TIME MOTION ANALYSIS OF VARSITY CUP SOCCER

by

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DECLARATION

I, **Sam Masingi,** hereby declare:

- That the master's research dissertation that I herewith submit at the University of the Free State for the master's degree qualification Human Movement Science is my independent work and that I have not previously submitted it for a qualification at another institution of higher education.

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- I have acknowledged all main sources of help.

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SUMMARY

Introduction: *Soccer is an intermittent sport characterised by periods of moderate-intensity running and short high-intensity bursts. Understanding the physical and physiological demands of the sport is essential for constructing sport-specific and position-specific conditioning programmes.*

Objectives: *The purpose of this study was to quantify the physical and physiological demands of different positions in second division soccer. The main focuses calculated were the total distance covered, distance covered in high-intensity, distance covered in different velocity categories, and player load of the different positions in second division soccer and to compare results to higher level leagues.*

Methods: *GPS data on a total of twenty-four (24) players were collected and a total of thirteen soccer matches were analysed for the study. Therefore, a total of hundred and forty-nine (149) GPS data sets (player games) were analysed. Minimax X4 Catapult GPS units, as well as a Polar HR monitors and chest straps, were used to determine the physical and physiological demands of soccer players. The following variables were recorded: Distances covered, player load, the velocity bands 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 ($p<0.05$) associated with the null-hypothesis of zero mean difference between the pair of playing positions in question.

Results: *Soccer players in the current study performed at 75% of the maximum HR. The CM had the highest mean HR (161.5 b/min), while the GK had the lowest mean HR (143.3 b/min). The W had the highest mean maximum HR (213m), while the CA had the lowest maximum HR (207.9m).Outfield soccer players in the current study cover between 8241.5m and 10024.9m mean total distance, while the GK covers 4,7km mean total distance. The W covered the highest total distance (10024.9m), closely followed by the CM (9734.9m) and CA (9911.5m). The GK, on the other hand, covered the lowest total distance (4692.4m). The GK covered the highest walking distance (3361.6m) and lowest distance in every other movement* *classification. The CM covered the highest jogging distance (5009.3m), while the CA covered the highest running distance (936.5m). The W covered the highest sprinting distance (258.4m), closely followed by the CA (175.2m). The CM had the highest total player load (1044.5au), player load per meter (0.107au/m), and player load per minute (11.085au/min), whereas the GK had the lowest player load in all categories.*

Conclusions: *Based on player load and mean HR, it appears that the CM experiences a greater physiological demand than all the other positions on the field, while the GK experiences the lowest physiological demand. Training the CM, therefore, should focus on improving aerobic capacity to ensure readiness for the in-match rigours of the position. The total distance covered by the W suggests that the W experiences the highest physical demand among all positions. Since the W covers the highest sprinting distance among all positions, training regimens should focus on improving the W's anaerobic capacity and repeated sprint ability to prepare the W for the high-intensity demands associated with the position. When using these results as an aid in the design of conditioning programmes, coaches and trainers are advised to consider that this study adds to a limited number of studies conducted on South African soccer. Furthermore, the current study was conducted in the second division of South African soccer. As a result, comparisons with studies from other countries should be made with utmost caution, particularly owing to differences in performance standards, as well as climatic and other environmental differences.*

Key words: *global positioning systems; GPS; second division soccer players; physical profile; physical demands; distance covered; heart rate; player load.*

DEDICATION

To all black kids who are constantly told, overtly and covertly, that their blackness is equivalent to mediocrity. Stand your ground, wear your blackness with pride, and never apologise for it. You stand on the shoulders of giants!

Izwe lethu!

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ADP	Adenosine Diphosphate
AFC	Asian Football Confederation
AFCON	Africa Cup of Nations
ATP	Adenosine triphosphate
ATP-PC	Adenosine triphosphate-phosphocreatine
CA	Central attack
CAF	Confederation of African Football/Confédération Africaine de Football
CAM	Central attacking midfielder
CB	Centre back
CDM	Central defensive midfielder
CM	Central midfielder
CONCACAF	Confederation of North, Central America and Caribbean Association Football
CONMEBOL	Confederación Sudamericana de Fútbol/South American Football Confederation
CVO2max	Central venous oxygen content/saturation
EPL	English Premier League
EPO	Erythropoietin
FASA	Football Association of South Africa
FIFA	International Federation of Association Football/*Fédération Internationale de Football Association*
FW	Forward
GK	Goalkeeper
GPS	Global Positioning Systems
HIA	High intensity actions
HIR	High intensity running
HR	Heart rate

HRmax	Heart rate maximum
HSR	High-speed running
IFAB	International Football Association Board
LB	Left back
LW	Left winger
LWB	Left wing-back
NFD	National First Division
FB	Fullback
OFC	Oceania Football Confederation
PC/PCr	Phosphocreatine
Pi	Phosphate
PSL	Premier Soccer League
RB	Right back
RSA	Repeated sprint ability
RW	Right winger
RWB	Right wing-back
SAAFA	South African African Football Association
SABFA	South African Bantu Football Association
SACFA	South African Coloured Football Association
SAFA	South African Football Association
SAID	Specific Adaptations to Imposed Demands
SAIFA	South African Indian Football Association
SASF	South African Soccer Federation
THSR	Total high-speed running distance
TMA	Time-motion analysis
TSD	Total sprint distance
UEFA	Union of European Football Associations/Union des Associations Européennes de Football
UFS	University of the Free State
VHI	Very high intensity running
VO2max	Maximal oxygen uptake
W	Wing/winger

CHAPTER 1: INTRODUCTION AND PROBLEM STATEMENT

1.1 Introduction

Soccer is the most popular sport in the world. Played in over two hundred countries, soccer has developed significantly since its primitive forms before the 1800s. As of 2018, two hundred and eleven associations are registered with the International Federation of Association Football/*Fédération Internationale de Football Association* (FIFA). These associations are duly divided into six continental confederations, namely Confederation of African Football/*Confédération Africaine de Football* (CAF), South American Football Confederation/*Confederación Sudamericana de Fútbol* (CONMEBOL), Confederation of North, Central America and Caribbean Association Football (CONCACAF), Oceania Football Confederation (OFC), Asian Football Confederation (AFC), and the Union of European Football Associations/*Union des Associations Européennes de Football* (UEFA) (FIFA, 2018). In South African soccer, the Premier Soccer League (PSL) was formed in 1996 with eighteen founding members. A year earlier, Orlando Pirates had become the first Southern African club to win the CAF Champions League (SA History Online, 2011). In 2002, the number of teams in the PSL was reduced to sixteen teams to address fixture congestion (News24, 2002). Below the PSL lie the National First Division (NFD), SAFA ABC Motsepe League, and the SAFA SAB Regional League. The stability offered by the PSL has resulted in the league becoming one of the most financially lucrative in the world (Harris, 2014). In order to compete at the highest levels, soccer players have to adapt to the demands placed on their bodies (Reilly, 2000). Measuring the players' physical and physiological responses during match-play is one way to quantify these demands. Following the quantifying of these demands, efficient sport-specific conditioning programmes can be designed to enhance soccer performance.

1.2. Background and literature review

Technology has, over the years, found more prominence in sport (Liebermann *et al.,* 2002). Soccer has been at the forefront with the introduction of goal-line technology and other advanced systems. This has coincided with an increased need for physical and mental conditioning to combat injuries and optimize performance. According to Bloomfield *et al*. (2007), detailed knowledge on the requirements of performance is necessary for the maintenance and optimization of physical and physiological status of elite soccer players. Time-motion analysis (TMA) allows researchers to position-specifically quantify the physical demands of different players. In TMA, video analysis and global positioning system technology (GPS) are used to directly measure player movements during match-play. The latter provides more detailed analysis than mere observation, as would be the case if only video analysis was used (Varley *et al*., 2014).

With the aim of understanding movement patterns in sport, various systems have been developed and used, including video-analysis (Rampinini *et al*., 2007; Di Salvo, 2009) GPS. Through these systems, individual and multiple players can be evaluated simultaneously in a timely manner to gather information that enhances the conditioning and tactical approaches of coaches (Carling *et al*., 2008). TMA does not require the researchers to be on the field during match-play and, potentially, interfere with the spontaneity of the players. TMA provides an objective yet non-invasive method for quantifying work-rate during field sports such as soccer, which ensures that the players' work-rates during match-play are as natural as possible. Data gained from TMA enhances the design of physical conditioning and testing programs (Deutsch *et al.*, 2007). Deutsch *et al*. (2007) further posited that field positions affect the physical demands on the players. In the English Premier League (EPL), central midfielders (CM) generally cover the most distance during match-play, closely followed by fullbacks. These findings could be a result of the tactical identity of the team, physical capacity and the role of the players involved. In a study done by Mohr *et al.* (2003) there was a significant variation in physical demands in each playing position, largely due to the tactical role and physical capacity of the players involved. One midfield player covered a total distance of 12.3km, with 3.5km being covered at a high intensity, while another midfielder covered a total distance of 10.8km, of which 2.0km was at high intensity. The individual differences in playing style and physical performance should be taken into account when planning the training and nutritional strategy. This is in line with the principle of Specific Adaptations to Imposed Demands (SAID), which advocates for training programs to be structured according to the specific demands of the particular sport (Hoff & Helgerud, 2004).

Bradley *et al.* (2013) compared the match performance and physical capacity of players across three levels of English soccer: the Premier League, Championship, and the League One championship. Players in League One and the Championship covered more distance overall and at higher-intensity, while Premier League players displayed superior technical indicators such as total passes, successful passes, forward passes, balls received and touches per possession. Although substantial research has previously been done on TMA in European soccer, minimal studies have been conducted on South African soccer. This raises concerns as it makes it challenging to quantify the performance gaps between the South African soccer leagues. Factors such as the cost of TMA equipment and a low number of experts who focus on TMA can possibly be attributed for the lack of such studies in South African soccer.

Modern soccer players cover greater distances than their earlier counterparts (Strudwick & Reilly, 2001). This could be due to developments in sport science, such as improved conditioning methods and nutritional approaches, as well as improved playing surfaces and equipment. Understanding the demands of modern soccer, thus, allows coaches and trainers to design programs that adequately prepare players for these demands. Information on distances covered and work-to-rest ratios during match-play can assist physical trainers in establishing measures to combat or delay muscular fatigue. This is important due to the risk of losing a match in the latter stages of a match when intensity is expected to drop substantially. Soccer teams and individual players typically display a 5% drop in distance covered after the half-time interval. This intensity, however, rises again as the match reaches its closing stages (Bangsbo, Nørregaard & Thorsøe, 1991). Several studies (Aughey, 2010; Bradley & Noakes, 2013; Sparks, Coetzee, & Gabbett, 2016) indicate that some players use pacing strategies to ensure that they can handle the rise in high-intensity running towards the end of a match.

Fatigue is most pronounced in centre-backs and strikers than in midfield players and full- backs, who tend to have higher VO_{2max} values (Reilly, 1997). Although midfield players typically cover the greatest distances among players in outfield roles, their superior aerobic fitness levels enable them to maintain higher exercise intensities throughout the game (Strudwick & Reilly, 2001).

1.3. Rationale

TMA studies have continued to gain popularity in sport, particularly with the development and use of advanced technological systems at the elite level. Initially conducted through the use of video systems, more recent TMA studies have featured the use of GPS. GPS has been used extensively in the military, aviation, and law enforcement. Although sport has only had commercial access to specialized GPS devices since 2003 (Edgecomb & Norton, 2006), a lot of inroads have been made to tackle numerous training and performance challenges. Through GPS tracking, injury prevalence can be lowered (Bowen, 2017) and, most importantly, comparative studies can be conducted to indicate areas which require necessary interventions. By identifying injuries at an early stage, preventative decisions can be taken to avoid long-term layoffs. By comparing performances in different playing levels and leagues, performance deficits can be identified and ways of countering those deficits can be devised. In addition, match simulations and training strategies can be enhanced through the data gathered by means of GPS technology (Edgecomb & Norton, 2006).

1.4. Formulation of problem

Aerobic and anaerobic fitness capacities play a vital role in success in soccer at the highest competitive level. In order to adequately prepare these systems for competition, the amount of time spent in each movement pattern such as walking, running, jogging, the total distances covered and work-to-rest ratios, need to be quantified. These variables are then evaluated and compared to those in leading soccer leagues. Such comparisons allow physical trainers to narrow the fitness and performance gaps that may exist between different leagues and divisions, such as a performance gap that may exist between a premier division and the first division. If necessary, training and nutritional programs are then restructured to fit the renewed training and performance goals.

1.5. Aim of the study

This research study aims to quantify the physical and physiological demands of different positions in second division soccer. The main focuses will be to calculate the total distance covered, distance covered in different intensities, and distance covered at high-intensity in second division soccer. A secondary aim of the study will be to compare these results to higher level leagues.

1.6. Primary objectives

The objectives of this study are:

1. To determine the **distance covered (km)** by second division soccer players and to compare **differences between positions**,

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

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

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

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

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

2. To determine the total **player load (Load $^{TM}\cdot$min $^{-1}$ (au))** of second division soccer players as well as the player load of the different positions during match play.

3. To compare the **player load (Load $^{TM}\cdot$min $^{-1}$ (au))** and **distance covered (km)** by second division soccer players to that of players in higher leagues.

1.7. Motivation for the study

In order to design efficient, sport-specific conditioning programmes, coaches and trainers need to familiarise themselves with the physiological and physical demands of sport competition (Deutsch *et al.*, 2007). TMA studies have garnered global popularity to meet this need. However, most TMA studies are conducted in European, North American and South American leagues, which makes the information potentially misleading due to climatic and performance differences. The current study being the first of its kind conducted on the African continent could potentially provide more reliable information that can not only aid in the design of sport- specific conditioning programmes, but also provide insight into the design of programmes that can be applicable in an African context. The current study was conducted on one team taking part in the ABC Motsepe League, which is the second division of South African soccer, in order to add to what is otherwise an under-researched area in South Africa. It is envisaged that the knowledge gained from this study will not only improve the overall performance standard of South African soccer, but also give rise to similar studies across all playing levels of the South African game.

