions (except for the C), mean differences ranging between 66.9 and 228.5m. Furthermore, the GA covered significantly ($p<0.05$) more distance the GD, GK and GS with a mean difference between 68.3 and 161.6m. The distance covered by the GK in velocity band 4 was significantly ($p<0.05$) lower than all the other positions. The same can be said for the difference between GS and all other positions except for the GD and the GK.

Table 4.10 Distance covered: Mean distance covered [m] in different velocity bands

Movement classification	Velocity Band ($m.s^{-1}$)	Playing Position						
		C	GA	GD	GK	GS	WA	WD
Standing	0 – 0.1	20.6	22.7	23.1	33.2	34.8	24.7	28.3
Walking	0.2 – 1.7	1387.1	1412.8	1465.7	1243.8	1107.5	1470.5	1468.3
Jogging	1.8 – 3.6	1418.9	1044.4	944.1	387.3	469.9	1088.1	879.9
Running	3.7 – 5.3	467.9	229.9	161.7	68.3	98.4	296.8	186.1
Sprinting	>5.4							
Mean Total distance		3276.3	2694.3	2602.6	1761.1	1800.4	2879.6	2556.7

Mean: Least squares mean from mixed model analysis.

Table 4.11 Distance covered: Mean differences between playing positions in Velocity band 1 (Standing) (0 – 0.1m.s^{-1})

Playing Position	Statistic	Comparison with Playing Position						
		C	**GA**	**GD**	**GK**	**GS**	**WA**	**WD**
	Mean	20.60	22.69	23.10	33.22	34.84	24.67	28.35
	SE	4.55	4.58	4.51	4.68	4.65	4.61	4.53
C	**Difference**	-	-2.09	-2.50	-12.62	-14.24	-4.07	-7.75
	P-value	-	0.4779	0.3988	**0.0002**	**<.0001**	0.1336	**0.007**
GA	**Difference**		-	-0.41	-10.53	-12.15	-1.98	-5.66
	P-value		-	0.8928	**0.0021**	**0.0001**	0.5215	0.0613
GD	**Difference**			-	-10.12	-11.74	-1.57	-5.25
	P-value			-	**0.0004**	**0.0007**	0.6104	0.0753
GK	**Difference**				-	-1.62	8.55	4.87
	P-value				-	0.6402	**0.0114**	0.1335
GS	**Difference**					-	10.17	6.49
	P-value					-	**0.0035**	0.0524
WA	**Difference**						-	-3.68
	P-value						-	0.1619

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

Table 4.12 Distance covered: Mean differences between playing positions in Velocity band 2 (Walking) (0.2 – 1.7m.s^{-1})

Playing Position	Statistic	Comparison with Playing Position						
		C	**GA**	**GD**	**GK**	**GS**	**WA**	**WD**
	Mean	1387.1	1412.8	1465.7	1243.8	1107.5	1470.5	1468.3
	SE	77.7	78.2	78.1	80.9	81.5	78.9	78.5
C	**Difference**	-	-25.7	-78.6	143.4	279.7	-83.3	-81.1
	P-value	-	0.6044	0.1160	**0.0113**	**<.0001**	0.0573	0.0816
GA	**Difference**		-	-52.9	169.0	305.4	-57.6	-55.4
	P-value		-	0.3063	**0.0038**	**<.0001**	0.2749	0.2795
GD	**Difference**			-	221.9	358.3	-4.7	-2.5
	P-value			-	**<.0001**	**<.0001**	0.9279	0.9585
GK	**Difference**				-	136.3	-226.6	-224.5
	P-value				-	**0.0277**	**0.0001**	**0.0001**
GS	**Difference**					-	-363.0	-360.8
	P-value					-	**<.0001**	**<.0001**
WA	**Difference**						-	2.2
	P-value						-	0.9586

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

Table 4.13 Distance covered: Mean differences between playing positions in Velocity band 3 (Jogging) (1.8 – 3.6m.s^{-1})

Playing Position	Statistic	Comparison with Playing Position						
		C	**GA**	**GD**	**GK**	**GS**	**WA**	**WD**
	Mean	1418.9	1044.4	944.1	387.3	469.9	1088.1	879.9
	SE	76.3	78.3	77.2	85.1	86.8	80.3	78.4
C	**Difference**	-	374.5	474.8	1031.6	949.1	330.8	539.0
	P-value	-	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**
GA	**Difference**		-	100.3	657.1	574.6	-43.7	164.5
	P-value		-	0.2835	**<.0001**	**<.0001**	0.6482	0.0782
GD	**Difference**			-	556.8	474.2	-144.0	64.2
	P-value			-	**<.0001**	**<.0001**	0.1314	0.4710
GK	**Difference**				-	-82.5	-700.8	-492.6
	P-value				-	0.4460	**<.0001**	**<.0001**
GS	**Difference**					-	-618.3	-410.1
	P-value					-	**<.0001**	**0.0004**
WA	**Difference**						-	208.2
	P-value						-	**0.0086**

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

Table 4.14 Distance covered: Mean differences between playing positions in Velocity band 4 (Running) (3.7 – 5.3m.s^{-1})

Playing Position	Statistic	Comparison with Playing Position						
		C	**GA**	**GD**	**GK**	**GS**	**WA**	**WD**
	Mean	467.9	229.9	161.7	68.3	98.4	296.8	186.1
	SE	25.1	25.8	25.4	28.7	29.7	26.3	25.6
C	**Difference**	-	238.0	306.3	399.6	369.5	171.1	281.8
	P-value	-	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**
GA	**Difference**		-	68.3	161.6	131.5	-66.9	43.8
	P-value		-	**0.0382**	**<.0001**	**<.0001**	**0.0453**	0.1726
GD	**Difference**			-	93.3	63.3	-135.2	-24.5
	P-value			-	**0.0015**	0.0851	**<.0001**	0.4338
GK	**Difference**				-	-30.1	-228.5	-117.8
	P-value				-	0.4413	**<.0001**	**0.0012**
GS	**Difference**					-	-198.5	-87.7
	P-value					-	**<.0001**	**0.0192**
WA	**Difference**						-	110.7
	P-value						-	**<.0001**

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

4.6 Player load (PL)

4.6.1 Total PL

The boxplots in Figure 4.8 display the distributions of the total player load and player load per meter by the different playing positions. Descriptive statistics for these variables are presented in Table 4.15. The results of the statistical comparison of the different playing positions with regard to player load and player load per meter are presented in Tables 4.14 and 4.15 respectively.

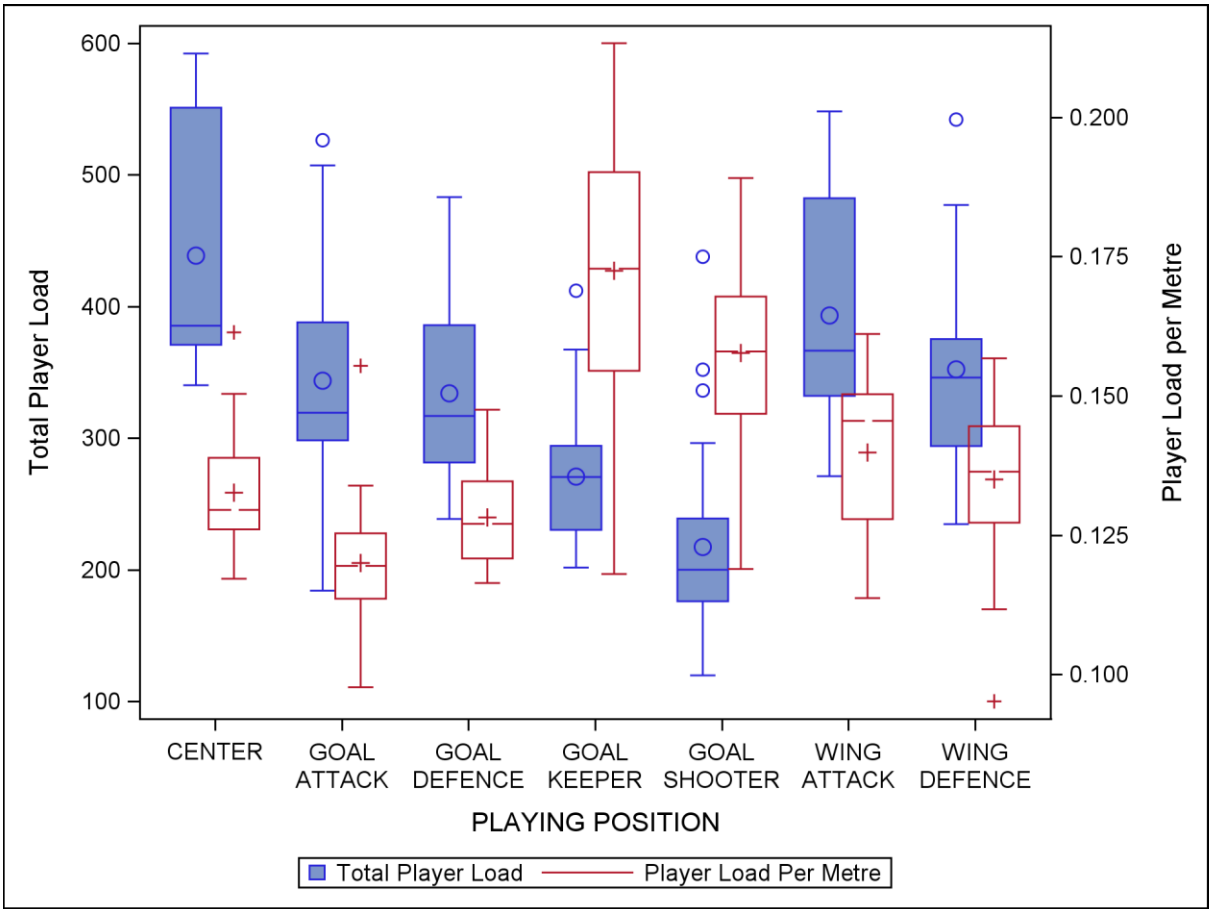

Figure 4.8 Box plot: Player load and Player load per meter (n=140 player games)

The boxplots illustrates that the C and WA had a higher player load than all the other positions. In contrast the GK and GS display the lowest player load with the upper quartile approximately equal to, or lower, than the lower quartiles for the other playing positions. However, these two positions (GS and GK) had a higher player load per meter than all the other positions. The IQR for player load per meter of the C, GA, GD, WA and WD overlap, which suggests that there are no clinically significant differences in player load per meter between these positions. The C had the highest mean player load (438.6 Load $^{TM}\cdot$min $^{-1}$ (au)) while the GS recorded the lowest player load (217.3 PlayerLoad^{TM} (au)). On the other hand, the GS and GK had a higher mean player load per meter than all the other positions with 0.158 PlayerLoad $^{TM}\cdot m^{-1}$ (au) and 0.172 PlayerLoad $^{TM}\cdot m^{-1}$ (au) respectively and the GA presented with the lowest mean player load per meter with 0.12 PlayerLoad $^{TM}\cdot m^{-1}$ (au).

The results of the statistical comparison of the different playing positions with regard to player load and player load per meter are presented in Tables 4.14 and 4.15, respectively. The C had a statistically significantly ($p<0.05$) higher mean player load than all the other positions, mean differences ranging from 92.71 to 162.43 PlayerLoad^{TM}(au). The GS and GK presented with a significantly ($p<0.05$) lower player load than all the other positions with the mean difference between 20.1 and 162.43 PlayerLoad^{TM}(au). However, the GS and GK had a significantly ($p<0.05$) higher player load per meter than all the other positions, mean differences ranging between 0.011 and 0.038 PlayerLoad $^{TM}\cdot m^{-1}$ (au). In addition, the GK presented with a statistically significantly ($p=0.0162$) higher player load per meter than the GS.