1.8. Structure of the dissertation

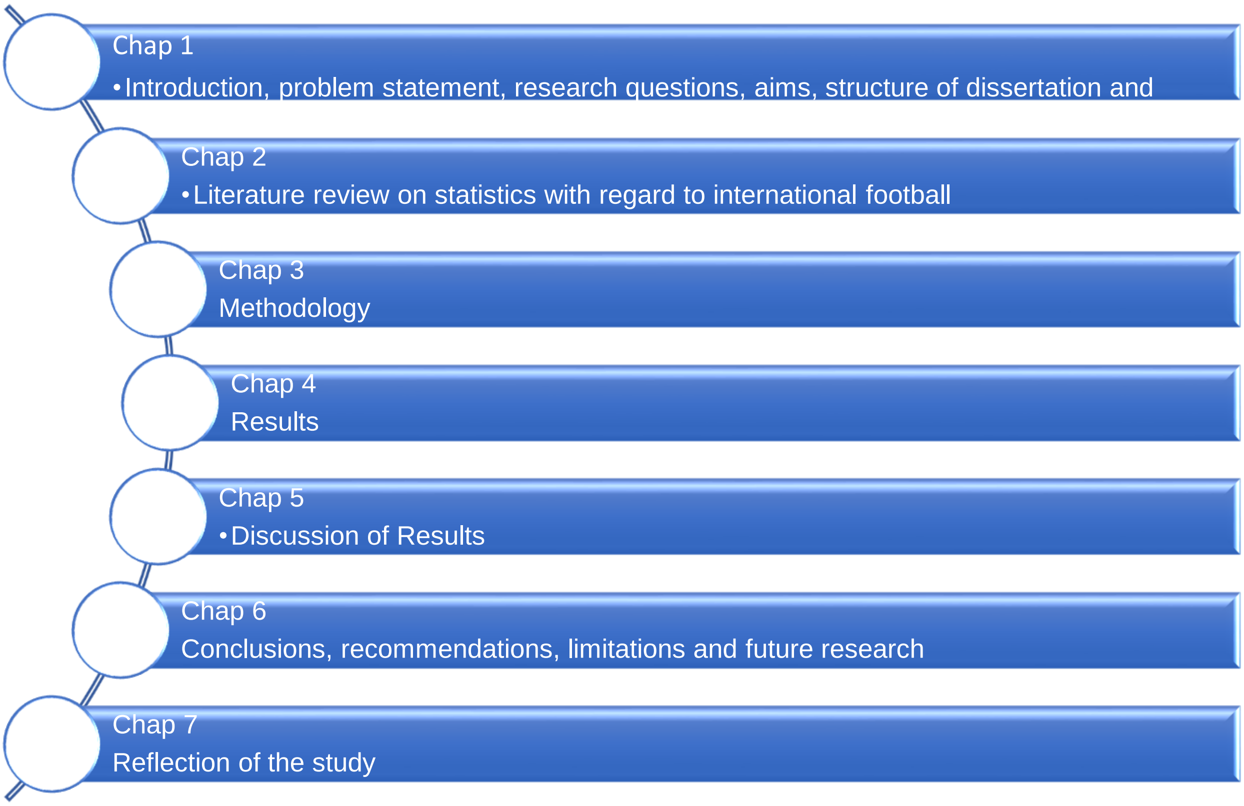

Figure 1.1: Outline of the study

CHAPTER 2: LITERATURE REVIEW

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Soccer, also known as association football, is the world's most popular sport. By 2007, over 270 million male and female people were active participants in the sport, including 5 million referees (Kunz, 2007). Soccer is a male-dominated sport, with approximately 90% of players being male (FIFA Magazine, 2007). A soccer team comprises of 11 starting players and 7 reserve players, of which 3 of the players may take part in the match as substitutes in an official FIFA-organised match (IFAB, 2017). However, the use of a fourth substitution in extra time has recently been permitted, as witnessed during recent tournaments such as the 2018 FIFA World Cup. In some matches, the number of possible substitutions can be decided prior to the match, with as many as twelve substitutions being named and six being allowed to play in the match. The number of positions on the soccer field is determined by the playing formation. However, the positions are often divided into defence, midfield, and attack.

In order to design efficient and sport-specific conditioning programmes, the physiological demands of sport must be understood (Miller *et al.,* 1994). Through the use of TMA, performance indicators such as speed, distance covered, and work-rest ratios can be quantified. TMA can provide feedback to coaches and players (Liebermann *et al.,* 2002), and indicate discrepancies in performance between players in different positions (Davidson *et al.,* 2008). Although various TMA studies have been conducted globally (Table number 3), a limited number of studies have been published on African soccer.

Table 2.1 Total distance covered in different positions

Source	Competition	Position	Total Distance Covered (m)
Barros *et al.* (2007)	Brazilian Super League	Central Defender	9020 (15)
		Fullback	10642 (12)
		Forward	9612 (8)
		Winger	10598 (9)
		Central Midfielder	10476 (11)
Bradley *et al.* (2009)	English Premier League	Central Defender	9885 (92)
		Fullback	10710 (84)
		Forward	10314 (62)
		Winger	11535 (52)
		Central Midfielder	11450 (80)
Bradley *et al.* (2013)	English Premier League	Central Defender	9816 (34)
		Fullback	10730 (41)
		Forward	10320 (24)
		Winger	11612 (50)
		Central Midfielder	11445 (41)
	English Championship	Central Defender	10732 (36)
		Fullback	11426 (35)
		Forward	11256 (30)
		Winger	12200 (22)
		Central Midfielder	11878 (32)
	English League	Central Defender	10980 (77)
		Fullback	11474 (83)
		Forward	11391 (57)
		Winger	12043 (75)
		Central Midfielder	12277 (74)
Braz *et al.* (2010)	UEFA Euro 2008	Central Defender	9498 (120)
		Forward	10108 (51)
		Winger	10274 (99)
		Central Midfielder	10905 (134)
Dellal *et al.* (2010)	French League	Central Defender	10426 (1000)
		Fullback	10656 (756)
		Forward	10943 (464)
		Winger	12030 (202)
		Central Defensive Midfielder	11501 (952)

		Central Attacking Midfielder	11726 (166)
Dellal *et al.* (2011)	Spanish La Liga	Central Defender	10496 (624)
		Fullback	10650 (212)
		Forward	10718 (262)
		Winger	11241 (100)
		Central Defensive Midfielder	11247 (616)
		Central Attacking Midfielder	11780 (82)
	English Premier League	Central Defender	10617 (1704)
		Fullback	10775 (132)
		Forward	10803 (724)
		Winger	11041 (50)
		Central Defensive Midfielder	11556 (1356)
		Central Attacking Midfielder	11780 (76)
Di Salvo *et al.* (2007)	Spanish La Liga	Central Defender	10627 (63)
		Fullback	11410 (60)
		Forward	11254 (52)
		Winger	11990 (58)
		Central Midfielder	12027 (67)
Lago *et al.* (2010)	Spanish La Liga	Central Defender	10491
		Fullback	11050
		Forward	10686
		Winger	11425
		Central Midfielder	11320
Number in brackets denotes the number of players per position in each study * Dellal et al. (2010; 2011) used observations in analyses, rather than matches played			

n=number of participants

This chapter aims to review the existing research that has been conducted on the physical and physiological demands of soccer, the use of TMA in soccer, and the use of (GPS) to measure the distance covered by soccer players in different positions during a match. Additionally, factors that influence the performance of soccer players such as energy systems, environmental conditions, work-rest ratios, playing formations, and ergogenic aids are reviewed.

2.2. Soccer

Played in over two hundred (200) countries (FIFA, 2010), soccer has developed significantly since its primitive forms before the 1800s. As of 2017, 211 associations are registered with FIFA (Fédération Internationale de Football Association). These associations are duly divided into 6 continental confederations, namely CAF (Africa), CONMEBOL (South America), CONCACAF (North America), OFC (Oceania), AFC (Asia), and UEFA (Europe). According to FIFA (2018), all six confederations are tasked with the organisation of continental tournaments, as well as the upholding FIFA's values. As the primary governing body, all operations within associations and confederations have to be in line with FIFA's objectives. To maintain discipline and order in soccer, seventeen Laws of the Game are enforced by match officials and compiled, authorised, and monitored by the International Football Association Board (IFAB). Along with the English Football Association's establishment in 1863, the first Laws of the Game were drawn up. However, clubs from Sheffield had, in 1857, announced their own set of rules. Disputes stemming from the differing laws persisted until the formation of the IFAB in 1886. In its current composition, IFAB comprises four members from FIFA, as well as representatives from the founding member associations, namely England, Wales, Scotland, and Northern Ireland. In 1904, FIFA was founded with Spain, Sweden, Denmark, France, Belgium, the Netherlands, and Switzerland as the original members (IFAB, 2019). Ten years later, FIFA joined the IFAB (IFAB, n.d.). In 1930, and under the leadership of FIFA's third president Jules Rimet, the first FIFA World Cup was hosted in Uruguay. Originally composed of thirteen invitational teams, the tournament was expanded and participating teams now must qualify for the 32-team spectacle. Only the host nation earns automatic qualification since FIFA discontinued the automatic qualification of world champions (Bond, 2001). As of the 2026 showpiece, forty-eight nations will participate in the World Cup, with the 2022 World Cup possibly experiencing the same expansion (Conn, 2018).

2.2.1. South African soccer

South African soccer can trace its roots to the mid-1800s, when British settlers introduced the sport to natives. In order to coordinate South African soccer, the South

African Football Association (SAFA) was founded in 1892 (Alegi, 2004). SAFA became the first non-European member to join FIFA. However, SAFA's intention to exclusively further the development of white soccer spawned other associations which would cater for black, Indian, and coloured people. The South African Bantu Football Association (SABFA), the South African Indian Football Association (SAIFA), the South African African Football Association (SAAFA), and the South African Coloured Football Association (SACFA) were formed in the early 20th century. The latter three formed the non-racial and anti-apartheid South African Soccer Federation (SASF) in 1951. In 1956, SAFA renamed itself Football Association of South Africa (FASA). A year later FASA became a founding member of the Confederation Africaine de Football (CAF), along with Sudan, Egypt, and Ethiopia. In 1960, FASA was expelled from CAF for its racially segregated nature. A year later, FIFA followed suit by suspending FASA (Alegi, 2004).

South African club soccer experienced substantial growth at the turn of the 19th century. Mass migration as a result of the gold rush and the formation of the Durban and District Native Football Association resulted in the formation of several soccer clubs. Clubs such as African Wanderers and Zulu Royals soon found prominence as Durban became a hub for black soccer. Wits University, Orlando Pirates, Moroka Swallows, and Manning Rangers soon followed in present-day Gauteng (Alegi, 2004).

After exhausting a ban for apartheid policies, South Africa made its way back from the sporting wilderness in the early 90s. The progress made from that point onwards was echoed by the re-formation of the South African Football Association (SAFA) as a non-racial body in March 1991 (SA History Online, 1992). South Africa attained relative success during their first decade on the international scene. As hosts, Bafana Bafana won the 1996 Africa Cup of Nations (AFCON) and lost in the final two years later in Burkina Faso. A place at the 1998 FIFA World Cup in France was secured to cap a rich decade of soccer. Even after a decent outing at the 2002 World Cup and being awarded 2010 World Cup hosting rights, Bafana Bafana entered a lean period of success. A quarterfinal finish at the 2002 AFCON was followed by group stage exits in the next three editions, while not qualifying for the 2010 edition. At the 2010 World Cup, South Africa made unenviable history by becoming the first hosts to exit the tournament at the group stage. South Africa missed out on the 2012 AFCON tournament and could only muster a quarterfinal exit a year later. From the 2013 edition, CAF decided to only commission AFCON tournaments in odd years to avoid a clash with World Cup tournaments (Africa Update, 2013). Testament to the decline of the South African national team, Bafana Bafana were ranked 78 in 2018, after a high of number 19 in 1996 (FIFA, 2017).

Locally, the year 1996 ushered the establishment of the Premier Soccer League (PSL) with eighteen founding members, which was later reduced to sixteen teams to alleviate fixture congestion. The National First Division, SAFA ABC Motsepe League, and the SAFA SAB Regional League make up the rest of South Africa's professional soccer structure. Due to its stability, the PSL has become one of the world's best leagues (Harris, 2014). However, a vast majority of South African fans are shared by Kaizer Chiefs, Orlando Pirates, Mamelodi Sundowns, and Bloemfontein Celtic. This is in part due to the economic and administrative control of the game being centred in the Gauteng Province (Hamil & Chadwick, 2010), where the clubs, bar Celtic, are based.

While women's soccer in South Africa has existed since the 1960s, its development has been negligible. Even though the women's national team was established in 1993 (Pelak, 2010), a structured national league was only formed before the turn of the millennium and only professionalised in 2009 with the SAFA SASOL Women's League (SAFA, n.d.). The SASOL Women's League, the highest level of soccer in South Africa, comprises hundred and forty-four teams, with each province contributing sixteen teams. Provincial winners proceed to the national tournament (SAFA, n.d.).

2.2.3. Game structure

Tactical advances in soccer have changed the way teams set up and approach matches. The organisation and performance of players can be influenced by the tactical principles applied by the coaching staff (Costa *et al.,* 2009). The world's leading soccer nations have contributed proficient playing approaches that have subsequently been copied by other nations (Krause & Szymanski, 2017). In the 1950s through the 1960s, Italian coaches relied on the *Catenaccio* system, which is a defensive and counter-attacking approach to the game. Dutch club Ajax Amsterdam pioneered the *TotalFootball*, which would go on to inspire the use of the Tiki Taka by the FC Barcelona sides of the late 2000s and 2010s (Bialkowski *et al.,* 2014). Limited research been conducted on the tactical identities of South African teams.

Tactical approaches may determine how much certain positions are involved during match play. Although many clubs have taken up possession soccer as a tactical approach, this does not always translate into more scoring chances and goals (Bate, 1988). In fact, it is the entering of the opposition's final third, the reduction of backward and square passes, and increasing forward passes that improves the chances of success (Bate, 1988). Barcelona's famed Tiki Taka is characterised by precise, structured passes and not purposeless passing (Gyarmati, 2014) and has delivered considerable success for the Catalan club over the past decade.