Table 4.15 Player load and Player load per meter: Descriptive statistic

Variable	Statistic	Playing Position							
		C	GA	GD	GK	GS	WA	WD	All
Total Player Load	N	18	23	18	17	27	19	18	140
	Mean	438.6	343.6	334.0	270.7	217.3	393.2	352.2	329.2
	Min	340.1	184.1	238.6	201.6	119.7	271.1	234.6	119.7
	Q1	370.9	298.3	281.5	230.3	176.0	332.1	294.0	261.5
	Median	385.4	319.2	316.8	270.4	200.0	366.4	346.0	323.7
	Q3	551.0	387.9	385.8	294.1	238.9	482.2	375.2	384.4
	Max	592.1	526.3	483.1	412.0	437.8	548.2	542.0	592.1
Player Load per meter	N	18	23	18	17	27	19	18	140
	Mean	0.133	0.120	0.128	0.172	0.158	0.140	0.135	0.141
	Min	0.117	0.098	0.116	0.118	0.119	0.114	0.095	0.095
	Q1	0.126	0.114	0.121	0.155	0.147	0.128	0.127	0.124
	Median	0.130	0.119	0.127	0.173	0.158	0.146	0.136	0.138
	Q3	0.139	0.125	0.135	0.190	0.168	0.150	0.145	0.155
	Max	0.161	0.155	0.148	0.213	0.189	0.161	0.157	0.213

N: Number of player games

Table 4.16 Total Player load PlayerLoad™(au): Mean differences between playing positions

Playing Position	Statistic	Comparison with Playing Position						
		C	GA	GD	GK	GS	WA	WD
	Mean	430.8	333.1	338.1	288.4	268.4	368.7	342.7
	SE	20.0576	20.3855	20.3485	22.1996	22.9634	20.5581	20.4135
C	Difference	-	97.69	92.71	142.42	162.43	62.15	88.16
	P-value	-	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**
GA	Difference		-	-4.98	44.73	64.75	-35.54	-9.52
	P-value		-	0.7903	**0.0395**	**0.0005**	0.0601	0.6031
GD	Difference			-	49.71	69.72	-30.56	-4.54
	P-value			-	**0.0014**	**0.0021**	0.1054	0.7966
GK	Difference				-	20.01	-80.27	-54.26
	P-value				-	0.4059	**0.0003**	**0.0095**
GS	Difference					-	-100.29	-74.27
	P-value					-	**<.0001**	**<.0001**
WA	Difference						-	26.02
	P-value						-	0.0537

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

Table 4.17 Player load Load per meter (PlayerLoad™. m^{-1}(au): Mean differences between playing positions

Playing Position	Statistic	Comparison with Playing Position						
		C	**GA**	**GD**	**GK**	**GS**	**WA**	**WD**
	Mean	0.004	0.005	0.005	0.005	0.006	0.005	0.005
	SE	89.4	90.1	85.2	72.5	60.2	93.1	91.9
C	**Difference**	-	0.004	0.003	-0.034	-0.016	0.003	0.004
	P-value	-	0.5168	0.6552	**<.0001**	**0.0272**	0.6155	0.4272
GA	**Difference**		-	-0.001	-0.038	-0.019	-0.001	-0.008
	P-value		-	0.8589	**<.0001**	**0.0017**	0.8445	0.1737
GD	**Difference**			-	-0.037	-0.018	0.000	-0.007
	P-value			-	**<.0001**	**0.0114**	0.9851	0.2375
GK	**Difference**				-	0.019	0.037	0.030
	P-value				-	**0.0162**	**<.0001**	**<.0001**
GS	**Difference**					-	0.018	0.011
	P-value					-	**0.0130**	**0.0130**
WA	**Difference**						-	-0.007
	P-value						-	0.1537

Mean: Least squares mean from mixed model analysis. **Difference:** Difference between relevant pair of least squares means. **P-value:** P-value associated with the null-hypothesis of zero mean difference between playing positions, from mixed model analysis. The mixed model fitted Playing Position as fixed effect, and Game, Team, the Game x Team interaction term, and Player as random effects.

CHAPTER 5

DICUSSION OF THE RESULTS

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

5.1 Introduction

Time motion analysis (TMA) research in netball, especially junior netball, is very scares. This study, to the knowledge of the research team, is the first to investigate the physical characteristics and physical demands of u/19 female netball players and to statistically compare the differences between all seven playing positions (GS, GA, WA, C, WD, GD, and GK). Furthermore, netball has developed into a professional sport over the last few years. Therefore, knowledge regarding the physical characteristics and physical demands of netball match play are being prioritised by numerous coaches and conditioning coaches all over the country in an attempt to optimally prepare the athletes for competition. As can be seen from Table 2.5 and Table 2.6, previous TMA research on netball focussed on elite or adolescent netball players. Most of these studies had a small sample size and did not include all the playing positions whereas the current study had 44 participants and all the different playing positions were included in the study. The 44 participants played in numerous netball matches during the 2017 season and a total of 140 (n=140 for GPS data) player games were recorded for analysis. Only matches where the participants played in all four quarters of the match were used in the analysis. Furthermore, physical measurements and their preferred playing position were collected from 42 (n=42) for physical measurements participants.

5.2 Physical profile of participants

As previously mentioned research related to the physical profile of u/19 female netball players in scarce, however, Thomas *et al.* (2016) published one of few studies to investigate the height and body weight of u/19 female netball players. The current study examined the height, body weight, body fat percentage and BMI of 42 participants and demonstrated differences between the different playing positions.

5.2.1 Body weight

The results of the current study found the mean body weight of u/19 female netball players (n=42) to be 64.3kg. This is similar to previous research (Chad *et al.,* 1991) that reported a mean body of 61.4kg for elite New South Wales netball players (aged 19.7 ± 3.4). Additionally, Hopper (1997) also reported a similar mean body weight of 66kg (u/21 with a mean age of 19.2). However, McCabe (2014) reported a much higher mean body weight of 72.3kg; but, these players had a mean age of 25.58 ± 3.99 years. Additionally, Van

Jaarsveld (2015) and Ferreira (2010) found female netball players (aged 18-25) to have a mean body weight of 68.8kg, Cormach *et al.* (2013) reported a mean weight of 67.8kg (mean age = 22.6) and Thomas *et al.* (2016), who also investigated u/19 players reported the mean body weight for u/19 female netball players to be 69.8kg, that is 5.5kg heavier than the current study suggested.

The results from Table 4.3 suggest that the GS (75kg) and the GK (70kg) are the heaviest players on court, while the C (59.1kg), GD (59.7kg) and the WD (58.9kg) are found to be much lighter. Chad *et al.* (1991) who grouped the different playing positions in three groups namely: Shooters (GS and GA), Centres (WA, C and WD) and Defenders (GD and GK), reported that the Defenders are the heaviest players with a mean body weight of 67.2 ± 9.5kg followed by the Shooters (63.1 ± 5.5kg) and the Centres with a mean weight of 62.9 ± 7.2kg.

To conclude, as expected increase average weight of elite netball players with increase in age, however it is important to note that the elite netball players in this study was also much shorter than the elite netball players reported in other studies.

5.2.2 Height

The current study found the mean height of u/19 female netball players to be 170.1cm. This is similar to the results of Hopper (1997) who reported a mean height of 173.1 ± 5.8cm for u/21 (mean age = 19.2) netball players. However, the results reported for height in the current study is 5cm less than previous research suggests. McCabe (2014) found the mean height of elite netball players to be 175 ± 5.76cm. This correlates with Van Jaarsveld (2015) as well as Cormach *et al.* (2013) who reported a mean player height to be 176 ± 5cm (aged 18-25) and 174.3 ± 6.6cm (mean age = 22.6) respectively. Surprisingly, Thomas *et al*. (2016, 34) who investigated u/19 netball players also reported a similar height (176cm).

Previous research (Chad *et al.,* 1991) reported elite Defenders (GK and GD) and Shooters (GS and GA) to have a mean height of 174cm and 170cm respectively. This is similar to the mean height of the u/19 players that participated in the current study where the GK had a mean height of 176cm and the GS 177.8cm. The mean height of the C (166.3cm), WA (162.1cm) and WD (168.5cm) is similar to the mean height reported by Chad *et al.* (1991) who reported the Centres (WA, C and WD) to have a mean height of 165.5 ± 5cm.

To conclude, it is interesting to note, that this population of elite u/19 netball players in Bloemfontein is shorter than the average elite netball player reported in the literature. However, the younger age of the population of the current study could have be the reason for the differences measured in height comparing to the older participants in the reported studies.

5.2.3 Body fat percentage and BMI

The results of the current study suggest that the mean body fat percentage of u/19 female netball players (n=42) is 25.8%. This is similar to Ferreira (2010) who investigated players from the first, second, third and fourth league as well as the U19 A and B netball teams and reported a mean body fat percentage of 27%. In contrast, Van Jaarsveld (2015) reported a mean body fat percentage of 19.8%. However, it must be mentioned that Van Jaarsveld (2015) investigated elite players aged between 18-25 years. The results of the current study highlighted the higher body fat percentage of the GK (29.1%) whereas the GD had the lowest percentage body fat (22%). Ferreira (2010) further reported a mean BMI of 22 which is the same as the results from the current study. The results of the current study show the GS (24.1) and GK (22.6) had the highest BMI whereas the WA and GD only had a BMI of 20.8 and 20.3 respectively.

To conclude, it is evident that certain positions are characterized be certain body types. A reason could be the different roles of each positions as well as the court restriction rule in netball. For example, the GS and GK are found to be taller than the other positions. It must be mentioned that the methods used to determine the body fat percentage may differ between the various researchers, which may contribute to the differences reported by the different researchers.

5.3 Heart rate (HR) response

The current study found the mean maximum HR of all participants to be 200.5 b/min and the mean HR of all participants to be 174 b/min (Table 4.4). This is similar to other intermittent sport such as soccer (152 – 186 b/min) (Krustrup *et al.,* 2005) and basketball (171 b/min) as reported by Abdelkrim *et al.* (2007). Krustrup *et al.* (2005) documented that soccer players perform at a mean of 86% of their maximum HR. The current study showed similar results for netball players (87% HR_{max}), however, Abdelkrim *et al.* (2007) reported that basketball players perform at an even higher mean HR (91% HR_{max}). This highlights the considerable physiological demands placed on these athletes during match play. The reason for difference in % HR_{max} between the different sports could be the difference in court size, the age and sex of the subjects and the level of participation of the subjects. Abdelkrim *et al.* (2007) investigated elite u/19 male basketball players and Krustrup *et al.* (2005) focused on elite female soccer players (mean age of 24years) where the participants of the current study were all u/19 female netball players playing in the Bloemfontein u/19 school league.

Chandler *et al.* (2014) reported similar, but lower HR_{max} values for collegiate female netball players. It must be mentioned that the sample size used by Chandler *et al.* (2014) (n=8) was considerably smaller than the sample size of the current study (n=140). Mean HR response results on netball players measured by Chandler *et al.* (2014) were in agreement with the results from the current study. The reported findings from the current study also agree with Chandler *et al.* (2014) that the C and WA perform at a higher mean HR than the other positions, suggesting that these positions have a higher physiological demand than the other positions. Chandler *et al.* (2014) reported a mean HR of 185 b/min and 182 b/min for the C and WA respectively, which are lower than the results of the current study. However, the findings of the current study was in agreement with McCabe (2014) who reported similar mean HR values for the C , WA and GA during match play (Table 4.4). The results from the current study show a similar mean HR response for the GA (180 b/min), however, Chandler *et al.* (2014) found the GA (156 b/min) to have the lowest mean HR of all the other positions. The suggestion that the GS and GK have lower physiological demands than the other positions is emphasised by the findings of this study. The GS presented with the lowest mean HR (161b/min), which was significantly lower than all the other positions except for the GD and WD. This is similar to the mean HR for the GS reported by McCabe (2014) and Chandler *et al.* (2014). However McCabe (2014) reported that the GK had the lowest mean HR. Mean HR values seem to range between 161 - 180 b/min. This is similar to previously reported research that mean HR values ranges between 152 - 178 b/min (McCabe, 2014) and 156 - 185 b/min (Chandler *et al.,* 2014).

In conclusion, it seems that the GS performs at a significantly lower mean HR than all the other positions except for the GD. As can be seen from previous research (Chandler *et al.,* 2014); (McCabe, 2014) and from the results displayed in Figure 4.3 from the current study it is evident that the GS perform at a lower mean and maximum HR than all the other positions. Therefore, suggesting a lower physiological demand during match play. In contrast, the C and WA seem to perform at a higher mean HR than the other positions. The court restriction rule and the different responsibilities of the positions in netball may be responsible for the higher mean HR of the C and the WA. These two positions have a bigger surface area to cover on court and are responsible to take the ball up court to the GS and GA who is the only two players that can score a goal in netball. The GS on the other hand may only move in one third of the court, which may explain the lower HR response during netball match play.

5.4 Velocity

As mentioned in Chapter 2, Dwyer *et al.* (2012) investigated GPS data to determine velocity ranges of field sport athletes and stated that previous research classified locomotor activity in an attempt to simplify TMA results. The most common methods used to define locomotor activities are defined as a range of velocity thresholds, a mean velocity or as previously mentioned, subjective descriptions. Researchers such as Aughey (2011) and Rampinini *et al.* (2009), classified velocity bands as low-intensity running (LIR), moderate-intensity running (MIR) and high-intensity running (HIR), whereas others (used subjective descriptions to classify velocity bands (Table 2.7 and 2.8). On the other hand, some researchers did used absolute values to classify velocity bands; however, none of those studies used netball players (Table 2.9).

The current study made use of the velocity bands for female hockey players as defined by Dwyer *et al.* (2012) – Standing = 0-0.1m.s^{-1}, Walking = 0.2-1.7m.s^{-1}, Jogging = 1.8-3.6m.s^{-1}, Running =3.7-5.3 m.s^{-1} and Sprinting = >5.4m.s^{-1}. The reasoning behind this decision was the fact that Dwyer *et al.* (2012) expressed his concern of what constitutes as a sprinting activity by stating that numerous sport scientists classified activities or efforts above a given threshold of 6 – 7 m.s^{-1} are classified as a sprint. However, Dwyer *et al.* (2012) enumerates that many maximal effort sport sprints start from a standing position and only last about 1-2 seconds. Although these activities are completed at maximal effort, the duration of these activities are too short to achieve the sprinting velocity threshold. Dwyer *et al.* (2012) reported that a sprint lasting only 1 second can cover up to 4.2 meters and sprints lasting 2 seconds could cover 7 meters. However these activities would not be classified as a sprint because the maximum velocities of these sprints were not greater than the traditional sprint velocity threshold of 5.6m.s^{-1}. Therefore, Dwyer *et al.* (2012) investigated data sets of five different sports including male and female sports and acknowledged the traditional sprinting threshold of 5.6 m.s^{-1}.

The results show the mean maximum velocity reached by u/19 female netball players ranged between 4.11 and 5.22m.s^{-1}. The C presented with the highest mean maximum velocity, suggesting a higher physical demand. The court restriction rule as well as the technical and tactical demands of each position may have an influence on the maximum velocity reached during a match. This finding suggests that u/19 female netball players do not exceed speeds that can be classified as a sprint.

5.5 Distance covered

Belka *et al.* (2014) remarked that the distance covered by athletes during competition is one of the most studied variables in the field of sport science. Total distance covered have been measured in various team sports and varies from 5-6km covered in under 19 rugby union (Cunningham *et al.,* 2016) to 5-8km covered in rugby league (Twist *et al.,* 2014) and 8-12km covered during a soccer match (Mohr *et al.,* 2003). Badminton players cover a mean total distance of 2km (Liddle *et al.,* 1996), however, the distance covered in court sports such as Badminton depends on the length of the game till victory is reached. The variation in total distance covered between the various sports may be reflected by the total playing time of a match as well as the size of the different playing courts or fields. Soccer is played on a much larger playing surface than badminton and netball. The length of the match would also have a big influence on the total distance measured in the different sport codes. Soccer is played for 90 minutes whereas netball is played for 60 (four quarters of 15min each) minutes at elite senior level. The length of a u/19 netball match is only 40 (four courters of 10min each) minutes in duration. This could explain the differences observed in distance covered between senior netball players and u/19 netball players.

A study by Yong *et al.* (2015) on adolescent netball players reported midcourt positions (WA, C and WD) to cover a greater distance during match play whereas attacking positions (GS and GA) cover the least amount of meters. However it must be mentioned that Yong *et al.* (2015) only investigated one match consisting of six quarters. The results from the current study also suggest that the C, WA, WD together with the GA cover a greater mean total distance than the other playing positions, suggesting the these players have a higher physical demand during match play.

Although the current study agrees with Davidson *et al.* (2008) that the GK and GS to cover similar distances during a netball match, Davidson *et al.* (2008) reported a far greater distance covered by the GS (4210m) and GK (4283m) during match play, whereas the results from the current study suggest a mean total distance covered by the GS and GK ranging from 1761.1 to 1800.4m. The suggestion that the C has a higher physical demand is further highlighted by Davidson *et al.* (2008) who reported that the C travelled statistically significantly further than the other playing positions. However, Davidson *et al.* (2008) again reported a far greater distance covered by the C (8km) whereas the current study documented the C to cover a mean total distance of 3276.3m during match play. A few factors could be responsible for the difference in distance covered between the different studies. The participants from the study by Davidson *et al.* (2008) were all senior elite players playing Super league in England. For one the age difference could have an influence on the results. The level of participation could also influence the results and lastly the length of the match could play a big role in the outcome of the results. As previously mentioned, the length of a u/19 netball match is 20min in total shorter than a senior match.

The difference in distance covered observed between the different playing positions could be described to the fact that the C has a greater distance to cover due to the areas on the court that the different positions are allowed to move. As previously described the C can move in all areas of the court accept for the shooting circle while the GK and GS are restricted to move in only one third of the court. Furthermore when the ball is in the opposite end of the court the GS or GK (depends on which team is in possession of the ball) will stand still until the ball reaches their side of the court. However, the C will follow the ball either on attack or as a defensive player. To summarize, the results agreed that the GS and GK cover significantly less meters than the other playing positions. The opposite can be said for players in the C position who cover significantly more distance during match play than all the other positions, mean difference ranging from 397m to 1515m.

Davidson *et al.* (2008) in agreement with Steele *et al.* (1992) reported a significant difference in the distance covered while jogging and running between the C and GK and GS. However, these studies made use of subjective movement classifications (Table 2.7), whereas the current study classified the different movement categories into objective velocity bands. These velocity bands are summarised in Table 4.10. Therefore, comparing the results of the current study with previous research would not be faultless. However, Davidson *et al.* (2008) and Steele *et al.* (1992) reported that the C covers significantly more distance jogging and running. This finding is in agreement with the current study. The C travelled statistically significantly further than all the other positions in velocity band 3 (Jogging) and velocity band 4 (Running), mean differences ranging from 330.8 to 1031.6m (Table 4.13). Furthermore, the C covered the least amount of meters in velocity band 1 - Standing (20.6m) while the GK and GS recorded the greatest distance in velocity band 1 with 33.2m and 34.8m respectively. Conversely, the GK only covered 387.3m in velocity band 3 and only 68.3m in velocity band 4, which was the lowest of all positions. Surprisingly, no scores were recorded for velocity band 5 by any of the playing positions. The level of participation and sport code could yet again be the defining reason for the lack of data in velocity band 5 – Sprinting. Although the velocity bands set by Dwyer *et al.* (2012) were based on female participants, these were senior state field hockey players in peak physical condition. Therefore, the results (or lack of results in velocity band 5 – Sprinting) of the current study could be described to the fact that even though the participants exerted facets maximal efforts during the match, the peak velocity reached did not exceed $5.4 m.s^{-1}$ and therefore that effort could not be classified as a sprint.

To conclude, age, level of participation and the type of sport will all have an influence on the distance covered by an athlete during competition. Furthermore, the study emphasised the positional differences in distances covered by netball players. As mentioned before, the velocity thresholds used to classify the different movement patterns may also influence the results. According to the results from the current study none of the participants performed a sprint during any of the matches. Therefore, when interpreting these results it should be emphasised that the velocity thresholds used in the study were not netball specific and were adopted from senior elite female hockey players (Dwyer *et al.,* 2012) and used in the current study where the participants were all school level u/19 netball players. From the results it can be seen that the GS and GK cover the most distance in velocity band 1and 2 (Standing and Walking) and the least distance in velocity band 3 and 4 (Jogging and Running). Surprisingly, all the playing positions are most active in velocity band 2 (Walking). As mentioned distance covered by the GS and GK in velocity band 2 ranges between 1108m and 1244m, which are 68% and 74% of the mean total distance covered by the GS and GK respectively. The C, the least active of all positions in velocity band 2, covers 43% of its mean total distance covered in this velocity band. However, the C is the most active of all positions in terms of distance covered in velocity band 3 and 4 covers a mean of 42% and 14% of the mean total distance covered in velocity band 3 (Jogging) and 4 (Running) respectively. In contrast, the GS and GK cover the least distance in velocity band 3 (Jogging) and 4 (Running), mean percentage of 23% (GS) and 20% (GK) in velocity band 3 (Jogging) and only 4% (GS) and 3% (GK) in velocity band 4 (Running). The court restriction rule in netball could have influenced the above mentioned results. The positions in the goal circle (GS and GK) can only move in one third of the court and is not actively involved in the game if the ball is on the other side of the court. The main role of the GS and GA are to score goals and in order to do this these players must twist, turn and sprint away from the defending players to put them into a position to receive the ball from a team mate. The GK and GD are responsible to defend the GS and GA in an attempt to turn over the possession of the ball. On the other hand, the C is allowed to move in more areas of the court (Table 2.4), which may explain the higher mean total distance covered. The C and WA is mostly responsibly to open up the playing court and to ensure that the ball reach the GS or GA in the shooting circle. This require high intensity short sprints in an attempt to either move away from the defenders in order to be in a position to receive the ball or the draw defenders away from teammates to put them into a positions to receive the ball.

5.6 Player load (PL)

The recent development of small wearable devices such as the Catapult Minimax X4 that are capable of measuring various variables such as player load has provided new opportunities for research in sport sciences (Montgomery *et al.,* 2010). These accelerometer units measures accelerations in the frontal-, sagittal- and transverse axes of movement to determine a variable called PL (Gabbettt*,* 2012). Numerous authors found the C position to be the most physical demanding position (Chandler *et al.,* 2014); (Cormack *et al.,* (2013) (Fish *et al.,* 2014) and (McCabe, 2014). Since the results of the current study found the C to cover the greatest distance, the load placed on the C should also be greater. The centre court positions (C, WA and WD) presented with the highest total player load followed by the GD and GA, suggesting higher physical demands during match play. On the other hand, the GS and GK presented with the lowest total PL of all the playing positions. As previous research suggested, the current study also found the C position to present with the highest PL. These findings are in agreement with Davidson *et al.* (2008), Cormack *et al.* (2013), McCabe (2014) and Fish *et al.* (2014) that the C position exposed the greatest load during match play. It must be mentioned that previous researchers (Chandler *et al.,* 2014); (Fish *et al.,* 2014); (McCabe, 2014); (Cormack *et al.,* (2013) normalized PL measurements for playing time and reported as arbitrary units Load $^{TM\cdot}$min $^{-1}$ (au). The current study presented PL as total player load (PlayerLoad^{TM}(au)) for the match and player load per meter (PlayerLoad$^{TM\cdot}$m^{-1}(au)). Therefore, comparisons between the absolute values of the current study and previous research would be very difficult.

However, the current study found the C to have a significantly higher mean total PL than all the other positions, a mean difference ranged between 62.15 and 162.43 (PlayerLoad^{TM}(au)). This correlates with previous research such as Chandler *et al.* (2014)

and Fish *et al.* (2013) who reported a higher mean PL per minute for the C. Additionally, McCabe (2014) stated that the C presents with a mean PL of 38.33 Load $^{TM\cdot}$min $^{-1}$ (au) higher than the WD position which, according to McCabe (2014) has the second highest PL. However, the current study reported the WA to have the second highest mean total PL followed by the WD. The similarity between the WA and WD highlight the link between the physical demands and the court restrictions of the different playing positions. The GS and GK positions presented with the lowest mean total PL, on average 142.42 to 162.43 (PlayerLoad^{TM}(au)) lower than the C. The results of the study agreed with McCabe (2014) and Chandler *et al.* (2014) and acknowledged the lower mean total PL of the GS and GK in comparison with the other playing positions. However, the GS and GK had a significantly higher PL per meter than all the other positions, mean differences ranging between 0.011 and 0.038 (PlayerLoad$^{TM\cdot}$m^{-1}(au)). Furthermore, the GK presented with a significantly higher PL per meter than the GS.