During the 2010 and 2014 FIFA World Cups, teams with more ball possession than their opposition won 41% and 44% of matches, respectively. Figure 1 (FIFA Technical Reports) also details the number of matches won by teams with less ball possession, as well as drawn matches, penalty shootouts, and matches in which the possession was equal.

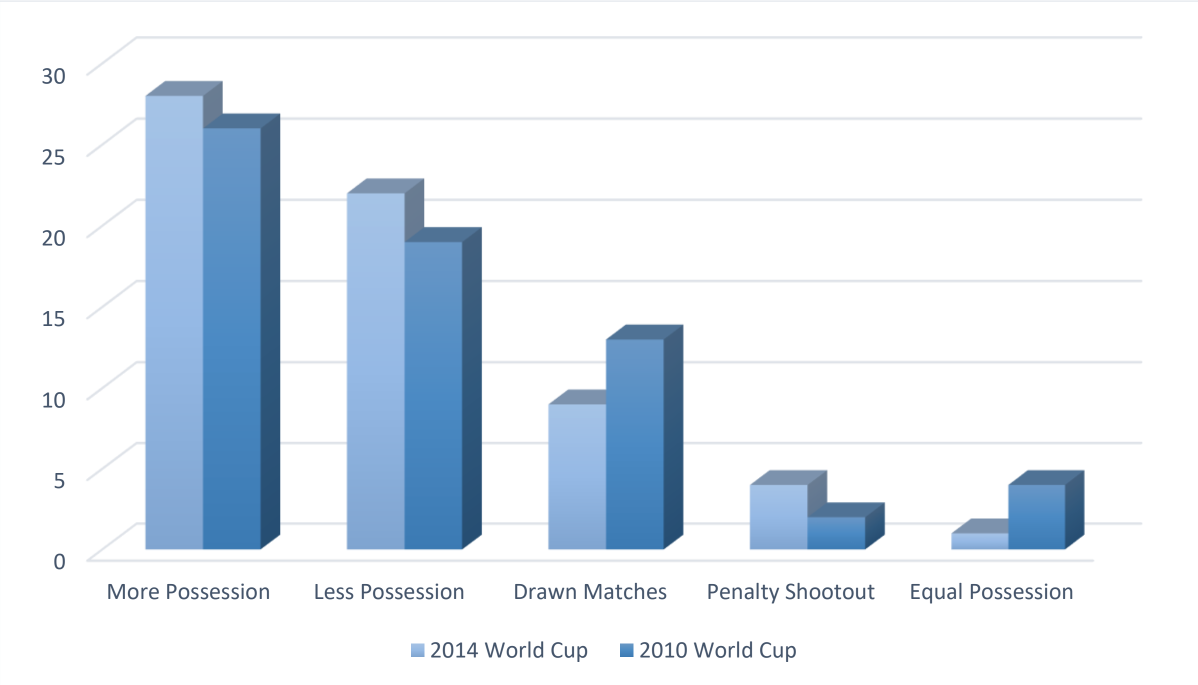

Figure 2.1: Number of matches won in relation to ball possession (2010 and 2014 FIFA World Cups)

2.2. Time-motion analysis

Soccer has, over the years, benefited from technological advances. From lighter boots to goal-line technology, steps to enhance sport have not eluded the game of soccer. Through technology, coaches and players can receive feedback regarding the quality of their performances (Liebermann *et al.,* 2002). Performance can be improved by the provision of immediate feedback, the creation of a performance database, players and team evaluation and the improvement of specific performance areas. With a focus on movement patterns in sport, various systems have been developed and used, including video-analysis (Di Salvo, 2009; Rampinini, 2007) and global positioning systems. Through these systems, individual and multiple players can be evaluated simultaneously in a timely manner to gather information that enhances the training approaches of coaches (Carling *et al.,* 2008).

As soccer continues to evolve, training protocols must undergo similar evolution to accommodate the changes. Understanding the demands of modern soccer, thus, allows coaches and trainers to design programmes that adequately respond to these demands. In order to construct suitable and individualised training protocols, the physical and physiological demands of soccer need to be quantified. Previous research by Castellano and Casamichana (2010) utilises the terms physical and physiological to refer to distance covered and heart rate data, respectively. Developing training protocols which simulate actual competitive match-play is vital (Di Salvo, 2009), which is in line with the SAID principle.

In order to foster this development, performance feedback must be provided to players, trainers, and coaches. Coaches and trainers use performance indicators, which are action variables that determine performance, to evaluate the individual or team performance (Hughes & Bartlett, 2002). Performance indicators such as the total distance covered at different intensities, duration of different movements during match play, work rates, and energy demands must be quantified to foster conclusive analysis. Components of the total distance covered include walking, jogging, cruising, sprinting, backward and shuffling movement. With TMA, movement patterns in soccer can be quantified and injury risk detected much earlier than without the use of TMA. The two most-utilised forms of TMA are video analysis and GPS. Previously, GPS technological devices were “bulky” and limiting, particularly due to their inability to be used in official competition. This made video analysis a more feasible method of monitoring player activities (Di Salvo *et al.,* 2006: 109). However, technological improvements have resulted in lighter and smaller wearable devices (Montgomery, Pyne & Minahan, 2010), most notably produced by Catapult. Following their initial use in military settings (Cummins *et al.,* 2013), GPS has gained popularity in sport, with trixaxial accelerometers gaining favour for their unobtrusive nature (Montgomery *et al.,* 2015). GPS has proven to be ideal in quantifying the physical demands of sport (Hollville *et al.,* 2015), particularly for outdoor sports (Montgomery *et al.,* 2010). GPS combats challenges that are associated with other systems of quantifying physical and physiological demands (Boyd *et al.,* 2011). For example, during high-intensity intermittent physical activity, the validity of heart rate measurement is considered questionable (Terbizan *et al.,* 2002). On the other hand, video analysis has previously been criticised for being susceptible to human error and only tracking individual players at a time (Edgecomb & Norton, 2006). Developments in GPS technology have yielded valid measurements of multiple players simultaneously, which can be applied in training settings (Harley *et al.,* 2011).

Although GPS can aid in decision making regarding player performance (Malone *et al.,* 2017) and injury predication and prevention (Ehrmann *et al.,* 2016; Rossi *et al.,* 2018), the massive scope of data derived through GPS technology is often uninterpreted, which may present challenges for coaches and trainers.

For comprehensive information, player movements are recorded throughout an entire match. Elements such as total work rate, distances covered, and heart rates are recorded with the use of amenities such as compact heart rate monitors and GPS devices. Furthermore, information on the duration spent in different intensities helps coaches and trainers focus on the dominant energy systems and, thus, optimize them. Furthermore, the feedback gained from this information can help coaches and trainers enhance the specificity of conditioning programmes (Roberts *et al*., 2006). In addition, the data retrieved with TMA can help trainers objectively manage player load, reduce the possibility of injury, and improve a team’s decision making (Catapult, 2019).

TMA studies have increased in popularity, with some European soccer leagues collaborating with statistical companies to have quantified data readily available. A notable example is the partnership between the English Football Association and Opta Sports. Through this partnership, Opta Sports provides detailed statistical data of all matches in the English Premier League and a majority of matches across the other English leagues (Opta, 2018). This information includes the distances covered by individuals and teams, amount of time spent in each half on the pitch, and the amount of time spent in different performance intensities. Additionally, Opta provides performance-specific data in the form of passes completed by players, tackles, interceptions, dribbles, and clearances. This information is vital to performance analysts as it can be used to indicate tactical and technical gaps, as well as to track player performance and improvement throughout a season. For instance, the number of clearances per match or goals-to-minute ratio can be used to determine which defender or striker should start a match. With the latter, for instance, a low goals-per-minute ratio would suggest that more shooting training should be brought into the training regime.

Information gathered through performance analysis allows the players and coaches to not only improve performance and fitness, but it allows for heightened tactical awareness. Furthermore, such information can allow a team to be better prepared for the opposition. For instance, in the lead-up to a cup final, team A may conduct a detailed study on team B's likely penalty takers and the goalkeeper's preferred diving side. This would then ensure that team A's preparations for a possible penalty-shootout, for instance, are more informed and specific. Bar Eli and Azar (2009) recommend intense preparation for penalty shootouts that focuses on shooting towards that top corners of the goal. This could increase success rate in pressure situations.

Since TMA provides individual and team statistics, shortfalls in performance can thus be detected and rectified. Despite heavy financial investment in South African soccer (Hamil & Chadwick, 2010), there are few TMA studies conducted relative to the extensive research in Europe and the Americas. However, this is changing, with some professional teams such as Mamelodi Sundowns, Orlando Pirates, Bloemfontein Celtic, Cape Town City, and Ajax Cape Town investing in TMA equipment. Additionally, the South African national soccer team has forged a partnership with

Catapult Sports to monitor the team in the lead up to the 2019 Africa Cup of Nations (Catapult, 2019).

2.3. Physical capacities of soccer players

In order to compete at the highest levels, soccer players have to adapt to the demands placed on their bodies (Reilly *et al.,* 2000). Measuring the players' physiological responses during match-play is one way to quantify these demands. Furthermore, the difference between success and failure in matches can be identified.

Although the physical capacities of soccer players are heterogeneous, some players are still predisposed to certain positions (Reilly *et al.,* 2000). Even though tall players have been known to have an advantage in positions such as central defence and attack (Reilly *et al.,* 2000), midfielders are no longer required to fit the strong, combative description. Short-statured, highly-skilful midfielders are now prevalent in modern soccer across the world. It is common to see coaches fielding midfielders entirely for their passing and positional ability rather than for their physical strength. In a study conducted on under 19 soccer players by Rebelo *et al.* (2012), it was found that on the elite level goalkeepers were the heaviest, while central defenders were the tallest. Additionally, full-backs and midfielders were slightly shorter and lighter than forwards.

2.3.1. Anthropometry

An early study by Martirosov *et al.* (1987) found soccer players to be well-balanced between mesomorphic and endormophic types. Recent studies have found a dominance of balanced-mesomorphic profiles (Hazir, 2010; Orhan *et al.*, 2013; Rienzi, 2000) in soccer players; additionally, some soccer players are ectomorphic-mesomorphs or mesomorphic-ectomorphs. In a study with 46 soccer players between the ages of 20 to 24 years old, Bandyopadhyay (2007) found that soccer players are typically ectomorphic-mesomorph. Physical profiles of soccer players vary according to positional roles, with goalkeepers and central defenders typically taller (Puga *et al.,* 1993; Hazir 2010; Tahara, 2006; Cossio-Bolanos, 2012) and heavier (Bangsbo, 1994;

Rebelo *et al*., 2012) than midfielders, fullbacks, and strikers. Midfielders are generally shorter and lighter; this could be reflective of the new direction (Whitehouse, 2012) the game has taken. A Peruvian study by Cossio-Bolanos *et al.* (2012) found that goalkeepers had the highest fat percentage, followed by midfielders and strikers, while defenders were the leanest in this regard. Orhan *et al.* (2013) recommends the use of alternative methods to identify talented players as there is no clear relationship between playing position and somatotype. In modern soccer, there is a consistent reflection of these findings. Rak *et al.* (2014) found similar patterns at under 13, under 15 and under 17 levels. This may be a result of coaches positioning players based on their physical profiles. Table 2.2 outlines selected anthropometric values, as researched in various leagues.

Table 2.2: Anthropometric values according to different playing positions

Country and authors	Competition	Position (*n*)	Height (cm)	Mass (kg)	Fat %
Denmark	**Unknown**				
Bangsbo (1994)		Goalkeeper (5)	1.90 (0.06)	87.8 (8.0)	
		Central defender (13)	1.89 (0.04)	87.5 (2.5)	
		Midfielder (21)	1.77 (0.06)	74.0 (8.0)	
		Full Back (12)	1.79 (0.06)	72.1 (10.0)	
		Forward (14)	1.78 (0.07)	73.9 (3.1)	
India	**National League**				
Dey *et al.* (2010)		Goalkeeper (23)	173.8 (5.33)	66.7 (5.56)	14.0 (2.61)
		Defender (44)	170.8 (5.78)	63.2 (8.07)	13.8 (2.05)
		Midfielder (48)	171.9 (5.98)	64.9 (6.52)	13.3 (2.41)
		Striker (35)	170.9 (5.76)	63.5 (6.38)	13.6 (2.15)
Portugal	**U/19 League**				
Rebelo *et al.* (2012)		Goalkeeper (18)	178.1 (4.6)	78.7 (8.1)	12.4 (4.5)
		Central Defender (26)	183.3 (3.6)	78.0 (6.6)	10.7 (3.7)
		Full Back (27)	174.7 (5.7)	69.3 (6.5)	10.4 (2.9)
		Midfielder (68)	174.8 (7.1)	71.6 (7.1)	10.8 (3.3)
		Forward (41)	175.1 (6.8)	71.7 (7.4)	11.1 (2.9)
Peru	**First League**				
Cossio-Bolanos *et al.* (2012)		Goalkeeper (8)	1.85 (0.03)	82.57 (7.46)	11.84 (2.50)
		Defender (18)	1.79 (0.06)	76. 51 (7.65)	11.28 (2.69)
		Midfielder (27)	1.75 (0.05)	72.50 (7.88)	11.76 (3.38)
		Striker (15)	179 (0.06)	77.83 (5.26)	10.68 (2.87)
Turkey	**Super League**				
Hazir (2010)		Goalkeeper (22)	184.8 (3.73)	82 (5.50)	
		Defender (49)	178.6 (5.26)	75.6 (6.21)	
		Midfielder (59)	176.1 (4.62)	73.9 (4.75)	
		Striker (31)	177.9 (5.89)	76.6 (6.44)	

Japan	**Unknown**				
Tahara *et al.* (2006)		Goalkeeper (6)	177.8 (3.9)	71.4 (3.5)	13.7 (4.1)
		Defender (31)	173.8 (5.2)	65.5 (4.8)	8.5 (2.4)
		Midfielder (23)	171.2 (5.3)	62.8 (5.2)	9.5 (2.5)
		Forward (12)	172.8 (5.2)	65.8 (5.5)	10.9 (2.9)
Portugal	**Division 1**				
Puga *et al.* (1993)		Goalkeeper (2)	186	84,4	
		Central Defender (3)	185,3	75,9	
		Full Back (2)	175	67,5	
		Midfielder (8)	176,8	74	
		Attacker (6)	174,6	71,1	

2.3.2. Energy demands

Soccer is composed of different movements (sprinting, jogging, jumping, multi-directional shuffles) which vary in intensity. Just like volleyball, basketball, and badminton, soccer involves intermittent exercise (Bangsbo, 2000). Consequently, these movements can be fulfilled through a series of metabolic pathways which breakdown macronutrients to generate adenosine triphosphate (ATP) for muscular contraction. Depending on the type, intensity, and duration of an activity, different energy systems and bioenergetics substrates are utilised to fulfil the needs of different activities (Abernethy *et al.,* 1990). Energy requirements during exercise are fulfilled by 3 different energy systems which function simultaneously (Gastin, 2001). Consistent regeneration of energy is required for continuous performance of all movements over the course of a soccer match. Predicated on the use of oxygen to produce energy for muscular contraction, these energy sources are labelled aerobic and anaerobic.