The conclusion could be made that the C position, which presented with a significantly higher total distance covered as well as a significantly higher PL than all the other playing positions, could be considered as the most active position on court. As previously mentioned the centre court positions are allowed in a bigger surface area as the GS and the GK therefore these positions are likely to cover a greater distance and present with a higher total PL as the other positions during match play. The main role of the centre court positions on attack is to create space and opportunity for the team to move the ball into the shooting circle where the GS and GA have an opportunity to attempt to score a goal. In doing so the centre court positions must move into space away from defending players in order to be in a position to receive the ball from a teammate. In the case of a turnover in the opposition's shooting circle, the ball must travel through the whole length of the court and must be handled at least once in every third of the court. Therefore, the centre court positions, especially the C, need to cover the length of the court either in an attacking or defending capacity. Furthermore, the GS and the GK are only allowed in one third of the court with the main role of scoring a goal in the case of the GS or defending the GS in the case of the GK. In order to create opportunities to receive the ball from teammates the GS must either execute short, high intensity sprints to move away from the defender or jump up high into the air to either receive the ball when thrown over the defending players or to try to catch the ball from a rebound. The GK on the other hand must defend the GS. Therefore the GK must attempt to move with the GS either in the frontal, sagittal or transverse plane. In the case of a rebound, the GK normally compete for possession of the ball therefore, these players are also required to execute numerous jumping activities during match play. As mentioned previously, PL is data captured by the Catapult Minimax X4 during match play as a measure of physical activity by measuring the accumulation of accelerations in all 3 planes of movement (frontal, sagittal and transverse (Chandler *et al.,* 2014)). Therefore, explaining the higher PL per meter of the GS and the GK positions. Although these two positions cover the least amount of meters, they are required to execute numerous high intensity jumping and sprinting activities.

To conclude, the need for position-specific conditioning programs is highlighted by the differences in physical demands of the different playing positions in netball. The C needs execute numerous short, multidirectional high-intensity sprints and needs to cover a larger playing area than the GS and the GK, suggesting a higher physical demand than the GS and GK positions.

CHAPTER 6

CONCLUSION AND FUTURE RESEARCH

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

6.1 Introduction

In order to optimize player performance it is critical to have an understanding of the physical demands of the specific sport to ensure sport specific exercise programs. Fox *et al.* (2013) for one highlighted the importance of sport specific training programmes for optimal athlete performance. As can be seen from Chapter 2, various researchers previously investigated the nature of netball and the physical demands placed on the players throughout match play (Otago, 1983); (Steele *et al.,* 1991); (Davidson *et al.,* 2008); (Fox *et al.,* 2013); (Cormack *et al.,* 2013); (Chandler *et al.,* 2014); (Yong *et al.,* 2015); (Thomas *et al.,* 2016). The majority of these studies did not investigate the difference between all of the playing positions in netball and mainly targeted senior netball players. Although some of these studies studied the difference in load of between lower standard and higher standard netball players, they grouped the playing positions together, therefore creating a gap in the literature to investigate the difference in physical demand of all the playing positions at u/19 level. As a result, the outcomes of those studies could be of too high standard for coaches and conditioning coaches at u/19 level. The current study focussed on u/19 female netball players and investigated the differences in physical profile, PL, distance covered, HR response, maximum velocity and distance covered in various movement classifications between all the different playing positions. A summary of the differences will follow in the next section.

6.2 Conclusion

The study revealed that the physical profile and physical demands of u/19 female netball players differ between the different playing positions. The results of the current study suggest that u/19 female netball players have a mean body weight of 64.3kg, a mean height of 170.1cm, a mean body fat percentage of 25.8% and a mean BMI of 22.2. The results from Table 4.3 suggest that the GS (75kg) and the GK (70kg) are the heaviest players on court, while the C (59.1kg), GD (59.7kg) and the WD (58.9kg) are found to be much lighter. Furthermore, the GS (177.8cm) and GK (176cm) are much taller than players in the C (166.3cm), WA (162.1cm) and WD (168.5cm) positions. The GK (29.1%) presented with the highest body fat percentage while the GD (22%) presented with the lowest percentage body fat percentage. It is therefore evident that certain positions are characterized be certain body types.

The current study suggested that u/19 female netball players perform at 87% of the mean maximum HR of 200 b/min with a mean HR of 174 b/min. This highlights the considerable physiological demands placed on these athletes during match play. The GA, C and the WA presented with the highest mean HR (182 b/min) while the GS, suggesting that these positions have a higher physiological demand than the other positions. On the other hand, the GS (160 b/min) recorded the lowest mean HR, the mean differences ranging from 8 to 18 b/min. The court restriction rule and the different responsibilities of the positions in netball may be responsible for the higher mean HR of the C and the WA. These two positions have a bigger surface area to cover on court and are responsible to take the ball up court to the GS and GA who is the only two players that can score a goal in netball. The GS on the other hand may only move in one third of the court, which may explain the lower HR response during netball match play.

The suggestion that the C has a higher physical demand is highlighted by the fact that the C travelled statistically significantly further than the other playing positions with a mean distance covered of 3276.3m during match play, mean difference ranging from 397m to 1515m. As mentioned the C (together with the WA and GA) presented with the highest mean HR. Furthermore, the results from the study suggested that the C also presented with the highest mean maximum velocity (5.22 $m.s^{-1}$), the highest mean PL (430.8 PlayerLoad ^{TM}$\cdot m^{-1}$ (au)) as well as the greatest total distance covered (3293.6m). The C also travelled statistically significantly further than all the other positions in velocity band 3 (Jogging) and velocity band 4 (Running) and covered the least amount of meters in velocity band 1 - Standing (20.6m) of all the positions. On the contrary, the GS and GK (together with the GD) presented with the lowest mean HR (160 b/min), recorded the lowest mean maximum velocity, covered the least amount of meters during match play, presented with the lowest total PL of all the playing positions. Furthermore, the GK and GS recorded the greatest distance in velocity band 1 (Standing) with 33.2m and 34.8m respectively. GK only covered 387.3m in velocity band 3 (Jogging) and only 68.3m in velocity band 4 (Running), which was the lowest of all positions. However, the GS and GK presented with a significantly higher PL per meter, suggesting that these positions have a higher load in the vertical axis as their main role in the team setup is to compete for possession of the ball in the air. These findings emphasize the difference in physical demand between the different positions as well as the different type of load placed on the different positions. Coaches and conditioning coaches must implement the findings of the study to develop sport-specific, and more importantly, position-specific conditioning programs.

6.3 Limitations, future research and recommendations

A limitation of the study was that only u/19 level netball players were investigated. Previous research found differences in PL across different standards of netball, suggesting a higher physical demand for elite netball players compared to u/19 level netball players. Therefore, comparing the results of the current study with studies based on elite senior netball could be problematic. Another limitation to the study was the different definitions for the different movement classifications. Previous studies on TMA of netball, such as Otago (1983), Steele *et al.* (1992), Davidson *et al.* (2008), Fox *et al.* (2013) and Yong *et al.* (2015) made use of subjective movement classifications whereas the current study used objective velocity bands to classify movements. Therefore, comparing the results of the current study with previous research would not be faultless. The velocity bands used in the current were inherited from Dwyer *et al.* (2012); however these bands were based on elite female hockey players and not u/19 level netball players. Therefore, the current study reported no activities in velocity band 5 (Sprint). The results (or lack of results in velocity band 5 – Sprinting) of the current study could be described to the fact that even though the participants exerted facets maximal efforts during the match, the peak velocity reached did not exceed $5.4 m.s^{-1}$ and therefore that effort could not be classified as a sprint.

Therefore, future research on TMA on netball is necessary. Future studies should attempt to define velocity bands specifically based on netball players. The differences in the physical demands of netball players between different standards of play and different age groups should be investigated. Some variables measured by the Catapult Minimax X4 not included in the current study include the following:

- How many times a player execute the different movement classifications during match play,
- Work to rest ratio
- Total number of accelerations,
- Total number of jumps,
- Player load in the three different axis (frontal, sagittal and transvers)

The question must be asked: “Would TMA knowledge make any difference in performance and the outcome of the match?” Therefore future research should investigate whether TMA would have any influence on the outcome of a match.

In order to optimize performance and to construct sport-specific conditioning programmes, players and coaches must understand and be able to cope with these sport- and position specific requirements (21); 1) Player/load management, 2) Periodization, 3) Recovery, 4) Session planning and 5) the Role of strength and conditioning coach and coaches. Our findings emphasize the difference in physical demand between the different playing positions in netball as well as the different type of load placed on the different positions. Strength and conditioning coaches can use the findings of this study to develop position-specific conditioning programs. For example, conditioning programmes for the GK and GS should focus on developing speed and power in the vertical axis in order for these players to beat opponents to the ball or to successfully compete for a rebound after an unsuccessful shot at goal. Conditioning programmes for midcourt players (C, WA, WD) should accommodate frequent accelerations, short sprints, quick reaction time and jumps. These players should have high levels of anaerobic performance to accommodate the short recovery periods between high-intensity activities. In order for players to perform at a high intensity throughout the duration of the match, netball players also need to improve their aerobic as well as anaerobic endurance using high-intensity training modalities. This main aim of this study was to determine the physical characteristics of and physiological demands on elite u/19 netball players in the various playing positions during competition. Further research is required that focuses on training recommendations for elite u/19 female netball players.

CHAPTER 7

Reflexion on the Research Process

Referencing within the chapter and the list of references at the end thereof has been done in accordance with the guidelines of the Free State University.

7.1 Introduction

Research in its own can be a very intimidating and frustrating process. However, knowing that you may write something that very few people (or no one) have done before, create a curiosity (for the topic) inside you that drive you do the research and to do it well. Research gives us the opportunity to have an in depth look at a certain question and the answer to that question provides us with the knowledge and skill to be better in your field of practise. Many professionals stagnate because of a lack of doing research and in that way equipping themselves to be better at what they do. Like Albert Einstein once said: *"The important thing is not to stop questioning."* That in short was the driving force behind this project. I wanted to know more about the physical demands of netball players and how I, as a Biokineticist and conditioning coach, can use the information from this project to further develop netball players and other athletes to excel in their sport.

7.2 Reflecting on the research process

As many other students I was unsure where to start and how to begin the process. So I asked myself one simple question: "How to do a research project?" As many other people would, I GOOGLED it and came across a simple 6 step plan:

Step 1: Find the right supervisor
Step 2: Don't be shy, ASK!
Step 3: Select the right topic
Step 4: Keep your plan realistic
Step 5: Prepare a project timeline
Step 6: Write, write, write…

Step one: Find the right supervisor

My first reaction was that this couldn't be too difficult. Or so I thought. I in fact started with the third step (select the topic). I had an idea of what I wanted to achieve, but that idea could only be formulated into a research question after I knew who my supervisor and co-supervisors would be. The first step was relatively easy. Choose someone to guide you during the research project that is an expert in the field. So the relationship between Prof F.F Coetzee and me started. It really was an easy choice if you consider that Prof Coetzee was part of a very successful Springbok rugby team between 2004 and 2007, he has won a rugby world cup with the Springboks in 2007 and was part of the conditioning team that accompanied the Springboks at the 2011 rugby world cup. His experience as condition coach and his interpersonal relationships made him the obvious choice to be my senior supervisor for this project. But that is not where it stopped. I was searching for someone that is an expert in TMA. Dr W.J Kraak who has just finished his Doctoral on TMA were approached and asked to be my co-supervisor. He is up to date with the latest technology and research in TMA and would eventually play a big role in the final product. Lastly, I was looking for an expert in Biostatistics. Prof R. Schall was the final addition to the team. His experience, expertise and knowledge of his field of practise must be mentioned. Collecting the data is one thing, but to present it in a highly professional manner require skills from the very best. All three supervisors played a huge part in the final product and their guidance helped me to deliver and to present it in such a good manner.

Step 2: Don't be shy, ASK!

"Mistakes might not give you answers. But they give you questions for a great answer." As I mentioned I did not know where to start the research process. The professional approached of all three my supervisors made it a lot easier to ask questions whenever something was unclear.

Step 3: Select the right topic

This could be an overwhelming process when you are unsure of the WHAT and WHY of your research project. As previously mentioned I luckily had an idea of what and why I wanted to do the research. Formulating the title and research question was another story. I again took to the internet and started looking for research projects on the physical demands of athletes and formulated the title and research question based on similar studies.

Step 4: Keep your plan realistic

Know what questions you want to be answered at the end of the project and stick to that. I experienced that while I was busy reading articles and collecting the data that there is so much more to be done, but that the current study will only focus on certain variables. The GPS device used in the study was the Catapult Minimax X4. The capability of that particular GPS system is astonishing. Therefore, only certain variables formed part of the current study.

Step 5: Prepare a project timeline

The objective of my research was to determine the physical demands of under 19 female netball players, measuring them on certain variables. As part of the inclusion criteria, the participants must play netball in the u/19A Bloemfontein netball league. Data were collected from the matches played during the above mentioned competition, therefore, the timeline for the study was created around the set dates of the u/19A Bloemfontein league. Dates were set to finish the research protocol in time so that ethical clearance was received before the start of the league.

Step 6: Write, write, write…

This is where it got difficult. It sometimes can be very difficult to communicate the correct message in English for an Afrikaans speaking man like myself. However, that formed part of the learning process. Doing research not only comprises of doing an intervention of some kind. It is also important do look at what other researchers previously investigated. The best advice I can give is to start writing from day one. At the beginning, writing the literature review was time consuming, frustrating and unpleasant to say the least. However, understanding what the literature had to say on my topic, made me more curious about what the outcomes of my study might be like. The literature review also helped me understand the shortcomings of the previous research. That created an opportunity do individualise the research project. The writing of the results and coming to a conclusion were more exciting. You finally have your own findings to compare to previous research.

7.3 Personal remarks

I have come to the conclusion that this thesis is only the first step in my journey as a researcher. Great lessons were learnt throughout the process. I have grown as an individual and in my field of practise. I have learnt to write, to save your work on a regular basis, not to use multiple computers and memory sticks, backup your work online and understand statistics.

Good professional friendships were formed during the research project. As mentioned above, I have the biggest respect for my supervisors, Prof Derik Coetzee, Prof Robert Schall and Dr Wilbur Kraak. Their knowledge, experience and guidance must not be

underestimated. Lastly, without our heavenly Farther this project would not have seen the light. I was blessed with patience, knowledge and ideas when you expect it the least.

I urge all to go out and further your knowledge through research. *Do not watch the clock, do what it does – KEEP MOVING.*

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APPENDIX A-1: Information document

Appendix A.1 : Information sheet (English)

INFORMATION DOCUMENT

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

Dear Ms

I, Michael Shaw, a Masters student at the Department Exercise and Sport Sciences, am doing research on the time motion analysis of elite female netball players during an elite netball competition. Research is the process to learn the answer to a specific question. In this study we want to learn more about the total distance covered, the total high-intensity distance covered, the percentage work rate/ ratio the number of jumps, accelerations and decelerations of the different positions. This information will help coaches and conditioning coaches to prescribe programs specific to each position.

Netball players affiliated with the Mangaung Metro u/19 Netball Team and/or netball players that play u/19A in the Bloemfontein league whom are willing to participate would be included in the research study.

Data collection will be done in two parts. This first part will be done one week before the Bloemfontein u/19 netball league starts. The participants' age, mass (kg), length (cm), playing position, team as well as anthropometric data will be collected during this part of data collection. The same data will be collected from the Mangaung Metro u/19 netball team one week before the start of the National u/19 Netball competition. The researcher will make an appointment with the team to collect the data. This part of data collection will commence at the participating schools. The researcher will make an appointment with every school to take all the anthropometry measurements. The researcher will be responsible for the measurements and an assistant will be present to capture the measurements on the data collection form. The researcher and his assistant will also be responsible to take all the apparatus that will be used during this part of data collection to the schools. Measurements will be taken in a private room at the schools to ensure confidentiality.

The Information document, an Informed consent form as well as an Child Assent (if a participant is a minor) form must be signed before the participant would be allowed to participate in the study.

Thereafter, the study will focus on a time motion analysis of elite netball players during competition. The participants will wear a MinimaxX4 Catapult tri-axial accelerometer during match play. The researcher will aim to collect data from at least 3 of your team's matches during the Bloemfontein u/19 Netball season and all the Mangaung u/19 Netball team matches will be analysed during the National u/19 Championship.

The following variables will be investigated during this study.

- Total distance covered during a netball match
- The percentage work rate/ ratio
- The total high-intensity distance covered
- Time spend during each activity (standing, walking, jogging, running, sprinting, shuffling)
- The number of Jumps
- Number of accelerations
- Number of decelerations
- % of time spent in each activity
- Heart rate response

Each playing position will be investigated individually and comparisons regarding the variables will be made between the different playing positions.

The accelerometer will be located at the upper back and contained within a vest worn underneath the netball dress and will not influence the players performance at all. The accelerometer is a devise which measures the acceleration, total distance covered and the total high-intensity distance covered. From that information we can calculate the work/rest ratio and differentiate the physiological differences between the playing positions. Other measurements that will be taken include weight, height and body composition. The measurement procedure is pain free and non-invasive and will have no effect on your sporting performance.

As lacks of sleep and kilojoule intake have an effect on performance during matches the participants are kindly requested to take the necessary precautions before the measurement (competitive netball match) take place.

Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which the participants are otherwise entitled; participation may be discontinued at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Participation would be absolutely free of any costs and no payments or remuneration will be made to participants. After completion of the study the results will be published.

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law. Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Health Sciences Research Ethics committee of the University of the Free State.

____________________________ __________________ Date:________

Parent / Guardian (If applicable) Participant

____

Michael Shaw

0825618880

Master's Degree Student

APPENDIX A-2: Informed consent

UFS·UV

Appendix A.2 : Written consent form (English)

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

INFORMED CONSENT

You are asked to participate in a research study conducted by Michael Shaw, from the Exercise and Sports Science Department, University of the Free State, the results of which will form part of the dissertation for his Master's Degree. You were selected as a possible participant in this study because you are an female netball player and part of the Mangaung Metro u/19 Netball Team or play netball for your school at U19 level in the Bloemfontein league.

1. PURPOSE OF THE STUDY

The primary aim of this study is to provide accurate, up-to date information on the physiological demands and work rate demands placed on female netball players. The researcher will aim to collect data from at least 3 of your team's matches during the Bloemfontein u/19 Netball season and all the Mangaung u/19 Netball team matches will be analysed during the National u/19 Championship.

2. PROCEDURES

Data collection will be done in two parts. This first part will be done one week before the Bloemfontein u/19 netball league starts. The participants' age, mass (kg), length (cm), playing position, team as well as anthropometric data will be collected during this part of data collection. The same data will be collected from the Mangaung Metro u/19 netball team one week before the start of the National u/19 Netball competition. The researcher will make an appointment with the team to collect the data. This part of data collection will commence at the participating schools. The researcher will make an appointment with every school to take all the anthropometry measurements. The researcher will be responsible for the measurements and an assistant will be present to capture the measurements on the data collection form. The researcher and his assistant will also be responsible to take all the apparatus that will be used during this part of data collection to the schools. Measurements will be taken in a private room at the schools to ensure confidentiality.The second part of the data collection process will involve analysis of tri-axial accelerometer data from netball players that compete at u/19 level. Each of the players will be equipped with a Catapult Minimax X4 tri-axial accelerometer during match play in the above mentioned tournaments during the 2017 season. The following variables will be measured during a full game of Netball: total distance covered, total high intensity distance covered, % of time spend during activity (standing, walking, jogging, running, sprinting, shuffling), time spend in minutes during each activity, work / rest ratio, number of accelerations, number of decelerations, number of jumps, total player load and heart rate response during a netball match. Each playing position will be measured individually and each variable will be analysed and comparisons will be made between each playing position.

3. POTENTIAL RISKS AND DISCOMFORTS

These tests will not cause any additional discomfort or injury risk.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

This research project will provide valuable information to conditioning coaches and coaches regarding the specific nature of the physical requirements placed on netball players during matches. The results will also provide conditioning coaches and players with valuable information that can assist with the development of physical programmes that are both individualised and specific.

5. PAYMENT FOR PARTICIPATION

Participation would be absolutely free of any costs and unfortunately there is no payment for your participation in this study, but a comprehensive report of the outcomes will be issued on request. After completion of the study the results will be published.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of allocating numbers to participants. Information will be kept with the investigator only and raw data held under lock and key. All processing of data will be governed by a PC password protector. Only the findings will be published with the strictest of confidentiality to the individual athletes.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Michael Shaw (+27 82 561 8880; email: shaw2michael@yahoo.com or Prof Derik Coetzee (051 401 2944- Department Exercise and Sports Sciences, University of the Free State).

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact :

The Chair: Health Sciences Research Ethics committee of the University of the Free State; Dr SM Le Grange For Attention: Mrs M Marais Block D, Room 104, Francois Retief Building Po Box 339 (G40) Nelson Mandela Drive Faculty of Health Sciences University of the Free State Bloemfontein 9300 Mrs M Marais Head: Administration Mrs J du Plessis Administration 051-4017795; 051-4017794 Fax number:051-4444359 Email ethicsfhs@ufs.ac.za Office hours 07h45 – 16h30.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me, _________________________, by Michael Shaw in *English* and I am in command of this language. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent to voluntarily participate in this study /I hereby consent that the subject/participant may participate in this study. I have been given a copy of this form.

____

Name of Parent / Guardian (if participant is under age)

____ _________

Signature of Subject/Participant or Parent/ Guardian Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to __________________ and his representative ____________________ was encouraged and given ample time to ask me any questions. This conversation was conducted in English and *no translator was used.*

________________________ ______________

Signature of Investigator **Date**

________________________ ________________

Researcher's signature **Date**

APPENDIX A-3: Child assent

UFS·UV

Appendix A.3 : CHILD ASSENT FORM

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

CHILD ASSENT FORM

You are being asked to take part in a research study being done by the University of the Free State. In this study, we are interested to know more about the demands of a netball game. We have asked permission from your parent or guardian whether it is OK for you to participate, but now we want to see if it is OK with you.

If you decide to take part in this study, your body composition measurements will be taken one week before the start of the league you participate in. These measurements will take place at your school. Thereafter, you will be given a Catapult GPS unit and a vest to wear during your netball matches. This will not have any influence on your performance. The researcher will aim to collect data from at least 3 of your team's matches during the Bloemfontein u/19 Netball season and all the Mangaung u/19 Netball team matches will be analysed during the National u/19 Championship.

This Catapult units measure your performance during the match. All the information we collect will be kept secret. We will not use your name so everything will remain private.

Participation would be absolutely free of any costs and no payments or remuneration will be made to participants. After completion of the study the results will be published.

By signing this you are showing that you understand what is going to be happening and have asked any questions you may have about the research. You can also ask questions later if you cannot think of them now.

Signing this form does not mean that you have to finish the study- you can pull out from the study at any time without explaining why.

__________________________ __________________

Child signature **Date**

_______________________________ _____________________

Parent/Guardian **Date**

Contact details of the researcher:

Michael Shaw

Shaw2michael@yahoo.com

082 561 8880

APPENDIX B-1: Permission letter – Head coach

Appendix B.1

Permission letter – Head coach

08 Buccaneer
Pellissier Drive
Pellissier
Bloemfontein
9301
09 January 2017

Dear
Head Coach of

RESEARCH PROJECT (Magister Artium):

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

M. Shaw (Masters Student) and The Department Exercise and Sport Sciences, University of the Free state hereby request permission to conduct research on u/19 Netball players from the Mangaung Metro u/19 Netball Team and the u/19A school netball teams participating in the Bloemfontein league. The research will be done in accordance with Prof. Derik Coetzee (Adjunct Professor & Head of Department: Department of Exercise and Sport Sciences).

Netball is evolving globally as a professional sport; as such it is vital that the players are optimally prepared for the physical demands of the sport. Each sport has its own specific physiological demands that coaches need to consider when preparing for competition. In this study we want to learn more about the total distance covered, the total high-intensity distance covered, the percentage work/ rest ratio, the time spend in each activity (standing, walking, jogging, running, sprinting, shuffling), the number of jumps, accelerations and decelerations and the heart rate response of the different positions in netball. This study will focus on a time motion analysis of female elite and u/19 netball players during competitions. Data collection will be done in two parts. This first part will be done one week before the Bloemfontein u/19 netball league starts. The participants' age, mass (kg), length (cm), playing position, team as well as anthropometric data will be collected during this part of data collection. The same data will be collected from the Mangaung Metro u/19 netball team one week before the start of the National u/19 Netball competition. The researcher will make an appointment with the team to collect the data. This part of data collection will commence at the participating schools. The researcher will make an appointment with every school to take all the anthropometry measurements. The researcher will be responsible for the measurements and an assistant will be present to capture the measurements on the data collection form. The researcher and his assistant will also be responsible to take all the apparatus that will be used during this part of data collection to the schools. Measurements will be taken in a private room at the schools to ensure confidentiality.The second part of the data collection process will involve analysis of tri-axial accelerometer data from netball players that compete at u/19 level. Each of the players will be equipped with a Catapult Minimax X4 tri-axial accelerometer during match play in the above mentioned tournaments during the 2017 season. Each playing position will be measured individually and each variable will be analysed and comparisons will be made between each playing position. The participants will wear a Minimax X4 Catapult tri-axial accelerometer during match play in the National u/19 Netball Championship and the u/19 Bloemfontein netball league. The accelerometers (worn by all the players during the match) will be housed in a custom made harness under the players netball dress that will prevent unwanted movement and hold the units in place in the middle of the upper back. Therefore limiting any potential hindrance on performance. The researcher will aim to analyze at least 3 matches of each team in the Bloemfontein u/19A Netball league and all the Mangaung u/19 Netball team matches will be analysed during the National u/19 Championship.