It is worth noting that a change in energy systems is not sudden; rather, it is a gradual process (Urhausen *et al.,* 2000). If a full-back makes an attacking move at moderate pace, he requires immediate energy should the ball be lost and a counter-attack ensue. The adenosine triphosphate and phosphocreatine (ATP-PC), aerobic, and the anaerobic glycolytic systems are tasked with meeting the energy demands of the muscular system. Improving maximal oxygen uptake (VO_{2max}) enhances soccer performance in the form of total distance covered, work intensity, and total sprints in a match (Helgerud *et al.,* 2001). Training with the aim of improving player fitness is therefore a complicated process, which relies on an improvement in both aerobic and anaerobic elements of performance (Dupont *et al.,* 2004).

Performance in many sports is dependent on the ability to reproduce ATP. The ability to produce energy aerobically and anaerobically should be the focal point for high intensity exercise training. (Tabata *et al.,* 1997). The ability to sustain the required work rate for 90 minutes is largely dependent on a strong aerobic base; however, the anaerobic component is usually decisive at crucial points in a game (Di Salvo *et al.,* 2008). In order to meet a through ball from a team-mate, win a header, or make a timely tackle, high-intensity bursts are required. Adequate preparation of players for matches requires training regimens which focus on all three energy systems (aerobic, anaerobic, and alactic). Alactic entails an anaerobic pathway which does not result in lactic acid build up (Gastin, 2001). A high work output and sustaining high-quality sprints should be the focus (Coyle, 2000). This will allow soccer players to cope with the intermittent demands of the sport. Elite soccer is typically played at an energy expenditure of approximately 75% maximal aerobic power. On the other hand, a relative metabolic loading of approximately 75% Ç$_{VO2max}$ is equivalent to about 165 beats min-1 heart rate. Midfielders have the highest energy expenditure, which is a result of the superior distances they cover (Reilly, 1997).

2.3.2.1. ATP-PC System

The ATP-PC system, which comprises adenosine triphosphate (ATP) and phosphocreatine (PC), provides immediate energy for short term bursts no longer than 10 seconds. ATP and phosphocreatine are almost entirely responsible for the provision of this energy (McArdle *et al.,* 2006). ATP is stored in muscle at rest and is readily available for short bursts of movement. ATP stored in the myosin cross-bridges is broken down to release energy for muscle contraction. This forms one adenosine diphosphate (ADP) molecule and one phosphate (Pi) molecule. Creatine kinase then breaks down phosphocreatine into creatine and Pi. Phosphocreatine breakdown releases energy, which is then used to combine ADP and Pi, forming more ATP molecules (Powers & Howley, 2012). The ATP-PC system is ideal for maximal bursts lasting up to 10 seconds; this is typically in the primary stages of intense or explosive movements (Gastin, 2001). These may be in the form of a striker darting into the 18-yard box to meet a cross from a winger. Similarly, in the same scenario, a defender sprinting to intercept the winger's cross would require energy from the ATP-PC system. Recovery periods lasting 2-3 minutes are required for the replenishment of this energy store (Kenney *et al.,* 2012). Continuous high intensity activity results in partial replenishment of these stores due to shortage of energy to reform phosphocreatine through the combination of creatine and Pi. Furthermore, the replenishment of ATP in the muscle will be hindered by rate of ATP breakdown through other systems. Since PC and ATP levels are low after an all-out sprint, other energy sources are required to produce ATP (Kenney *et al.,* 2012).

2.3.2.2. Anaerobic Glycolytic System

Following the depletion of the ATP-PC system, the anaerobic glycolytic system plays a role in ATP production (McArdle *et al.,* 2006). Activities lasting longer than 10 seconds and up to 180 seconds derive a majority of the ATP from the anaerobic glycolytic system (Brussow, 2016). This system is more complex than the ATP-PC system and, as a result, takes relatively longer to produce the required energy. One advantage it has over the ATP-PC system is its larger capacity, which is vital in intermittent sports like soccer and rugby. This system produces 2 pyruvate molecules and 2 ATP molecules when it starts with the breakdown of glucose. If the process begins with glycogen, 3 ATP molecules are yielded (Powers & Howley, 2012).

The anaerobic energy system comprises alactic and lactic components, which denote the mechanisms responsible to produce lactic acid from carbohydrate by means of glycolysis, as well as the splitting of the stored phosphagens, ATP, and phosphocreatine. The anaerobic pathways can provide a limited amount of energy and reproduce ATP at high rates (Gastin, 2001).

2.3.2.3. Aerobic System

After two minutes of continuous muscular contraction, aerobic oxidation becomes the dominant source of energy. Although this system provides low power, it provides fuel for the longest duration. In a soccer match, over 90% of the energy can be attributed to aerobic sources (Bangsbo, 1994), which makes this system a vital element of performance. This system derives its ATP in one of 3 ways: the Krebs' Cycle, the Electron Transport Chain, and Beta Oxidation. In the aerobic system, oxygen is required for the burning of carbohydrates and fats to yield ATP (Gastin, 2001). The aerobic system is responsible for long efforts of low-moderate intensity. A high VO_{2max} enables a player to sustain continuous exercise (Reilly, 2003). During the 2014/2015 EPL season, the fittest players covered distances between 11 and 12 kilometres per match (Talksport, 2015). Even in equally-skilled players, the ones who can maintain a high-intensity work rate have an advantage over those who cannot sustain an equal work rate throughout a match (Impellizzeri, 2005). Reilly (1997) further asserts that high aerobic capacity is vital in recovery during high intensity intermittent exercise. Reilly and Thomas (1976) prove that physiological demands in soccer change based on the work rates of different positions and roles. Outfield players and midfielders have higher aerobic requirements than strikers and central defenders. Hoff *et al.* (2002) assert that due to the length of soccer matches, approximately 90% of the energy must be extracted aerobically. The average work intensity is closer to the lactate threshold during a 90 minute-match. This is approximately 80-90% of the VO_{2max} (Helgerud *et al.,* 2001). Although the aerobic system delivers energy at a slower rate than the anaerobic and ATP-PC systems, it has a much larger capacity (Gastin, 2001).

Midfielders have been reported to have higher relative uptake than defenders and forwards, while goalkeepers had the poorest VO_{2max} values (Tonessen *et al.,* 2013). Players in higher divisions (1st and 2nd) displayed greater VO_{2max} values than those in lower divisions (3rd to 5th divisions). Players younger than 18 demonstrated higher VO_{2max} values than their counterparts between the ages 23 and 26. Outfield soccer players have a VO_{2max} ranging from 50-75ml/kg/min, while goalkeepers range from 50 to 55ml/kg/min (Stolen *et al.,* 2005). Although different activities rely on the different energy systems, all energy systems remain active during the match. While the anaerobic energy system can contribute energy quickly, its capacity is lower than the aerobic system, which has a high energy-production quantity, although this energy is released at a slower rate (Gastin, 2001).

2.3.2.4. Relative Contribution of Each Energy System during a soccer match

Considering that soccer is an intermittent sport, all energy systems play a vital role in sustained physical activity. However, the contributions differ in percentage. Due to the duration of soccer, aerobic metabolism contributes the greatest proportion of energy. Only 10% of the average distance covered is at high intensity (Stolen *et al.,* 2005), with goalkeepers covering only 2% at high intensity (Di Salvo *et al.,* 2008). ATP-PC is responsible for high-intensity short bursts and the aerobic system for low to moderate intensity long efforts. Intense muscle power outputs can be immediately supported by the anaerobic system (Gastin, 2001). The ratio of involvement of each energy system in soccer varies according to the individual demands of each position, the tactical approach of the team, and the fitness level of each player. On average, central midfielders cover the most distance per match. Central midfielders - central defensive midfielders and deep-lying playmakers - are tasked with shielding the defensive line, controlling the tempo of the match, as well as being the link between attack and defence. Due to the endurance demands central midfielders are subjected to, the aerobic system is more active than the other systems. Although the aerobic system is known for its large capacity, central midfielders require discipline in order to maximise the use of this capacity. In other words, a defensive midfielder would need to stick to his/her role and avoid making offensive runs as the energy needs to be preserved for defensive duties. In fact, the initial stages of the second half tend to be less intense than those of the first half, which may suggest that players pace themselves throughout the match (Bradley & Noakes, 2013). Strikers and central defenders exhibit more power and speed movements – such as jumping to head the ball in offensive and defensive situations, respectively – which derive their energy from anaerobic sources.

2.3.2.5. Substrate Utilisation

For physical movements and mental functions to be executed, energy must be produced through the burning of macronutrients. Carbohydrate is the primary fuel for skeletal muscle contraction. Due to the limited amounts of endogenous carbohydrate (Hargreaves, 2000), pre-competition interventions have developed over the years with the key aim of maximizing muscle and liver glycogen stores. Interventions characterized by high-carbohydrate intake in the days leading up to competition have been extensively investigated. Furthermore, carbohydrate ingestion 3-4 hours prior to competition has proven to increase muscle glycogen stores (Coyle *et al.,* 1985), which in turn leads to improved performance (Sherman, 1989). Alternatively, delaying the depletion of glycogen stores is a vital component for optimal performance; liver glycogen reserves assist in the maintenance of blood glucose levels, which contribute to enhanced performance (Casey, 2000). In addition, increasing triglyceride stores preserves glycogen stores (Starling, 1997) in intermittent high-intensity exercise (Hargreaves *et al.,* 2004). Free-fatty acid concentrations in the blood rise during a match, with a heightened rise in the second half (Bangsbo 1994; Krustrup 2005).

2.3.2.6. Fatigue

The demands of soccer place constant stress on players (Walsh, 2014), as they constantly make decisions and follow tactics while dealing with external stressors such as large crowds, the need to perform, sponsors, and weather (Mellalieu, 2009).
Muscular fatigue, which Reilly (1997: 258) defines as a “decline in performance” resulting from the need to constantly perform, has been associated with depletion of carbohydrate/glycogen stores (Hargreaves, 2000) environmental conditions such as high altitude, and high lactate build-up. Soccer movements like kicking and heading require constant exertion of muscular force. A muscle’s reduced capability to produce force constitutes fatigue (Mohr *et al.,* 2003). As fatigue develops, more effort is required to execute physical movements on the field. Soccer players cover less distance in the second half compared to the first half (Reilly, 1997); Bangsbo *et al.* (1991) reported a decrease of 5% in the total distance covered by Danish players in the second half compared to the first. The influence of motivation, the magnitude of the match, and the lack of a warm-up leading up to the second half, among other possible factors have not been investigated in South African soccer.

Centre-backs and forwards, who typically have lower VO_{2max} values, experience more fatigue than midfielders and full-backs (Reilly, 1997). Superior aerobic capacity allows midfielders to not only cover the greatest distance among outfield players, but they can also sustain high exercise intensity for longer (Reilly, 1997). Various attributions for fatigue have been investigated, among them: tactical changes as the end of the game approaches, elevated risk-taking by the team chasing the match, and decreased concentration brought on by mental fatigue. The latter, however, was only Observed in less-skilled players (Marriott *et al.,* 1993). The physiological demands placed on players can be influenced by the playing style. A high-paced game is sustained by a direct approach (Reilly *et al.,* 1992). Reilly (1997: 259) went on to posit that "this style has a levelling effect on the work rate of out-field players, since they are all expected to work at a high intensity `off-the-ball'. There are particular demands on forwards to pressurize defenders and thus prevent a slow, methodical attack being built up".

A study by periodization specialist Verheijen (2012) suggests that adequate recovery not only reduces the likelihood of injury, but it also improves overall team performance. While Bengtsson *et al.* (2013) agree that match congestion increases the rates of muscle injuries, they found limited influence on team performance. After tracking over 27000 matches in European domestic and continental club competition, Verheijen (2012) found that teams with two recovery days between matches concede 75% more goals and score 70% more in the final 30 minutes of regulation time. He noted this to be a direct result of fatigue and recommended three recovery days as sufficient. There are, unfortunately, minimal scientific studies conducted on fixture congestion and its relation to injury frequency and performance in the South African league. Fatigue can be viewed as a way of preventing irreversible muscular damage. Training should be dedicated to the delay of the onset of fatigue. (Kirkendall, 2000).

The lack of recovery in soccer players is intensified in years in which tournaments like the World Cup and continental championships are held. Nedelec *et al.* (2012) notes that several Spanish players had played around 70 matches between the beginning of the 2009/10 season and the end of the 2010 FIFA World Cup. A contributing factor to this number could be the success of Spanish clubs in the UEFA Champions League, particularly Barcelona and Real Madrid, the former reaching the semi-finals in 2010. With the Euro 2016 Championships being held, a similar occurrence would not be much of a surprise. Considering that the tournament falls between seasons, the players will not have sufficient off-season periods leading up to the new season (2016/2017). This could then adversely affect their preseason regime, compromising their performance in the upcoming season. The reality, however, is distinct for the average South African player. Firstly, the South African league has a short break towards the end of the year, something players in the EPL are deprived of. Secondly, South African clubs rarely progress to the latter stages of continental competition, significantly lessening the strain on the players since less travelling will be involved. Furthermore, the need for a last push at the end of the season can be mentally taxing. In the 2013/14 season, Orlando Pirates went against the traditional failure of South African clubs when they made it to the CAF Champions League final. Although that was a great achievement, it meant that they had fallen behind in their domestic league commitments, which led to postponements of matches (Soccer Laduma, 2013). The situation is compounded when it is AFCON year, as this typically plays out in the middle of the season, between January and February. This means that remaining matches have to be played within a period of three to four months. The expected strain on the players cannot and should not be underestimated. This would be accentuated if the tournament was in conditions unfamiliar to the players. South Africa has relatively cooler conditions compared to countries in West, North, and East Africa. A study by Mohr *et al.* (2010) indicated that players fatigue quicker and experience a drop-in performance in warmer conditions. Dehydration could be a contributing factor, as well as the body's inability to adapt to the new environment. Players taking part in continental competition may require extra time to fully recover from the exertions of the game. In congested fixture situations, players may be granted less time to recover from physical activity, leading to poor performance and frequent muscular injuries and heat strains. Several leagues, including the Premier Soccer League, have introduced water breaks in response to this. The water breaks are typically taken 30 minutes into each half (Colorado Rapids, 2015). Duffield *et al.* (2012) recommend individualised strategies for rehydration following intense training to recover lost body water and electrolytes.

To combat the decline in performance, Kellis *et al*. (2006) recommend that pre-season programmes should focus on sustaining strength and kick performance under fatiguing conditions. This would ensure that players are better prepared for intense playing conditions. Based on different tactical approaches and the varied selection of players, the physical characteristics of players may differ between clubs and nations (Haugen *et al.,* 2013).

2.3.2.7 Load

Regular monitoring and evaluation of training load can assist in the prevention of fatigue and injury*.* A consolidated approach that Observes internal and external training load provides a more reliable outlook on training (Bourdon *et al.,* 2017). With the current use of scientific methods to prescribe training loads, coaches no longer need to solely rely on personal experience and intuition (Borresen & Lambert, 2009). These scientific advances, such as GPS and heart rate monitors, can assist conditioning coaches in designing training regimens which preclude under- and overtraining, while enhancing performance (Borresen & Lambert, 2009). The appropriate prescription of training load, which is the Objective of physical preparation, enhances performance (Meeusen *et al.,* 2006). An accurate level of training load is required for optimal performance, as an excessive training load may increase injury risk, while an inadequate training load lessens the chances of physical development. Meeusen *et al.* (2006) recommend a balance between training stress and recovery as a means for performance optimization and the avoidance of overreaching and overtraining. According to Kreider *et al.* (1998), overreaching and overtraining occur when training and non-training stress negatively affect performance. While overreaching may take a few days or weeks to recover from, overtraining may take months.

GPS allows for the assessment of external training loads, through indicators such as distance covered. Knowledge of players' training and match loads can ensure that conditioning coaches adequately prepare players for the rigours of competition through intense training, which aims to minimize injury prevalence (Gabbett, 2016). Due to the congested fixtures and low recovery periods between matches and training sessions, elite soccer players are subjected to high training loads (Malone *et al.,* 2016). Players subsequently experience high training stress (Gabbett, 2016), which predisposes players to injuries. Players being side-lined due to injury may negatively affect team performance (Arnason *et al.,* 2004), which makes injury prevention vital.

Coaches stand to benefit from practical methods of monitoring training intensity (Gilman, 1996). While speed is often used as a measuring tool for intensity, heart rates can be used to estimate oxygen uptake, which gives an idea of performance intensity. Jeukendrup and Dieman (1998) have shown heart rate to decrease during maximal exercise in athletes who are overreached. There are, however, less clear differences in heart rates at submaximal intensities. The relationship between HR and VO_2 cannot only be used to estimate VO_{2max}, but energy expenditure can also be derived from it. Through the linear relationship between HR and VO_2, selected heart rates can be used as indicators of training intensity (Gilman, 1996). Gilman cautions that, in certain conditions such as thermal stress and cardiac drift, heart rates do not accurately align with the VO_2. Furthermore, fatigue and hydration may also influence the relationship between heart rate and VO_2 (Freedson & Miller, 2000), while warm temperature, humidity, and emotional stress can raise the heart rate even though the VO_2 remains relatively unchanged (Melanson & Freedson, 1996; Montoye *et al.,* 1996). At 60% and 80% of VO_{2max}, Swain *et al.* (1994) discovered mean percentages of HR_{max} to be 76 and 89%, respectively. Gilman (1996) recommends the heart rate reserve method as a way of calculating heart rates in order to decrease the gap between the percent of HR_{max} and VO_{2max}. In fact, Weltman *et al.* (1989) found that, after using the heart rate reserve method, the percentages of heart rate were 55, 75, 85, and 95% at 55, 75, 80, and 95% VO_{2max}, respectively.

2.3.2.8. Anaerobic power and muscle strength

Muscle strength and power play a major role in player battles on the soccer field. Forwards and central defenders are often seen fighting to head the ball during corners and freekicks. Stronger and powerful players typically win such duels. This makes the two components vital to success. Considering the close relationship between strength and power, it is imperative for trainers to enhance both elements as a way of improving overall performance. Soccer movements such as sprinting and jumping rely on explosive power and acceleration, which are a direct result of muscle strength and power (Hoff & Helgerud, 2004). Like every other sport, soccer has undergone a multitude of evolutionary progressions. Five decades ago, muscle strength and power were the common denominators for great players. Short-statured players had minimal chances of success due to several factors. As small, dynamic soccer players began to dominate the matches, soccer became more welcoming and accommodative of such players. This can be witnessed in Barcelona’s team under manager Pep Guardiola.

2.3.3. Speed

Speed is an undoubtedly vital aspect in soccer. The importance of speed varies according to playing position and the individual characteristics of each player. In modern times, fullbacks are required to play a more pronounced role in the team's offensive play, thus making speed an indispensable quality. Central defenders are either called centre-backs or centre-halves, depending on the role. In the latter case, a centre-half is expected to join in the attack, which may make speed a useful trait. A creative midfielder with exceptional passing and vision could play a vital role in a team while possessing average speed. A study by Gregson *et al.* (2010) divided high speed activities into total high-speed running distance (THSR), high-speed running (HSR), total sprint distance (TSD) and the total number of sprints undertaken.

Repeated sprint ability (RSA) is indispensable in many team sports, including soccer. Players are required to execute multiple maximal or sub-maximal sprints with minimal recovery over the course of their participation in a sport event (Bishop *et al.,* 2001). The optimisation of aerobic fitness and RSA should be a priority for soccer training. Repeated sprint ability-based training has been proven to improve aerobic fitness in soccer players (Bravo *et al.,* 2008). A full-back may dart forward to the opposition half in a counter-attack, only to run back to his position if his team loses the ball. In extreme cases, the recovery period could be two seconds between his defensive and offensive runs. Players who possess high RSA would thus be likely to perform better (Bishop *et al.,* 2001). In this case, defensive players would likely complete more interceptions, while offensive players may create more scoring opportunities. Fitzsimons *et al.* (1993) describe repeated sprint ability as the ability to reproduce high-intensity short sprints with minimal recovery periods. In a study on repeated high-intensity in soccer (Carling *et al.,* 2012), full-backs were found to spend the most time in high intensity activity, while central defenders spent the least time. Furthermore, central defenders had longer recovery periods between high intensity efforts, while fullbacks had the shortest. Acceleration, agility, and maximal speed, all relatively independent qualities, make up the high-speed actions in soccer match-play (Little & Williams, 2005).

2.3.4. Acceleration

The rate at which a player can alter his velocity allows the player to swiftly perform at his maximal velocity (Little and Williams, 2005). This element of speed is particularly vital for forwards in offensive situations, such as meeting a through ball to complete a goal-scoring chance. Similarly, defenders who are caught out of position require acceleration in order to recover and prevent goals.

2.3.5. Agility

Although defining agility has proven to be a challenging task (Sheppard & Young, 2006), agility is commonly referred to as the ability to change direction and start and stop swiftly (Young, McDowell, and Scarlett, 2001), as a response to stimuli (Chelladurai, 1976). Soccer players are expected to perform multiple changes in direction during a match (Little & Williams, 2005), which makes agility training an important element for soccer players in one-on-one scenarios. An important aspect of agility during match-play is a player's ability to make quick turns. Bloomfield *et al.* (2007) conducted a study on English players and found that defenders performed more turns (700) in the 0-90 degree range than strikers and midfielders (600 and 500, respectively). In the 270-360 degree range, defenders performed the least number of turns. This could be due to efforts in close encounters to evade a marker or aspects of match-play were players are required to face their own goal and the ball is transferred overhead (e.g. goal-kick). Between 90 and 180 degree, there was negligible difference between the positions.

2.3.6. Maximum speed

Little and Williams (2005) describe maximum speed as a player's ability to sprint at maximal velocity. According to Coh *et al.* (2010), maximum speed is determined by stride frequency and length, two factors which have a negative relationship. That is, an increase in frequency leads to a decrease in length. Anthropometric elements such as body height and limb length also contribute to stride length. Performance in a straight-line sprint is the most important factor in the offensive phase when scoring, although these sprints are without an opponent and out of possession (Faude *et al.,* 2012). Elite soccer players have been recorded travelling at speeds around 37km/h with the ball (Flanagan, 2015).

Another important element that is related to speed is reaction time. According to Magill (1998, cited in Senel & Eroglu, 2006), the time between the beginning of a signal or stimulus and the onset of a movement reaction is known as reaction time. The reaction time for an auditory stimulus and visual stimulus is approximately 170ms and 250ms, respectively (Magill 1998). Tripo (1965) and Teichner (1954) (cited in Senel & Eroglu, 2006) divided reaction time into three parts: Perception time, decision time, and motor time. Perception time refers to the time the stimulus is received and the reaction to the stimulus is given. Decision time indicates the time for giving the fitting response to the stimulus. Lastly, motor time refers to the enacting of the order given. Reaction time is especially important for the goalkeeper in soccer. Situations which require excellent reaction time include a deflected shot at goal, which may require both the defender and the goalkeeper to change direction at the last second in order to prevent a goal. Similarly, a striker requires adequate reaction time in order to meet a through ball without being caught offside. Although it is possible to improve reaction time through training, it can be affected by factors such as age, gender, nutrition, and fatigue (Morehouse & Miller, 1976; Tripo, 1965).

2.3.4. Positional profiling

Soccer's continued development has been echoed by technological and scientific advances that have substantially enhanced player performance and injury prevention. In its most conventional format, soccer is played by two teams of eleven players each. Unlike rugby, jersey numbers do not stringently indicate player positions. Clubs can use their discretion in allocating numbers, without having to stick to the conventional 1-11 allocation. Even though this is the case, numbers like 1, 9, and 10 typically indicate a goalkeeper, striker, and creative attacking midfielder, respectively. Teams use formations to configure themselves on the field. The most common formations include the 4-4-2 and its modern version, the 4-2-3-1, the 4-3-3, and the defensively sound 4-5-1 (Bradley *et al.,* 2011). Modern coaches rarely deploy two strikers consistently, except in the 3-5-2 formation. Factors such as tactical identity, quality of players, and the magnitude of the match influence the formation used by each team. Even though some top clubs still rely on 4-2-3-1 (Fontana, 2017), the 4-2-3-1 formation has lost favour and popularity over the past few years (Winterburn, 2017). Teams have resorted to the 4-4-2 (Winterburn, 2017), as well as the 4-3-3 and the 3-4-3.

Figure 2.2: The standard 4-4-2 (left) and the 4-4-2 Diamond (right); direction of play: top to bottom.

Figure 2.3: The standard 4-3-3 and its variant, the 4-2-3-1; direction of play: top to bottom.

Figure 2. 4: The defensively sound 3-5-2; can also be used as a 5-3-2 with the LWB and RWB playing as LB and RB, respectively. Direction of play: top to bottom.

Table 2.3: Playing positions and their abbreviations.

GK	• Goalkeeper
CD	• Central Defender
LB	• Left-back
RB	• Right-back
LWB	• Left Wing-back
RWB	• Right Wing-back
CDM	• Central Defensive Midfielder
CM	• Central Midfielder
CAM	• Central Attacking Midifielder
LW	• Left Winger
RW	• Right Winger
ST	• Striker

2.4. Components of importance for soccer fitness

2.4.1. Distances covered

Although studies focusing on distances covered in soccer matches have increased in volume and popularity, there are few that focus on differences resulting from geographical and cultural differences. Most studies focus on European and South and North American leagues. Even though studies show that soccer players cover between 10 and 12km over 90 minutes, it is not uncommon to find extreme outliers. For example, in the 2012 UEFA Champions League group stage (Whitney, 2012), Barcelona's Lionel Messi averaged 8.2km, while Otelul Galati's Ioan Filip averaged 13,4km, of those who had played over 270 minutes; Filip managed to cover as much as 13,9km in one match. While it is generally believed that teams with less possession cover the most distance during a match, there are no studies indicating a clear correlation (Whitney, 2012). The justification for the idea is that teams without possession would have to run more to regain possession or apply pressure on their opponents off the ball. According to Reilly (2003), only 2% of distance is covered with the ball; the rest of the distance is covered in regaining possession, tackling, and marking.

Movements that contribute to the distance covered during a soccer match include walking, jogging, cruising, shuffling, jumping, and sprinting. Studies over the past four decades (Reilly & Thomas, 1979; Mayhew & Wenger, 1985; Van Gool *et al.,* 1988; Bangsbo *et al.,* 1991; Bangsbo, 1994; Rienzi *et al.,* 2000; Mohr *et al.,* 2003; Krustrup *et al.,* 2005) have established that the average distance covered in a soccer match is 10-13km in 90 minutes for outfield players. Goalkeepers, on the other hand, cover about 5,6km, of which 73% is covered at walking intensity and 2% at high intensity (Di Salvo *et al.,* 2008). In one of the earlier studies on the match performance of soccer referees, Catterall *et al.* (1993) reported that referees covered between 7977m and 10187m during a match. On average, 23% of this distance was covered while walking, 47% jogging, 11.8% running, and 18.2% reverse running (backwards running). Furthermore, referees experienced a decline in distance covered in the second half. This drop is also experienced by players (Reilly & Thomas, 1976; Bangsbo *et al.,* 1991; Mohr *et al.,* 2003). Referees experience fatigue during and towards the end of a competitive match and up to 6% drop in distance covered in the second half (Mallo *et al.,* 2007). Harley *et al.* (2002) reported lower distances at lower competitive levels. County League referees covered between 5760m and 8979m of distance during a match, where 3137m was walking distance, 3475m jogging, 225m running, while 660m was covered running backwards.