The goal of this study is:

- To determine the physical demands of elite netball players.
- To implement time motion analysis to ascertain the movement activities of elite netball players and to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain body composition measurements as well as tri-axial accelerometer data from the participating netball players on:

- Total distance covered during a netball match
- The percentage work rate/ ratio
- The total high-intensity distance covered
- The time spend in each activity (standing, walking, jogging, running, sprinting, shuffling)
- The number of Jumps
- Number of accelerations
- Number of decelerations
- % of time spent in each activity
- Time spend during each activity
- Heart rate response

Participation would be absolutely free of any costs and no payments or remuneration will be made to participants. After completion of the study the results will be published.

Your assistance in this matter will be greatly appreciated.

I, _____________________________, ID nr., _______________________________ hereby give permission to M. Shaw to collect and analyse accelerometer data from the netball players, who meet the inclusion criteria, and to publish the results of the study.

Date: ______________

____

Michael Shaw

Master’s Degree Student   Head Coach

APPENDIX B-2: Permission letter – Netball South Africa

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Appendix B.2

Permission letter – Netball South Africa

08 Buccaneer
Pellissier Drive
Pellissier
Bloemfontein
9301
09 January 2017

Dear Mrs C. Du Preez

Netball South Africa

RESEARCH PROJECT (Magister Artium):

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

M. Shaw (Masters Student) and The Department Exercise and Sport Sciences, University of the Free state hereby request permission to conduct research on u/19 Netball players from the Mangaung Metro u/19 Netball Team and the u/19A school netball teams participating in the Bloemfontein league. The research will be done in accordance with Prof. Derik Coetzee (Adjunct Professor & Head of Department: Department of Exercise and Sport Sciences).

Netball is evolving globally as a professional sport; as such it is vital that the players are optimally prepared for the physical demands of the sport. Each sport has its own specific physiological demands that coaches need to consider when preparing for competition. In this study we want to learn more about the total distance covered, the total high-intensity distance covered, the percentage work/ rest ratio, the time spend in each activity (standing, walking, jogging, running, sprinting, shuffling), the number of jumps, accelerations and decelerations and the heart rate response of the different positions in netball. This study will focus on a time motion analysis of female elite and u/19 netball players during competitions. Data collection will be done in two parts. This first part will be done one week before the Bloemfontein u/19 netball league starts. The participants' age, mass (kg), length (cm), playing position, team as well as anthropometric data will be collected during this part of data collection. The same data will be collected from the Mangaung Metro u/19 netball team one week before the start of the National u/19 Netball competition. The researcher will make an appointment with the team to collect the data. This part of data collection will commence at the participating schools. The researcher will make an appointment with every school to take all the anthropometry measurements. The researcher will be responsible for the measurements and an assistant will be present to capture the measurements on the data collection form. The researcher and his assistant will also be responsible to take all the apparatus that will be used during this part of data collection to the schools. Measurements will be taken in a private room at the schools to ensure confidentiality.The second part of the data collection process will involve analysis of tri-axial accelerometer data from netball players that compete at u/19 level. Each of the players will be equipped with a Catapult Minimax X4 tri-axial accelerometer during match play in the above mentioned tournaments during the 2017 season. Each playing position will be measured individually and each variable will be analysed and comparisons will be made between each playing position. The participants will wear a Minimax X4 Catapult tri-axial accelerometer during match play in the National u/19 Netball Championship and the u/19 Bloemfontein netball league. The accelerometers (worn by all the players during the match) will be housed in a custom made harness under the players netball dress that will prevent unwanted movement and hold the units in place in the middle of the upper back. Therefore limiting any potential hindrance on performance. The researcher will aim to analyze at least 3 matches of each team in the Bloemfontein u/19A Netball league and all the Mangaung u/19 Netball team matches will be analysed during the National u/19 Championship.

The goal of this study is:

- To determine the physical demands of elite netball players.
- To implement time motion analysis to ascertain the movement activities of elite netball players and to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain body composition measurements as well as tri-axial accelerometer data from the participating netball players on:

- Total distance covered during a netball match
- The percentage work rate/ ratio
- The total high-intensity distance covered
- The time spend in each activity (standing, walking, jogging, running, sprinting, shuffling)
- The number of Jumps
- Number of accelerations
- Number of decelerations
- % of time spent in each activity
- Time spend during each activity
- Heart rate response

Participation would be absolutely free of any costs and no payments or remuneration will be made to participants. After completion of the study the results will be published.

Your assistance in this matter will be greatly appreciated.

I, ______________________________, ID nr., ________________________________ hereby give permission to M. Shaw to collect and analyse accelerometer data from the netball players, who meet the inclusion criteria, and to publish the results of the study.

Date: _______________

____

Michael Shaw

Master's Degree Student

Mrs Chritene Du Preez

Netball South Africa

APPENDIX B-3: Permission letter – School Headmaster

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Appendix B.3

Permission letter – School Headmasters

08 Buccaneer
Pellissier Drive
Pellissier
Bloemfontein
9301
09 January 2017

Dear

HEADMASTER OF

RESEARCH PROJECT (Magister Artium):

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

M. Shaw (Masters Student) and The Department Exercise and Sport Sciences, University of the Free state hereby request permission to conduct research on u/19 Netball players from the Mangaung Metro u/19 Netball Team and the u/19A school netball teams participating in the Bloemfontein league. The research will be done in accordance with Prof. Derik Coetzee (Adjunct Professor & Head of Department: Department of Exercise and Sport Sciences).

Netball is evolving globally as a professional sport; as such it is vital that the players are optimally prepared for the physical demands of the sport. Each sport has its own specific physiological demands that coaches need to consider when preparing for competition. In this study we want to learn more about the total distance covered, the total high-intensity distance covered, the percentage work/ rest ratio, the time spend in each activity (standing, walking, jogging, running, sprinting, shuffling), the number of jumps, accelerations and decelerations and the heart rate response of the different positions in netball. This study will focus on a time motion analysis of female elite and u/19 netball players during competitions. Data collection will be done in two parts. This first part will be done one week before the Bloemfontein u/19 netball league starts. The participants' age, mass (kg), length (cm), playing position, team as well as anthropometric data will be collected during this part of data

collection. The same data will be collected from the Mangaung Metro u/19 netball team one week before the start of the National u/19 Netball competition. The researcher will make an appointment with the team to collect the data. This part of data collection will commence at the participating schools. The researcher will make an appointment with every school to take all the anthropometry measurements. The researcher will be responsible for the measurements and an assistant will be present to capture the measurements on the data collection form. The researcher and his assistant will also be responsible to take all the apparatus that will be used during this part of data collection to the schools. Measurements will be taken in a private room at the schools to ensure confidentiality.The second part of the data collection process will involve analysis of tri-axial accelerometer data from netball players that compete at u/19 level. Each of the players will be equipped with a Catapult Minimax X4 tri-axial accelerometer during match play in the above mentioned tournaments during the 2017 season. Each playing position will be measured individually and each variable will be analysed and comparisons will be made between each playing position. The participants will wear a Minimax X4 Catapult tri-axial accelerometer during match play in the National u/19 Netball Championship and the u/19 Bloemfontein netball league. The accelerometers (worn by all the players during the match) will be housed in a custom made harness under the players netball dress that will prevent unwanted movement and hold the units in place in the middle of the upper back. Therefore limiting any potential hindrance on performance. The researcher will aim to analyze at least 3 matches of each team in the Bloemfontein u/19A Netball league and all the Mangaung u/19 Netball team matches will be analysed during the National u/19 Championship.

The goal of this study is:

- To determine the physical demands of elite netball players.
- To implement time motion analysis to ascertain the movement activities of elite netball players and to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain body composition measurements as well as tri-axial accelerometer data from the participating netball players on:

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- The percentage work rate/ ratio
- The total high-intensity distance covered
- The time spend in each activity (standing, walking, jogging, running, sprinting, shuffling)
- The number of Jumps
- Number of accelerations
- Number of decelerations
- % of time spent in each activity
- Time spend during each activity
- Heart rate response

Participation would be absolutely free of any costs and no payments or remuneration will be made to participants. After completion of the study the results will be published.

Your assistance in this matter will be greatly appreciated.

I, _____________________________, ID nr., ______________________________ hereby give permission to M. Shaw to collect and analyse accelerometer data from the netball players, who meet the inclusion criteria, and to publish the results of the study.

Date: ______________

____

Michael Shaw

Master's Degree Student   Headmaster

APPENDIX B-4: Permission letter – Free State Department of Education

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Appendix B.4

Permission letter – Free State Department of Education

08 Buccaneer
Pellissier Drive
Pellissier
Bloemfontein
9301
09 January 2017

Dear

FREE STATE DEPARTMENT OF EDUCATION

RESEARCH PROJECT (Magister Artium):

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

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Date: ______________

____

Michael Shaw

Master's Degree Student   Free State Department of Education

APPENDIX B-5: Permission letter – Head of Kovsie Sport

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Appendix B.5

Permission letter – Head of Kovsie Sport

08 Buccaneer

Pellissier Drive

Pellissier

Bloemfontein

9301

09 January 2017

Dear Mr D.B Prinsloo

Netball South Africa

RESEARCH PROJECT (Magister Artium):

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

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Date: _______________

____

Michael Shaw   Mr D.B. Prinsloo

Master's Degree Student   Kovsie Sport

APPENDIX B-6: Permission letter – Head Free State Netball

Appendix B.6

Permission letter – Free State Netball

08 Buccaneer
Pellissier Drive
Pellissier
Bloemfontein
9301
09 January 2017

Dear Mrs B. De Kock

Free State Netball

RESEARCH PROJECT (Magister Artium):

Study title: **TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY**

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Date: ___________

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Michael Shaw	Mrs B. De Kock
Master's Degree Student	Netball South Africa

APPENDIX C: Data collection form

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Appendix C - DATA COLLECTION FORM

SUBJECT NUMBER:_____________________ **AGE:** ________

GENDER: _____________________

TEAM REPRESENTING: _____________________

PLAYING POSITION: _____________________

CURRENT INJURIES: ____

BODY COMPOSITION MEASURES:

1. **Body Weight:** ___________
2. **Length:** ___________

ANTHROPOMETRIC MEASURES:

SKINFOLD	*MEASUREMENT*
Tricep	
Supscapular	
Suprailiac	
Abdominal	
Anterior Mid Thigh	
Medial Calf	
SUM OF THE 6 SKINFOLDS	
FAT PERCENTAGE	

APPENDIX D: Ethics approval letter

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

20 March 2017

M SHAW
DEPT OF EXERCISE AND SPORT SCIENCES
FACULTY OF HEALTH SCIENCES
UFS

Dear M Shaw

HSREC 07/2017 (UFS-HSD2017/0048)
PROJECT TITLE: TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY

1. You are hereby kindly informed that the Health Sciences Research Ethics Committee (HSREC) approved this protocol after all conditions were met. This decision will be ratified at the next meeting to be held on 28 March 2017.
2. The Committee must be informed of any serious adverse event and/or termination of the study.
3. Any amendment, extension or other modifications to the protocol must be submitted to the HSREC for approval.
4. A progress report should be submitted within one year of approval and annually for long term studies.
5. A final report should be submitted at the completion of the study.
6. Kindly use the **HSREC NR** as reference in correspondence to the HSREC Secretariat.
7. The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

Yours faithfully

DR SM LE GRANGE
CHAIR: HEALTH SCIENCES RESEARCH ETHICS COMMITTEE
cc: FF Coetzee

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | F: +27 (0)51 444 4359 | E: ethicsfhs@ufs.ac.za
Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa
www.ufs.ac.za

APPENDIX E: Evaluation committee report

1

BYLAE 7

SCHOOL FOR ALLIED HEALTH PROFESSIONS
SKOOL VIR AANVULLENDE GESONDHEIDSBEROEPE

VERSLAG EVALUASIEKOMITEE
REPORT EVALUATION COMMITTEE - RESEARCH

NB. Evaluation committees should be appointed & approved by the Research Committee of the SAHP* six(6) *weeks before the set date. All members should receive the protocol at least ten (10) working days before the set date.

DISSERTATION/VERHANDELING: Ph.D. ......   Master/Magister: Full .√ mini......

CANDIDATE/KANDIDAAT : Michael Shaw.

DATUM/DATE:..12 Desember 2016.

TITLE/TITEL: Quantifying the physiological positional demands of elite under 19 female netball players

MEMBERS OF THE COMMITTEE/
LEDE VAN DIE KOMITEE

Chairman/Voorsitter:	Dr C Brandt
Lid van die Dagbestuur: **Member of Executive Committee:** .	....
Expert/Kundige:	Mnr R Schoeman.
Expert/Kundige:	Mnr P Botes.
Expert/Kundige:	....
Biostatistician/Biostatistiek:	Prof R Schall
Studyleader/promotor/Studieleier/ promotor:	Prof F Coetzee
Co Study Leader/promotor **Mede-Studieleier/mede promotor:** .	....
	....

PROCEDURE/PROSEDURE

1. **Word of Welcome/Verwelkoming**
   Al members and the candidate are welcomed by the chairperson.
2. **Agreement on handling of session and process in SAHP**
   Ooreenkoms oor die hantering van die sessie en proses in SAGB
   - The chairperson explains the procedure of discussing the protocol page/section by section.
   - Editorial corrections as indicated by the members of the committee will be given to the supervisor to be corrected under their supervision.
   - The title will be discussed at the end of the session.***(No title registration and appointment of examiners may take place before ethical approval has been granted).***
   - Any member of the evaluation committee may request to review the protocol again after the recommended corrections have been done. After the re assessment of the corrected

APPENDIX F: Letter from Statistical consultation unit

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
NATURAL AND AGRICULTURAL SCIENCES
NATUUR- EN LANDBOUWETENSKAPPE

13 January 2017

Ethics Committee
Faculty of Health Sciences
UFS

Project title: TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY

Researcher: Mr Michael Shaw

Supervisor: Prof FF Coetzee

I herewith confirm that I have reviewed the protocol for this study. I have discussed the protocol with the researcher and have provided input into the study. After data collection I will assist the investigator with data analysis and interpretation.

Sincerely

Robert Schall
Professor: Statistical Consultation Unit

Department Mathematical Statistics and Actuarial Science
T: +27(0)51 401 2295 | F: +27(0)51 401 3019
205 Nelson Mandela Drive/Rylaan | Park West/Parkwes | Bloemfontein 9301 | South Africa/Suid-Afrika
P.O. Box/Posbus 339 | Bloemfontein 9300 | South Africa/Suid-Afrika | www.ufs.ac.za

BYLAAG A-:1 Inligtingstuk

UFS·UV

BYLAAG A.1 : Inligtingsblad (Afrikaans)

INLIGTINGSBLAD

Studie titel: **TYDSBEWEGINGSANALISE VAN ELITE ONDER 19 VROULIKE NETBALSPELERS MET DIE GEBRUIK VAN GPS TEGNOLOGIE**

Geagte Me

Ek, Michael Shaw, ‘n Magister student aan die Departement Oefen en Sportwetenskappe, doen navorsing oor die tydsbewegingsanalise in elite onder 19 netbalspelers gedurende netball wedstryde. Navorsing is die proses om antwoorde te kry op ‘n spesifieke vraag. Na afloop van hierdie studie wil ons meer weet oor die totale afstand afgelê, die totale afstand afgelê teen ‘n hoë intensiteit, die werk tot rus verhouding van spelers en die hoeveelheid spronge en versnellings (positiewe en negatiewe versnellings) wat netbalspelers in verskillende posisies tydens netball wedstryde aflê. Hierdie inligting kan van groot waarde wees vir afrigters sowel as kondisioneringsafrigters waneer oefenprogramme vir spesifieke posisies voorgeskryf word.

Netbalspelers wat in gesluit is in die Mangaung o/19 netbalspan asook spelers wat in die Bloemfontein o/19A liga sal deelneem, sal deel vorm van die studie mits hulle gewillig is om aan die studied deel te neem en al die nodige dokumentasie volooi het.

Een week voor die aanvang van die netbal liga sal die antropometriese metings geneem word. Dit sal op afspraak by elk van die deelnemende skole plaasvind. Die navorser sal die metings neem terwyl sy assistant die data inlees op die datavorm. Die navorser en sy assistant sal verder ook verantwoordelik wees om al die toerusting wat gebruik gaan word in die studie saam te neem na die skole waar die toetsings sal plaasvind. Alle metings sal in ‘n private lokaal by elkeen van die skole geneem word om vertroulikheid te verseker.

Die Inligtingsblad, ‘n Ingeligte toestemmingsbrief sowel as ‘n kind instemmingsbrief (indien die deelnemer minderjarig is) moet voltooi word voordat die persoon mag deelvorm van die studie.

Die betrokke studie sal fokus op die tydsbewegingsanalise van elite netbalspelers gedurende wedstryde. Die deelnemers aan die studie sal gevra word om ‘n monitor (naamlik die MinimaxX4 Catapult sisteem) gedurende 3 van die betrokke span se wedstryde tydens die Bloemfontein o/19 liga te dra. Al die wedstryde van die Mangaung o/19 netbalspan gedurende die Nasionale o/19 Netbal kompetisie sal ook geanaliseer word.

Die volgende veranderlikes sal gedurende die studie gemeet word:

- Totale afstand afgelê gedurende ‘n wedstryd

- Die persetasie werk tot rus verhouding
- Die totale afstand afgelë teen 'n hoë intensiteit
- Die duur van elke aktiwiteit (staan, loop, draf, hardloop, voluit hardloop en sywaartse bewegings)
- Die hoeveelheid spronge
- Die hoeveelheid positiewe versnellings
- Die hoeveelheid negatiewe versnellings
- % van totale tyd afgelë tydens elke aktiwiteit
- Harttempo respons

Elke speelposisie sal individueel ondersoek word en vergelykings met betrekking tot die veranderlikes sal getref word tussen die verskillende speelposisies. Die spelers sal n harnas onder die netbalrokkies dra. Die harnas huisves die Catapult monitor op die bo-rug tussen die die twee bladbene en sal geen invloed op die spelers se vertoning tydens wedstryde nie hê. Soos reeds genoem monitor die Catapult sisteem die totale afstand sowel as die totale afstand teen 'n hoë intensiteit wat 'n speller tydens die wedstryd afgelê het. Van daardie inligting kan ons die werk tot rus verhouding bereken en onderskeid tref tussen die fisiologiese verskille tussen die posisies. Liggaamsgewig, liggaamslente en liggaamsamestelling sal ook gemeet word. Die meet prosedure sal pynvry en nie-indringend wees en sal geen effek op sport prestasie hê nie.

'n Verlaagde kilojoule inname en 'n tekort aan slaap kan 'n effek op prestasie hê. Daarom word deelnemers aan die studie gevra om die nodige voorsorg maatreels te tref voordat die toetsing (netball wydsryde wat gemonitor word) sal plaasvind.

Deelname aan die studie is vrywillig, en weiering om deel te neem aan die studie sal geen straf of verlies van voordele waarop die deelnemers anders geregtig is inhou nie; deelname kan enige tyd gestaak word sonder enige boetes of verlies van voordele waarop die deelnemers geregtig is.

Deelname sal gratis en vry van enige koste wees en geen betalings of vergoeding sal gemaak word aan deelnemers nie. Na voltooiing van die studie sal die resultate gepubliseer word. Pogings sal aangewend word om persoonlike inligting vertroulik te hou. Absolute vertroulikheid kan nie gewaarborg word nie. Persoonlike inligting kan openbaar gemaak word as dit deur die wet vereis word. Organisasies wat jou navorsing rekords mag kopieer en / of inspekteer vir gehalteversekering en data-analise sluit groepe soos die Gesondheidswetenskappe Navorsingsetiekkomitee van die Universiteit van die Vrystaat in.

____________________________ ___________________ Datum: ______________

Ouer /Voog (Indien toepaslik) Deelnemer

____

Michael Shaw

Magister Student

Kontak besonderhede van die navorser

082 561 8880

shaw2michael@yahoo.com

BYLAAG A-2: Ingeligte toestemming

UFS·UV

BYLAAG A.2: Skriftelike toestemming vorm (Afrikaans)
Studie titel: **TYDSBEWEGINGSANALISE VAN ELITE ONDER 19 VROULIKE NETBALSPELERS MET DIE GEBRUIK VAN GPS TEGNOLOGIE**

INGELIGTE TOESTEMMING

Jy word gevra aan 'n navorsingstudie wat deur Michael Shaw, van die Oefening en Sportwetenskap Departement, Universiteit van die Vrystaat, deel te neem. Die resultate sal deel vorm van die verhandeling vir sy meestersgraad. Jy is gekies as 'n moontlike deelnemer aan die studie omdat jy 'n vroulike netbalspeler is en 'n deel is van die Mangaung Metro O/19 netbalspan en/of netball speel vir jou skool op o.19-vlak in die Bloemfontein-liga.

1. DOEL VAN DIE STUDIE

Die primêre doel van hierdie studie is om opgedateerde en akkurate inligting oor die fisiologiese behoeftes en werkverrigtings eise van vroulike netbalspelers te bepaal. Die navorser sal poog om data in te samel van ten minste 3 wedstryde wat jou span tydens die Bloemfontein O / 19 Netbal seisoen sal speel. Daarby sal al die wedstryde wat die Mangaung O/19 Netbal span speel tydens die Nasionale O/19 Toernooi ontleed word.

2. PROSEDURES

Data-insamelingsproses sal in twee dele gedoen word. Die eerste deel sal plaasvind een week voordat die Bloemfontein O / 19 netbal liga begin en sal by die verskillende skole plaasvind. Die navorser en sy assistent sal verantwoodelik wees vir die meting en sal ook al die nodige apparate verskaf. Die deelnemers se ouderdom, massa (kg), lengte (cm), speel posisie, span wat verteenwoordig word asook antropometriese data sal geneem word gedurende hierdie deel van data-insameling. Dieselfde data sal ingesamel word die Mangaung Metro O / 19 netbalspan een week voor die aanvang van die Nasionale O / 19 Netbalkompetisie. Die navorser sal die span op afspraak by ‘n oefensessie besoek om die data in te samel. Metings sal in ‘n private lokaal by die skole plaasvind om vertroulikheid te verseker.

Die tweede deel van die data-insamelings proses sluit die analise van tri-aksiale versnellings data van netbalspelers wat meeding op O/19 vlak in. Elke speler sal toegerus word met 'n Catapult Minimax X4 tri-aksiale versnellings monitor gedurende wedstryde tydens die bogenoemde toernooie van die 2017 seisoen. Tydens ‘n volle netbal wedstryd sal die volgende veranderlikes gemeet word: totale afstand afgelê, totale afstand afgelê teen ‘n hoë intensiteit, % van die tyd bestee gedurende aktiwiteite (staan, stap, draf, hardloop, voluit hardloop, sywaartse skuifbewegings), tyd in minute gespandeer aan elke aktiwiteit, werk / rus verhouding, aantal positiewe versnellings, aantal negatiewe versnellings, aantal spronge, totale lading op spelers en hartklop respons tydens 'n netbal wedstryd. . Elke posisie sal afsonderlik ondesoek word sodat onderskeid getref kan word tussen die fisiologiese verskille tussen die posisies.

3. POTENSIëLE RISIKO'S EN ONGEMAK

Die toetsing sal geen ongemak of risiko vir besering veroorsaak nie.

4. POTENSIëLE VOORDELE VIR DEELNEMERS EN/OF DIE POPULASIE

Hierdie navorsingsprojek sal waardevolle inligting aan kondisioneringsafrigters en afrigters met betrekking tot die spesifieke aard van die fisiese vereistes wat geplaas word op netbalspelers tydens wedstryde verskaf. Die resultate sal kondisioneringsafrigters en spelers met waardevolle inligting toerus wat kan help met die ontwikkeling van fisiese programme wat geindividualiseer en spesifiek is.

5. VERGOEDING VIR DEELNAME

Deelname sal gratis wees en ongelukkig is daar geen vergoeding vir jou deelname aan hierdie studie nie, maar 'n omvattende verslag van die uitkomste sal op versoek uitgereik word. Na voltooiing van die studie is die resultate sal gepubliseer word.

6. VERTROULIKHEID

Enige inligting wat verkry word in verband met hierdie studie en wat geïdentifiseer kan word met jou sal vertroulik bly en sal slegs bekend gemaak word met jou toestemming of as dit deur die wet vereis word. Vertroulikheid sal gehandhaaf word deur middel van die toekenning van nommers aan deelnemers. Inligting sal slegs deur die ondersoeker gestoor word, en rou data sal gestoor word agter slot en grendel. Alle verwerkte data sal beskerm word deur 'n rekenaar wagwoord beskermer. Slegs die bevindings sal gepubliseer word met die strengste vertroulikheid van die individuele atlete.