2.4.2. High-Intensity Distance Covered

Running, high-speed running, and sprinting constitute the high-intensity distance covered during a match (Schoeman, 2010). Several researchers, including Barros *et al.* (2007) and Di Salvo (2010) categorise these activities under the following speed ranges:

Running: 14-19km/h

High-speed running: 19-23km/h

Sprinting: >23km/h

High-intensity efforts may be crucial in determining the final result (Di Salvo *et al.*, 2008). These may include clearing the ball, converting goal-scoring chances, intercepting through-balls, and preventing counter-attacks.

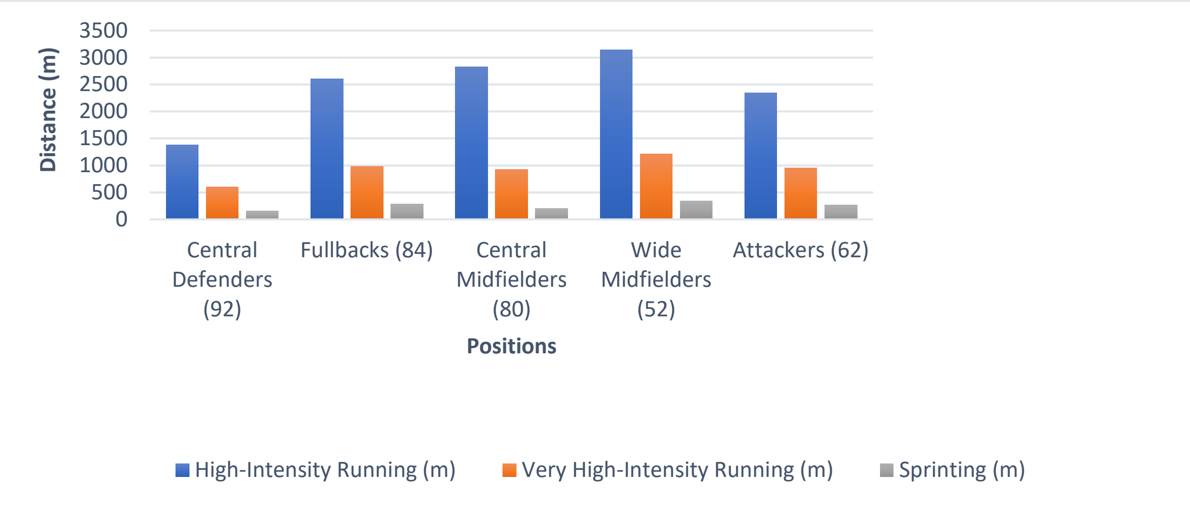

Figure 2.5: High-intensity running, very high-intensity running, and sprinting performance in different positions (Bradley et al., 2009).

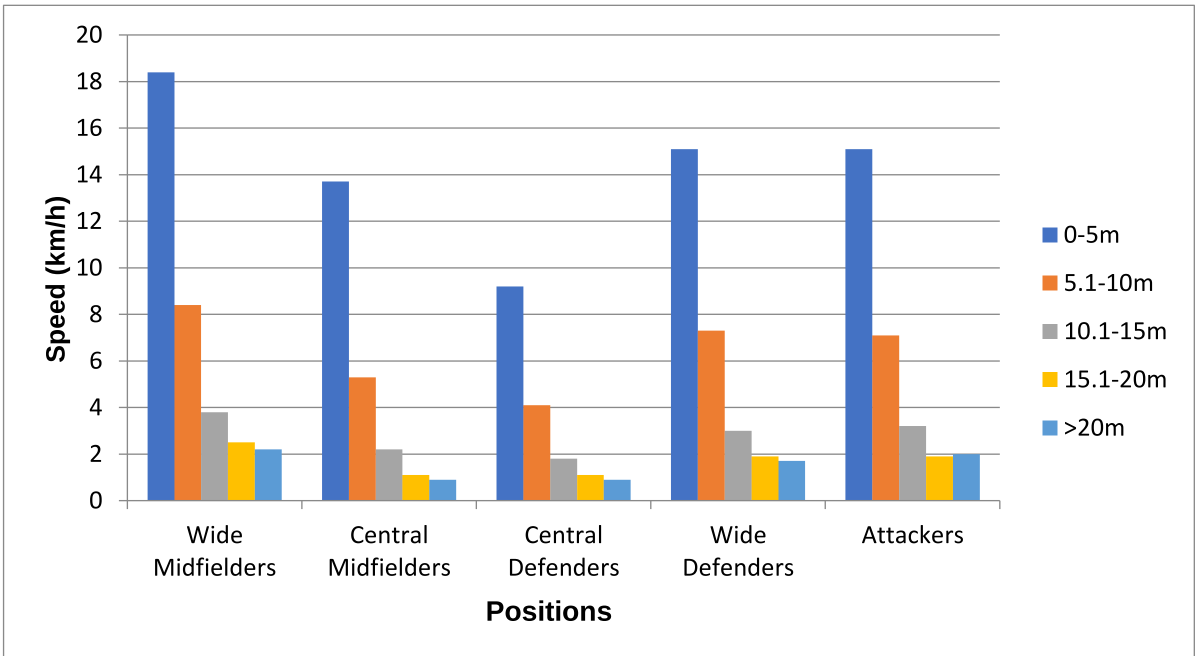

Figure 2.6: Positional differences for each of the five distance categories (Di Salvo et al., 2010)

2.4.3. Percentage Work-rate/ratio at High-Intensity

The average distance covered at high intensity in soccer is between 8% (Rampinini *et al.,* 2007) *and 10%* (Carling *et al.,* 2008) and sprinting ranges from 1-12% of the total distance covered (Rienzi, 2000). A study by Di Salvo (2010) and colleagues on European elite players in the UEFA Champions League and European Championship showed that wide midfielders perform the most sprints during a match, followed by attackers and wide defenders. Central defenders performed the fewest sprints. In the total sprint distance category, the players yielded similar results. In explosive sprints, central midfielders were only second to wide midfielders. Central defenders once again performed the fewest sprints. Goalkeepers on average may cover about 4km per match (Carling *et al.,* 2005) or as high as 5,6km (Di Salvo *et al.,* 2008). Of this distance, 73% is spent walking and only 2% is spent in high-intensity activity. However, these high-intensity efforts may prove decisive in preventing goal-scoring opportunities and saving a deflected shot.

2.4.4. Work-rest ratios

Earlier work by Astrand (1960) showed that high-intensity performance could be enhanced by alternating exercise with rest. A combination of intermittent and high-intensity exercise has gained popularity, owing to its ability to increase overall high-intensity work rate in ways greater than those achieved by continuous exercise efforts (Ballor & Volovsek, 1992). Due to its intermittent nature, soccer is characterized by runs in different intensity interspersed by short and long periods of recovery. These periods of recovery can either be passive or active (Dupont *et al.,* 2004). As a result, training should mimic actual match-play by encompassing submaximal and maximal intensity activity with short and long recovery periods.

Carling *et al.* (2012) conducted a study to characterize repeated high-intensity movement activity profiles of a professional soccer team in official match-play. The results of the study are depicted in the following tables.

Table 2.4: Frequency of recovery periods based on time elapsed between consecutive high intensity actions in relation to positional role.

Recovery Duration(s)	All Players	Fullback	Central Defender	Central Midfielder	Wide Midfielder	Centre Forward
	n=353	*n*=80	*n*=73	*n*=70	*n*=80	*n*=50
	x ± SD	x ± SD	x ± SD	x ± SD	x ± SD	x ± SD
Mean Recovery Time (s)	139.0 ± 42.6	115.8 ± 18.6	194.6 ± 48.4	134.7 ± 28.5	120.5 ±24.1	129.3 ± 27.6
%<20s	14.3 ± 6.0	16.1 ± 5.6	10.8 ± 5.3	16.4 ± 5.6	15.3 ± 5.7	12.4 ± 6.3
%<30s	18.9 ±7.0	21.6 ± 6.3	14.0 ± 6.5	21.0 ± 6.4	20.2 ± 6.1	16.9 ± 6.6
%31-60s	14.1 ± 6.0	16.6 ± 5.6	9.5 ± 5.2	14.2 ± 5.5	15.2 ± 5.0	15.1 ± 6.0
%>61s	67.0 ± 9.6	61.8 ± 7.6	76.5 ± 8.4	64.8 ± 8.1	64.6 ± 8.0	68.0 ± 8.2

Table 2.5: Frequency of repeated high-intensity bouts and characteristics of high-intensity bouts in relation to positional role

High Intensity Bouts	All Players	Fullback	Central Defender	Central Midfielder	Wide Midfielder	Centre-forward
	n=353	*n*=80	*n*=73	*n*=70	*n*=80	*n*=50
	x ± SD	x ± SD	x ± SD	x ± SD	x ± SD	x ± SD
No. of Bouts	1.1 ± 1.1	1.6 ± 0.8	0.4 ± 1.1	1.3 ± 0.6	1.4 ± 1.1	0.6 ± 0.8
No. of HIA/bout	3.3 ± 0.5	3.4 ± 0.6	3.3 ± 0.5	3.2 ± 0.4	3.2 ± 0.4	3.3 ± 0.6
HIA Duration	2.7 ± 0.7	2.9 ± 0.7	2.5 ± 0.8	2.5 ± 0.7	2.6 ± 0.6	2.8 ± 0.7
HIA Distance	16.5 ± 4.9	18.2 ± 4.6	15 ± 5.6	14.9 ± 5	16.2 ± 3.9	17.4 ± 4.4
HIA Recovery	13.6 ± 4.4	14.4 ± 5.2	11.4 ± 3.7	13.7 ± 4.7	13.6 ± 4.4	13.9 ± 4.4
HIA=High-Intensity Actions						

Table 2.6: Characteristics of running activities during recovery periods in between consecutive high-intensity actions in relation to positional role.

Running Activity	All Players	Fullback	Central Defender	Central Midfielder	Wide Midfielder	Centre-forward
	n=353	*n*=80	*n*=73	*n*=70	*n*=80	*n*=50
	x ± SD	x ± SD	x ± SD	x ± SD	x ± SD	x ± SD
% Standing	1.7 ± 0.9	1.6 ± 0.8	2.0 ± 0.9	1.6 ± 1.0	1.7 ± 1.0	1.6 ± 0.9

% Walking	61.3 ± 4.3	61.3 ± 3.6	62.7 ± 2.7	56.9 ± 3.0	62.2 ± 4.9	64.3 ± 2.4
% Jogging	30.3 ± 3.4	30.2 ± 3.2	30 ± 2.4	32.7 ± 2.3	29.4 ± 4.4	28.9 ± 2.3
% Running	6.7 ± 1.7	6.9 ± 1.1	5.3 ± 0.9	8.9 ± 1.5	6.7 ± 1.2	5.2 ± 0.8

Rampinini *et al.* (2007) found that centre-backs and forwards spent more time standing than midfielders (20% and 23% more). Midfielders spent the least time walking and the most time jogging and running. In high-speed running, fullbacks and midfielders covered more distance than the other positions. Consistent with other studies (Barros *et al.,* 2007; Di Salvo *et al.,* 2007), centre backs covered the least distance in the sprinting phase, while fullbacks covered the most distance in this category.

Table 2.7: Distances covered in different intensity according to playing position (Barros *et al.,* 2007; Di Salvo *et al.,* 2007.)

	Distance in Different Positions (m)				
Intensity	Central Defender	External Defender	Central Midfielder	External Midfielder	Attacker
0-11km/h	5488	5567	5673	5601	5325
	7080	**7012**	**7061**	**6960**	**6958**
11-14km/h	1291	1804	1775	1841	1469
	1380	**1590**	**1965**	**1743**	**1562**
14-19km/h	1340	1931	1937	1944	1645
	1257	**1730**	**2116**	**1987**	**1683**
19-23km/h	560	779	719	756	693
	397	**652**	**627**	**738**	**621**
>23km/h	352	562	367	457	437
	215	**402**	**248**	**446**	**404**

2.4.5. Implications for fitness training

Understanding the demands of a particular sport is at the basis of designing efficient conditioning programmes (Deutsch *et al.,* 1998). In fact, before assessing the fitness status of players, the duration, frequency, and intensity of movement patterns executed during a match need to be considered (Dotter, 1998). Several studies have proven that outfield soccer players typically cover 9-13km during match-play (see table 2.1). Furthermore, it is well established that player position influences the amount of distance players cover.

The thorough evaluation of high-intensity running and recovery times during match-play is a vital element in the development of ‘economically valid’ sprint tests (Mascio & Bradley, 2013). In the most-intense period, EPL players during the 2005-2006 season experienced increased work-rest ratios (from 1:12 to 1:2) and a 13% hike in high-intensity running. Considering that central defenders had longer recovery time (67%) between high-intensity bursts and a lower work-rest ratio (1:4 vs 1:2), fitness training and testing must be specific to positional role (Mascio & Bradley, 2013). Although soccer is an intermittent sport (Bangsbo, 2000), about 90% of the energy used in a match is derived aerobically (Bangsbo, 1994; Hoff *et al.,* 2002). Between 8% (Rampinini *et al.,* 2007) and 10% (Carling *et al.,* 2008) of the average distance is covered at high intensity, depending on the playing position. Central midfielders cover the most running distance, followed by fullbacks, wide midfielders, central defenders, and centre-forwards (Carling *et al.,* 2012). These positional differences must be taken into account in the design of efficient conditioning and testing programmes. In the training of the energy systems, the amount of time spent in each intensity must be considered to ensure adequate preparation for match performance.

Several studies (Owen *et al.,* 2004; Rampinini *et al.,* 2007b) have reported higher ratings of perceived exertion and higher physical and physiological workloads imposed on players in small-sided games where the individual playing area was increased. Considering that the individual playing area allows for the regulation of different aspects of soccer training intensity and influences the physical, physiological, and motor responses of players, coaches should take it into account when designing training drills (Casamichana & Castellano, 2010). In the presence of a coach encouraging players to raise their intensity, small-sided games can stimulate physiological adaptation (Rampinini *et al.,* 2007). Katis and Kellis (2009) found that 3-a-side games can improve technique, while 6-a-side games may facilitate tactical development. Furthermore, small-sided games can be used in place of interval training for the purposes of maintaining in-season fitness (Reilly & White, 2005). Moreover, small-sided games can ensure that players engage in “more actions per minute,” which places pressure on the phosphate system, likely resulting in a quicker restoration of the system (Verheijen, 2012: 86).

2.5. Differences between levels of competition

Bradley *et al.* (2013) compared the match performance and physical capacity of players across three levels of English soccer: Premier League, Championship, and the League One championship. Players in League One and the Championship covered more distance overall and at higher intensity, while Premier League players displayed superior technical indicators such as total passes, successful passes, forward passes, balls received and touches per possession. When players moved up in league standard, they covered less high-intensity running distance compared to when they moved down from the Premier League. Bradley *et al.* (2013), however, warn that this data should be carefully interpreted as more research needs to be conducted with larger samples from the lower divisions. There currently exist no published data detailing the distances covered in South African soccer at any level.

2.6. Factors affecting match-play

2.6.1. Magnitude of the game

The physical exertions of an elite team are dependent on the exertions and competitive level of their opponents (Rampinini *et al.,* 2007). Rampinini *et al.* (2007) found that players covered more total distance and more high intensity running against higher quality opponents (higher ranked teams).

2.6.2. Playing formation

The influence of playing formation on match-play has been an under-researched topic. Bradley *et al*. (2011) conducted a study comparing the three most-utilised formations in soccer (4-4-2, 4-3-3, and the 4-5-1). Although there was no difference in overall ball possession between the formations, other important indicators were noted. Attackers in a 4-3-3 covered more distance at high-intensity (HI) and very-high intensity (VHI) compared to those in a 4-4-2 and 4-5-1. Conversely, defenders in a 4-4-2 covered

11% more HI running than 4-5-1 and more VHI running than the 4-5-1 and 4-3-3. In possession, attackers, defenders, and midfielders in the 4-4-2 and 4-3-3 covered more VHI running than 4-5-1. Out of possession, defenders and midfielders in a 4-5-1 covered more VHI than those in a 4-4-2 and 4-3-3.

Attackers in a 4-5-1 covered the least distance, which may be attributed to their more pronounced defensive duties and their isolation upfront as the 4-5-1 sacrifices a forward for an extra midfielder, as well as being outnumbered by opposition defenders.

2.6.3. Environmental Conditions

Elite players fatigue quicker in hot and humid conditions, possibly due to the faster rate of dehydration in such conditions (Mohr *et al.,* 2010). In some leagues (including the ABC Motsepe League), match officials are permitted to grant competing teams a water break, commonly after 25 minutes of each half. During the 2014 FIFA World Cup, officials could grant players a discretionary water break after the 30th minute. While this may rehydrate and re-energise the players, it may also halt momentum. On the other hand, some coaches have taken advantage of the 90 second break to issue tactical instructions, a privilege previously non-existent.

A study by Özgünen *et al.* (2010) indicates that in soccer matches played at high temperatures and relative humidity, the body core temperature increased in the first half and the total distance covered in the second half decreased. Players may pace themselves to minimize thermal strain (Özgünen *et al.,* 2010) or risk early fatigue by over-exerting themselves. High altitude conditions such as hypoxia, excessive cold, and dehydration may lead to breathlessness, nausea and fatigue in soccer players. VO_{2max} and endurance performance decrease by 0,5-1% and 1,1-1,5% for every 100m altitude above sea level (Levine *et al.,* 2008)

This may hinder performance. Since FIFA banned international matches played at 2500m above sea level, FIFA's Sport Medicine Commission declared that matches at 3000m above sea level should only be played after 10 days of acclimatization (McSharry, 2007). Performance at 1700m above sea level without sufficient acclimatization leads to decreased aerobic performance (Demo *et al.,* 2007)

McSharry's (2007) study analysed 10 national teams over a 100-year period covering 1460 matches. High altitude teams performed better than low altitude teams, scoring more and conceding fewer goals in the process. Furthermore, high altitude teams also performed better at low altitude. This could be attributed to different levels of oxygen consumption between the teams. The living high and training low technique, which has become popular among coaches and trainers (Robach *et al.,* 2006), is known to increase maximal oxygen uptake and aerobic performance in athletes (Levine and Stray-Gundersen, 1997; Stray-Gundersen *et al.,* 2001).

2.6.5. Home and Away Matches

Unlike most leagues in the world, South African soccer clubs do not own the stadiums they call home. This has resulted in clubs using multiple stadiums to host visitors. Kaizer Chiefs, for example, have used a handful of stadiums (Soccer City, Rand Stadium, Peter Mokaba, and Nelson Mandela Bay) over the past 5 seasons.

While some studies have Observed the influence of home advantage on team performance (Pollard, 1986; Clarke & Norman, 1995) and player discipline (Nevill *et al.,* 1995), such studies have not been conducted in South Africa. There are cases in which home teams receive significantly fewer cards and more penalties. However, officials with more experience tend to give less home advantage (Boyko, 2007).

2.6.6. Ergogenic Aids

The competitive nature of modern sport has led to a winning against all costs mentality, while the desire to win is a driving force behind doping activity (Ehrnborg & Rosen, 2009). The potential economic gain (through endorsements, wages, and sponsorships), the low frequency of drug testing, and the efficacy of ergogenic aids may lead athletes to the use of drugs (Savulescu *et al.,* 2004). As a result, ergogenic aids, which are substances or strategies utilized to enhance sport performance, are often utilised to maximize the chances of success. Williams (1998) divides ergogenic aids into mechanical, psychologic, physiologic, pharmacologic, and nutritional ergogenics. Modern science has also improved biomechanical ergogenics.

Mechanical or biomechanical ergogenics are aimed at improving aspects like power, balance, traction/grip, while enhancing comfort and minimizing injuries. An example of this would be the Magista soccer boots which have a built-in ankle guard to provide extra stability. Furthermore, boots with traction and stability ensure faster movements and turns, while the design of the boots can influence accuracy and kicking speed (Hennig & Sterzing, 2010).

Psychologic ergogenics, which include imagery, self-talk, and stress management, are employed to enhance mental strength and coping ability. These aids may optimize both individual as well as team performance. Self-talk and imagery, for instance, can help a player prepare for a match by reaffirming their abilities and visualizing the events that may take place during a match. Nutritional ergogenics are used to supplement energy production, delay the onset of fatigue, increase blood oxygen, and these include protein supplements and energy drinks. Pharmacologic and physiologic aids include methylhexanamine, clenbuterol, and erythropoietin. Erythropoietin is known to increase red blood cell count and, as a result, VO_{2max}. The most commonly used physiologic ergogenics are blood doping, creatine, glycerol, sodium bicarbonate, and erythropoietin (EPO). Blood doping, also known as induced erythrocythemia, entails an increased blood volume as a way of enhancing oxygen transport capacity. An increased oxygen transport capacity enhances the aerobic energy systems. A common way of blood doping is through the removal, storage and reinfusion of blood belonging to the athlete (Brooks, *et al.,* 2005). In some cases, blood belonging to another person may be used; however, there is a risk of HIV infection, among other diseases. Considerable increases in work capacity and VO_{2max} have been reported as a result of blood doping. Decreased heart rate and cardiac output can be expected; however, stroke volume usually remains unchanged. Haemoglobin, which affects the binding of O_2 in red blood cells, and blood volume influence the blood's oxygen-carrying capacity. Haemoglobin concentration and haematocrit (the percentage of blood volume occupied by red blood cells) are typically normal in soccer players (Reilly & Doran, 2003)

Although it has been banned since 1984, blood doping continues to be used in sport, with prevalent cases in cycling. Blood doping is not as prevalent in soccer. Erythropoietin, a hormone produced in the kidneys, increases red blood cell production. Among its effects, it increases VO_{2max} and delays fatigue (Juhn, 2003), which directly improves performance in endurance activities. The World Anti-Doping Agency prohibits and regulates the use of certain performance-enhancing substances. Although the use of drugs is prevalent in sport, it is worth noting that not all cases are deliberate. There are cases in which banned substances are ingested through food and energy drinks. 2012 Comrades Marathon winner Ludwick Mamabolo was cleared after initially being charged with the use of methylhexaneamine. He went on to state in an article (Ludwick: Runners not educated about doping, 2013) that South African athletes are not educated enough regarding the testing procedures. He also lamented the handing out of open energy drinks at the end of each race. Considering that some substances are found in everyday dietary choices, substances such as caffeine and creatine monohydrate were removed from the banned list (Brooks *et al.,* 2005). McClaran and Wetter (2007) demonstrated that low doses of caffeine (1,5 and 3mg/kg body weight) can decrease heart rate at submaximal exercise. Sodium bicarbonate has been shown to enhance and sustain sprint performance in prolonged intermittent exercise (Price *et al.,* 2003). Doping in soccer is not as prevalent as it is in sports that focus on single abilities (force, endurance, speed), as soccer is focused on a combination of talents. This is due to the ‘positive effects’ being harder to attain in soccer than in the single ability sports (Haugen, 2004). Prior to the 2014 FIFA World Cup, all players had their urine and blood tested for illegal substances. Furthermore, two players from each team were randomly selected for testing after every match. None of the 512 samples returned positive results (Dvořák, 2014).

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

The aim of this research was to examine the physical and physiological demands placed on second division soccer players during competition and then to compare the demands to higher level soccer leagues. Despite heavy financial investment in South African soccer (Hamil & Chadwick, 2010), there are few TMA studies conducted relative to the extensive research in Europe and the Americas. This section will elaborate on the study design and methodology used to answer the research question. The research process including the participants, data collection procedure, equipment used and analysis of data will be described.

3.2. Theoretical perspectives on research design and methodology

Research methodology describes the process followed by the researcher to conduct research (Mouton, 2001). Tools and equipment are used to generate numerical data in the form of numbers or statistics while the researcher remains Objective and separated from the subject matter.

3.3. Study design

A quantitative study with a cross-sectional design by means of GPS and heart-rate monitoring was conducted to investigate the physical demands placed on second division soccer players during competition. The prevalence of the following variables was examined: total distance covered, high intensity distance covered, and heart rate changes experienced by soccer players. The results of the players were compared to determine positional differences.

3.4. Participants

This study made use of a non-random convenient sample. Only members of one specific soccer team participated in the study. Convenient sampling is described as a cohort of subjects that are most conveniently available to the researcher (Polit & Beck, 2004). TMA through GPS was conducted on a total of twenty-four (24) players who were involved in the seasonal squad of the UFS Soccer team taking part in the ABC Motsepe League. Starting and substitute data was collected on fifteen (15) matches during the 2017/18 season, of which one of the matches was in the regional Nedbank Cup competition. Players were studied according to their playing groups: goalkeepers, defenders, midfielders, and forwards. Although most of the players had specialist positions on the field, the coaching team would ultimately decide the positions players would play in each match. Furthermore, injuries, substitutions, and tactical approaches impacted the positions which the players took up in each game. As a result, it was common for a player to change their position midway through a match and, in some cases, play a different position in the following match. Moreover, this resulted in some players having more than one preferred position. Consequently, only the primary preferred position is mentioned below.

Of the 24 participants, three (3) players preferred to play CB, four (4) preferred to play CA, another four (4) preferred to play FB, eight (8) preferred to play CM, while three (3) players preferred to play W. Only two (2) players preferred to play GK.
Participation was voluntary but endorsed by team management (coaching and medical staff).

3.4.1. Inclusion criteria

1. The player must have been included in the University of the Free State 1st Soccer team by the coaching staff.
2. The player must have been healthy and free of illness or any disease that may have affected his performance or put the participant`s health at risk.
3. The player must have been free of any injuries which may have negatively influenced his performance.
4. The player must have been able and willing to give consent in English.
5. The player must have played a full match for the data to be included as a player game in the statistical analysis. A full match, in this case, was defined as the total time played by the player within 5 min of total match time.

3.4.2. Exclusion criteria

1. Any player excluded from the team squad was automatically excluded from the study.
2. Injured players did not partake in the study until they were fully rehabilitated and had the go ahead from the coach and medical staff.
3. Any player suffering from illness was excluded from the study until they had fully recovered.
4. Any player who refused or was incapable of providing consent in English was excluded from the study.
5. Any data from a player who did not play a full match was excluded in the analysis. A full match, in this case, was defined as the total time played by the player within 5 min of total match time.

3.4.3. Withdrawal of study participants

In the case of a participant sustaining an injury or becoming ill the participant will be withdrawn from the study. Although for team sports, there will be eleven (11) players available per match as players that are ill or injured will be replaced.

3.5. Data collection

TMA was conducted over fourteen (14) matches of the Free State ABC Motsepe League and one (1) match in the Nedbank Cup during the 2017-2018 season. A total of fifteen (15) matches was investigated. Thirteen (13) of these matches were official matches, while two (2) matches were used as part of a pilot study. Data was collected from the eleven (11) starting players and up to three (3) substitutes included in the University of the Free State 1st soccer team competing in the 2017/18 ABC Motsepe League. The ABC Motsepe League is the second division of the South African soccer league system. The competition consists of sixteen (16) teams participating in a round-robin league based on a home and away system. The ABC Motsepe League follows a similar structure to the PSL, in that the participating teams play each other on a home and away basis. This equates to a total of 30 matches in the Free State region. The winner of each provincial division goes through to promotional playoffs, where they face off in a two-stream round-robin. The two winners of the playoffs are promoted to the National First Division (SAFA).

Every player wore the GPS unit in a padded protected harness, positioned between his left and right scapula in the upper thoracic spine area underneath their playing jersey (Cahill *et al*., 2012). The harness is designed to be comfortable and prevent unwanted movement of the GPS unit but did not hinder performance. Pre-season matches and training sessions was used to familiarize players with the harness and device.