7. DEELNAME EN ONTTREKKING

U kan kies om deel te wees van hierdie studie of nie. As jy besluit om deel te wees kan u enige tyd onttrek sonder enige gevolge van enige aard. U mag ook weier om enige vrae te beantwoord en nogsteeds deel vorm van die studie.

8. IDENTIFIKASIE VAN DIE NAVORSERS

Indien u enige vrae of kommentaar oor die navorsing het, voel asseblief vry om ons te kontak. Michael Shaw (+27 82 561 8880, e-pos: shaw2michael@yahoo.com of Prof Derik Coetzee (051 401 2944- Departement Oefening en Sportwetenskappe, Universiteit van die Vrystaat).

9. PROEFPERSONE SE REGTE

Jy mag enigetyd jou ingeligte toesetemming terugtrek en onttrek van die studie sonder enige boetes of straf. Jy is nie kwyt geskel van enige wetlike eise of regte as gevolg van jou deelname aan hierdie navorsingstudie nie. Indien jy vrae het oor u regte as 'n onderwerp, kontak:

Die Voorsitter: Gesondheidswetenskappe Navorsingsetiekkomitee van die Universiteit van die Vrystaat; Dr SM Le Grange Vir aandag: mev M Marais Blok D, Kamer 104, Francois Retief-gebou Posbus 339 (G40) Nelson Mandelarylaan Fakulteit Gesondheidswetenskappe Universiteit van die Vrystaat Bloemfontein 9300 Mev M Marais Hoof: Administrasie Mev J du Plessis Administrasie 051-4017795; 051-4017794 Faks nommer: 051-4444359 E-pos ethicsfhs@ufs.ac.za Kantoorure 07h45 - 16h30.

HANDTEKENING VAN DIE DEELNEMER OF DIE DEELNEMER SE REGSVERTEENWOORDIGER

Die bogenoemde inligting is aan my, _________________________ verduidelik, deur Michael Shaw in Afrikaans en ek verstaan die taal. Ek is die geleentheid gegee om vrae te vra en my vrae is beantwoord na my sin.

Hiermee gee ek my toestemming om vrywillig deel te neem aan hierdie studie / Ek gee hiermee toestemming dat die deelnemer mag deelneem aan hierdie studie. Ek beskik oor 'n afskrif van hierdie vor

____

Naam van Ouer / Voog (indien deelnemer minderjarig)

____ _________

Handtekening van deelnemer se ouer / voog **Datum**

HANDTEKENING VAN NAVORSER

Ek verklaar hiermee dat ek die inhoud van die dokument verduidelik het aan__________________ en sy verteenwoordiger ____________________, Hulle was aangemoedig en genoeg tyd gegun om enige vrae aan my te vra. Hierdie gesprek is in Afrikaans en geen vertaler is gebruik nie.

______________________ _____________

Handtekening van ondersoeker **Datum**

________________________ ________________

Navorser se handtekening **Datum**

BYLAAG A-3: Kind instemmingsvorm

UFS·UV

BYLAAG A.3: KIND INSTEMMINGSVORM (Afrikaans)
Studie titel: **TYDSBEWEGINGSANALISE VAN ELITE ONDER 19 VROULIKE NETBALSPELERS MET DIE GEBRUIK VAN GPS TEGNOLOGIE**

KIND INSTEMMING VORM

Jy word gevra om deel te neem aan 'n navorsingstudie wat gedoen deur die Universiteit van die Vrystaat. In hierdie studie, ons is geïnteresseerd om meer oor die eise van 'n netbal speler te leer. Ons het toestemming gevra van jou ouer of voog of dit OK is vir jou om deel te neem, maar nou wil ons weet of dit OK is met jou.

Indien jy besluit om deel te neem aan hierdie studie, sal jou liggaamsamestellings gemeet en bepaal word. Dit sal 1 week voor die begin van jou liga plaasvind. Verder sal jy ook ‘n Catapult GPS-eenheid gegee word om te dra onder jou netbalrokkie tydens netbal wedstryde. Dit sal nie 'n invloed op jou prestasie hê nie. Die navorser sal poog om data in te samel van ten minste 3 van jou span se wedstryde tydens die Bloemfontein O/19 Netbal seisoen. Verder sal al die Mangaung O/19 Netbal span se wedstryde tydens die Nasionale O/19 Toernooi ontleed word.

Dit Catapult eenhede meet jou prestasie tydens die wedstryd. Al die inligting wat ons insamel sal in geheim gehou word. Ons sal nie jou naam gebruik nie sodat alles private sal bly. Deelname sal gratis wees en geen betalings of vergoeding sal aan deelnemers gemaak word nie. Na afloop van die studie sal die resultate gepubliseer word.

Deur hierdie dokument te teken toon jy dat jy verstaan waaroor die studie gaan en dat die navorser al jou vrae oor die studie beantwoord het. Jy kan ook vrae op ‘n latere geleentheid vra indien jy nie nou aan al jou vrae kan dink nie.

Deur hierdie vorm te teken, beteken nie dat jy die studie moet voltooi nie - jy kan enige tyd onttrek uit die studie sonder om te verduidelik waarom.

________________________ ________________
Handtekening van deelnemer Datum

________________________ ________________
Ouer / Voog Datum

Michael Shaw

Kontak besonderhede van die navorser

082 561 8880

shaw2michael@yahoo.com

BYLAAG B-1: Toestemmingsbrief - Afrigter

UFS·UV

BYLAAG B.1

TOESTEMMINGSBRIEF – HOOF AFRIGTER

08 Buccaneer
Pellissier rylaan
Pellissier
Bloemfontein
9301
09 January 2017

Geagte

Hoof afrigter van

NAVORSINGSPROJEK (Magister Artium):

Studie titel: Tydsbewegingsanalise van die elite onder 19 Vroue netbalspelers met behulp van GPS tegnologie

M. Shaw (Magister Student) en die Departement Oefen- en Sportwetenskappe, Universiteit van die Vrystaat versoek hiermee toestemming om navorsing te doen oor die eise van die Mangaung Metro O/19 netbalspan asook skoolspanne wat deelneem aan die o/19A Bloemfontein-liga. Die navorsing sal gedoen word in samewerking met prof Derik Coetzee (Adjunct Professor & Departementshoof: Departement Oefen- en Sportwetenskappe).

Netbal word wêreldwyd gesien as 'n professionele sport; dus is dit noodsaaklik dat die spelers optimaal voorberei vir die fisiese vereistes van die sport. Elke sport het sy eie spesifieke fisiologiese vereistes wat afrigters in ag moet neem in die voorbereiding vir kompetisie of liga. Na afloop van hierdie studie wil ons meer weet van die totale afstand afgelê tydens wedstryde, die totale afstand afgelê teen 'n hoë-intensiteit, die persentasie werk tot rus verhouding, die duur van elke aktiwiteit (staan, stap, draf, hardloop, voluit hardloop, sywaartse bewegings), die aantal spronge, positiewe en negatiewe versnellings en die hartklop respons van die verskillende posisies in netbal. Hierdie studie sal fokus op 'n tydsbewegingsanalise van vroulike elite en O / 19-netbalspelers tydens kompetisies.

Data-insamelingsproses sal in twee dele gedoen word. Die eerste deel sal plaasvind een week voordat die Bloemfontein O / 19 netbal liga begin en sal by die verskillende skole plaasvind. Die navorser en sy assistent sal verantwoodelik wees vir die meting en sal ook al die nodige apparate verskaf. Die deelnemers se ouderdom, massa (kg), lengte (cm), speel posisie, span wat verteenwoordig word asook antropometriese data sal geneem word gedurende hierdie deel van data-insameling. Dieselfde data sa ingesamel word die Mangaung Metro O / 19 netbalspan een week voor die aanvang van die Nasionale O / 19 Netbalkompetisie. Die navorser sal die span op afspraak by 'n oefensessie besoek om die data in te samel. Metings sal in 'n private lokaal by die skole plaasvind om vertroulikheid te verseker.

Die tweede deel van die data-insamelings proses sluit in die analise van tri-aksiale versnellings data van netbalspelers wat meeding op O/19 vlak. Elke speler sal toegerus word met 'n Catapult Minimax X4 tri-aksiale versnellings monitor gedurende wedstryde in die bogenoemde toernooie van die 2017 seisoen. Tydens 'n volle netbal wedstryd sal die volgende veranderlikes gemeet word: totale afstand afgelê, totale afstand afgelê teen 'n hoë intensiteit, % van die tyd bestee gedurende aktiwiteite (staan, stap, draf, hardloop, voluit hardloop, sywaartse skuifbewegings), tyd in minute gespandeer aan elke aktiwiteit, werk / rus verhouding, aantal positiewe versnellings, aantal negatiewe versnellings, aantal spronge, totale lading op spelers en hartklop respons tydens 'n netbal wedstryd. . Elke posisie sal afsonderlik gemeet word sodat onderskeid getref kan word tussen die fisiologiese verskille tussen die posisies.

Die doel van hierdie studie is:
• Om die fisiese vereistes van die elite netbalspelers te bepaal.
• Om tydsbewegingsanalise te implementeer om die bewegingsaktiwiteite van elite netbalspelers te bepaal en om die frekwensie en duur van elke betrokke komponent te bepaal.

Om op te som, om voort te gaan met die navorsing, word toestemming versoek om drie-aksiale versnellings data van die deelnemende netbalspelers in te samel. Die volgende veranderlikes sal gedurende die studie gemeet word:

- Totale afstand afgelê gedurende 'n wedstryd
- Die persetasie werk tot rus verhouding
- Die totale afstand afgelë teen 'n hoë intensiteit
- Die duur van elke aktiwiteit (staan, loop, draf, hardloop, voluit hardloop en sywaartse bewegings)
- Die hoeveelheid spronge
- Die hoeveelheid positiewe versnellings
- Die hoeveelheid negatiewe versnellings
- % van totale tyd afgelë tydens elke aktiwiteit
- Harttempo respons

Deelname sal gratis en vry van enige koste wees en geen betalings of vergoeding sal gemaak word aan deelnemers nie. Na voltooiing van die studie sal die resultate gepubliseer word. U samewerking in hierdie verband sal waardeer word.

Ek, ______________________________, ID nr., ________________________________ verleen hiermee toestemming aan M. Shaw om tyds bewegings analise data in te samel en te analiseer van die netbalspelers wat aan die kriteria voldoen insluiting en om die resultate van die studie te publiseer.

Datum: _______________

____________________________ ___________________

Michael Shaw Magisterstudent Afrigter

BYLAAG B-2: Toestemmingsbrief - Skoolhoof

BYLAAG B.2

TOESTEMMINGSBRIEF – SKOOLHOOF

08 Buccaneer
Pellissier rylaan
Pellissier
Bloemfontein
9301
09 January 2017

Geagte

Skoolhoof van

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- Harttempo respons

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Ek, ____________________________, ID nr., ______________________________ verleen hiermee toestemming aan M. Shaw om tyds bewegings analise data in te samel en te analiseer van die netbalspelers wat aan die kriteria voldoen insluiting en om die resultate van die studie te publiseer.

Datum: ______________

__________________________ __________________

Michael Shaw Magisterstudent Skoolhoof

APPENDIX G: Turn it in report

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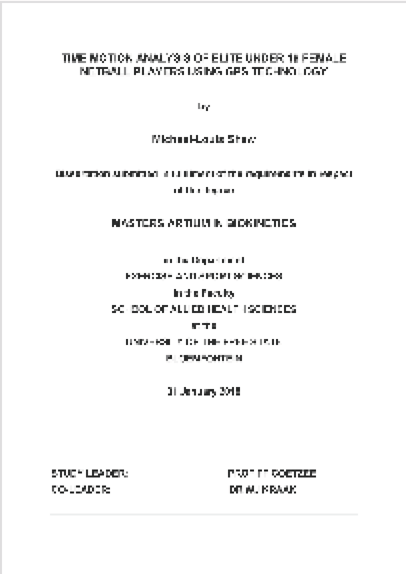
TIME MOTION ANALYSIS OF ELITE UNDER 19 FEMALE NETBALL PLAYERS USING GPS TECHNOLOGY

by

MASTERS ARTIUM IN BIOKINETICS

STUDY LEADER:

CO-LEADER:

DR W. KRAAK

M Shaw 16 January 2018

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