The strength and conditioning coach together with the researcher were responsible for supplying and fitment of the GPS units before the game. The GPS unit was fitted and switched on ten minutes before warmup starting approximately 40 minutes before the start of the match. Warmup data was collected but separated from match play data during analysis. GPS units was switched off directly after the match or when a player leaves the field of play due to substitution or injury. After the match, data was downloaded to a personal computer and further analysis was carried out using system software provided by the manufacturer.

Players were grouped according to their respective positions and groups within the team. Figure 3.1 shows the different classification systems that were used to group the players. In the first place, players were grouped as goalkeeper, centre back, outside back (left and right full back), central midfielder, winger, and central attack (central attacking midfielder and striker). Secondly, each individual playing position (numbers one to eleven) was Observed to determine specific positional movement patterns and physical demands (Cahill *et al*., 2012).

GK	Goalkeeper
CB	Centre back
FB	Fullback
CM	Central midfielder
W	Wing/Winger
CA	Central attack

Figure 3.1: Positional classification.

Figure 3.2: Soccer positions

This research investigated the following variables: total distance covered, high intensity distance covered, and work to rest ratios, velocity and changes of direction experienced by soccer players.

3.6. Equipment

3.6.1 Specification

Catapult Optimeye X4 GPS units were used to gather data for this research project. The device measures 96 x 52 x 14 mm with a weight of 67g and has a 5-hour battery life. GPS data was recorded at 10Hz for positional, velocity and acceleration measures. A 100Hz accelerometer is incorporated to measure linear motion, impact forces, acceleration and deceleration. Angular motion and rotation are measured by a

100Hz (2000 degrees/second) gyroscope. Magnetometers measuring at 100Hz are used to capture direction and orientation data. Heartrate data was collected by a Polar heart rate belt.

3.6.2. Validity and reliability

Although there is limited data on the validity and reliability of GPS devices (Portas *et al*., 2007), the GPS receivers evaluated by (Gray *et al.,* 2010) are valid in terms of measuring linear distance at low to high intensities. Jennings *et al*. (2010) Observed improvements in reliability and validity with an increased sampling frequency. Johnston *et al.* (2014) agreed that 10Hz and 15Hz units are more reliable than 1Hz and 5Hz units for measuring movement demands and proved valid and reliable instruments for measuring total distance covered. However, Johnston *et al*. (2014) also demonstrated higher validity and reliability of 10Hz Catapult units compared to 15Hz GPS units of other manufacturers.

During their review of the validity and reliability of GPS in team sports, Kelly *et al.* (2014) concluded that the validity of 10Hz units in measuring short sprint distance was acceptable. Furthermore, these devices have good intra- and inter-unit reliability when used to measure sprint distances between 15 and 30 meters (Castellano *et al*., 2011). Varley *et al*. (2012) found good to moderate validity and reliability for instantaneous velocity during constant velocity and acceleration, but poor validity for instantaneous velocity during deceleration. Catapult MinimaxX accelerometers were proven to be technically reliable by Boyd *et al.* (2011), both within and between devices for the measurement of physical activity in team sport during their research on Australian Soccer. Hernando *et al.* (2016) validated Polar heart rate monitors for use during physical activity (Hernando *et al.,* 2016), while Engström *et al.* (2012) reported good criterion-related validity and test-retest repeatability during exercise.

According to Catapult (2019), player load is calculated by dividing the instantaneous rate of change of acceleration by a scaling factor. Boyd *et al.* (2011) measure player load according to the following formula:

$$\text{Player load} = \sqrt{\frac{\left(a_{y1} - a_{y-1}\right)^2 + \left(a_{x1} - a_{x-1}\right)^2 + \left(a_{z1} - a_{z-1}\right)^2}{100}}$$

Where:

a_y = Forward accelerometer

a_x = Sideways accelerometer

a_z = Vertical accelerometer

Furthermore, player load provides an Objective outlook on the work done by a player independent of the distance covered. By categorising player load per unit distance covered, the efficiency of a player's movement can be determined. On the other hand, player load measured over time can indicate changes in the efficiency of a player's movement (Catapult, 2019).

3.6.2. Descriptions

The following table details various aims related to the study, their descriptions, and Microsoft Excel equations.

Table 3.1: Aims and descriptions

AIM	DESCRIPTON	EXCEL EQUATION
Physical profile of varsity soccer players	To determine the average Weight, Height and Body fat% of the different playing positions.	Determine the average of C, D and E and compare to the Playing positions in (F)
To determine the **HR (beats per minute)** response of elite varsity soccer players as well as the HR response of the different playing positions during match play	Determine the average HR of all players Determine the average HR of the different positions	Average of O Compare average HR (O) between the positions (F)
To determine the **total distance covered (km)** of elite varsity soccer players and to investigate the difference between the different positions	Determine the average distance covered of all players Determine the average distance covered of the different positions	Average of (I) Compare the distance covered (I) between positions (F)
To determine the total **player load (Load $^{TM}\cdot$min^{-1}(au))** of elite varsity soccer players as well as the player load of the different netball positions during match play	Determine the average PL of all players Determine the average PL of the different positions	Average of (J) Compare average PL (J) between the positions (F)
To determine **Player Load per Meter** of elite varsity soccer players and to investigate the difference between the **different positions**	Determine the average PL/m of all players Determine if there is a difference in PL/m between the different positions	Average of (L) Compare average PL/m (L) between the positions (F)
To determine **Player Load per Meter** of elite varsity soccer players and to investigate the difference between the different **Quarters of play**	Determine if there is a difference in PL/m between the different quarters of play	Compare PL/m (L) with Period name (B)
To determine the **Maximum Velocity** of elite varsity soccer players and to investigate the	Determine the maximum velocity of all players	Max Velocity (P)

difference between the **different positions**	Determine if there is a difference in Max velocity between the different positions	Compare Max Velocity (L) between the positions (F)
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 varsity soccer players and to investigate the difference between the different positions, **:** "**Walking:** Strolling locomotor activity in either a forward, 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."	Determine the distance covered in each velocity band Determine if there is a difference in distance covered in each velocity band between the different positions	Distance covered: Band 1 Walking: (Q) Band 2 Jogging: (R) Band 3 Running: (S) Band 4 Sprinting: (T) Band 5, 6, 7,8 (U), (V), (W), (x) Compare DISTANCE IN EACH VELOCITY BAND (Q, R, S, T, U, V, W, X) between the positions (F)
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 varsity soccer players and to investigate the difference between the different positions	Determine the % distance covered in each velocity band Determine if there is a difference in distance covered in each velocity band between the different positions	Distance covered: Band 1 Walking: (y) Band 2 Jogging: (Z) Band 3 Running: (AA) Band 4 Sprinting: (AB) Band 5, 6, 7, (AC), (AD), (AE), (AF) Compare **%** DISTANCE IN EACH VELOCITY BAND BETWEEN THE positions (F)
To determine **how many times** during a match the different positions perform each of the above-mentioned player movement patterns by elite varsity soccer players and to	Determine the effort count of the velocity bands	Velocity bands effort count: Band 2 Walking: (AW) Band 3 Jogging: (AX) Band 4 Running: (AY) Band 5 Sprinting: (AZ) Band 6, 7, 8, (BA), (BB), (BC)

investigate the difference between the different positions		Compare **EFFORT COUNT** IN EACH VELOCITY BAND BETWEEN THE positions (F)
To determine **how LONG** during a match the different positions perform each of the above-mentioned player movement patterns by elite varsity soccer players and to investigate the difference between the different positions	Determine the DURATION SPENT IN EACH of the velocity band	Duration: Band 1 Walking: (AG) Band 2 Jogging: (AH) Band 3 Running: (AI) Band 4 Sprinting: (AJ) Band 5, 6, 7, (AK), (AL), (AM), (AN) Compare **DURATON** IN EACH VELOCITY BAND BETWEEN THE positions (F)
To investigate the **time spent (sec)** during the above-mentioned player movement patterns by elite varsity soccer players and to investigate the difference between the different positions	Determine the average effort duration of each velocity band	Average effort duration: Band 2 Walking: (BK) Band 3 Jogging: (BL) Band 4 Running: (BM) Band 5 Sprinting: (BN) Band 6, 7, 8, (BO), (BP), (BQ) Compare **EFFORT DURATIION** IN EACH VELOCITY BAND BETWEEN THE positions (F)
To investigate the **percentage of total time,** spend during the above-mentioned player movement patterns by varsity soccer players and to investigate the difference between the different positions	Determine the % of total time spent in each velocity band	% Velocity band duration Band 1 Walking: (AO) Band 2 Jogging: (AP) Band 3 Running: (AQ) Band 4 Sprinting: (AR) Band 5, 6, 7, (AS), (AT), (AU), (AV) Compare **%** DISTANCE IN EACH VELOCITY BAND BETWEEN THE positions (F)
To determine the total number of Accelerations and Decelerations performed by each playing position	Determine the effort count of the Acceleration bands.	Total number of Accelerations: Acc effort count band 5 (CX) Acc effort count band 6 (CY) Acc effort count band 7 (CZ) Acc effort count band 8 (DA) Total number of decelerations Acc effort count band 1 (CT) Acc effort count band 2 (CU) Acc effort count band 3 (CV) Acc effort count band 4 (CW)

		Compare between positions (F)
To determine whether player load, total distance covered and total high intensity distance covered by elite varsity soccer players have an influence on the result of the match	Determine if a higher PL, higher Distance covered may influence the outcome of the match	Compare Total distance (I) Total PL (J) Winning and losing teams (G)

*Abbreviations in parentheses indicate column in Excel spreadsheet

3.6.3. Limitations

GPS may be limited by atmospheric interference or local overhead obstructions due to an error in the distance calculated between the satellite and the position and speed of the GPS unit (Larson, 2009). Most researchers agree that error in GPS units increased as the speed of movement increased. Furthermore, GPS units sampling at a lower frequency (1Hz and 5Hz) resulted in greater error for high intensity running and sprinting (Jennings *et al*., 2010; Johnston *et al*., 2012). Speeds higher than 20km/h pose a limitation on GPS systems regardless of the sampling rate (Johnston *et al*., 2014). The sports vest used to house the GPS unit also houses a heart rate monitor. Some of the players complained about irritation and discomfort caused by the HR monitor.

3.7. Ethical aspects

The following persons/bodies provided written permission for the study to be conducted:

- The Ethics committee of the Health Sciences Research Ethics committee of the University of the Free State;
- Department of Student Affairs, University of the Free State
- Director of the University of the Free State sport (KovsieSport)
- Head coach of the University of the Free State men's soccer team

All data collected during the study was only used for the purposes of this study and was kept confidential. Participation in the study was voluntary and each participant could withdraw from the study at any point. All participants were given an information sheet (appendix A-1) which was explained by the researcher. Following that, all participants completed and signed informed consent forms in English (appendix A-2). Before the first match, a practical information session was held to explain how the GPS unit, vest, HR monitor, and chest strap function. This was conducted to provide clarity and ensure that the fitting of the equipment would not impede on the match preparation process. Before each match, each player in the starting line-up received a vest, GPS unit, and HR monitor. Players were responsible for putting on the vest on; each vest had already been fitted with the HR monitor and GPS unit before being handed over to the players. The researcher was responsible for switching on all units before commencement of the match. At the end of a match or after a substitution, the GPS unit was handed to the researcher by the player. The GPS units were safeguarded by the researcher throughout the match.

3.8. Statistical procedures

The primary analysis Objective was to provide profiles of activity data for the different playing positions and to assess the differences between the playing positions with respect to the activity data. Because a primary analysis Objective was to assess the differences between the playing positions with respect to the activity data, a player's data for a given game was included in the statistical analysis if that player played the full game (no substitution or red card; defined as total duration played by the player within 5 min of total match duration). Thus, data from 149 player games were available for statistical analysis. All subsequent analyses are based on this data subset. Descriptive statistics for each activity variable are provided for the 149 player games, separately by playing position, and overall. Note that the sampling unit now is a player game, so that the summarised 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. The p-value was set at <0.05. 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.

3.9. Timeline of the study

August 2017: Ethical clearance granted

September 2017: Data collection commences

December 2017: Data collection concluded

January-May 2018: Statistical analysis

May-December 2018: Writing up of results and discussion

CHAPTER 4: RESULTS

4.1. Introduction

This chapter will present the results from the study, based on the primary aim of this study, which was to evaluate the physical and physiological demands of second division soccer players during official competition using a GPS accelerometer with built-in tri-axial (Catapult Minimax X4) and heart rate monitors (Polar). Through GPS data, insight will be gained on (1) total player load, (2) player load per meter and per minute, (3) heart rate (HR) response, (4) maximal velocity, (5) total distance covered and (6) distance covered in different velocity bands. These sets of data were collected during the ABC Motsepe League and the Nedbank Cup throughout the first half of the 2017/2018 season. Due to the matches being played in a league format, except the Nedbank Cup match, all matches were 90 minutes long plus injury time. In other words, none of the matches included extra time. In this chapter, the results from the study will be presented using tables and box plots for additional illustration.

4.2. Demographic information of participants

4.2.1. Number of players and number of player games analysed

Twenty-four (n=24) players forming part of the University of the Free State men’s soccer first team took part in the study. Although most of the players had specialist positions on the field, the coaching team would ultimately decide the positions players would play in each match. Furthermore, injuries, substitutions, and tactical approaches impacted the positions which the players took up in each game. As a result, it was common for a player to change their position midway through a match and, in some cases, play a different position in the following match. Moreover, this resulted in some players having more than one preferred position. Consequently, only the primary preferred position is mentioned below.

Of the 24 participants, three (3) players preferred to play CB, four (4) preferred to play CA, another four (4) preferred to play FB, eight (8) preferred to play CM, while three (3) players preferred to play W. Only two (2) players preferred to play GK.

A total of fifteen (15) completed matches were analysed. Of these fifteen matches, two were used as part of a pilot study. Although the HR and GPS data were collected from a total of 24 players, some of the players played more than one match and, therefore, were tested more than once. A total of hundred and forty-nine (149) HR and GPS data sets (player matches) were analysed. Therefore, data on a total of 298 (149 x 2) player halves were available and analysed.

4.3. Heart rate (HR) response

The boxplots in Figure 4.1 display the distributions of maximum HR and of mean HR for the different playing positions. Descriptive statistics for these variables are presented in Table 4.1.

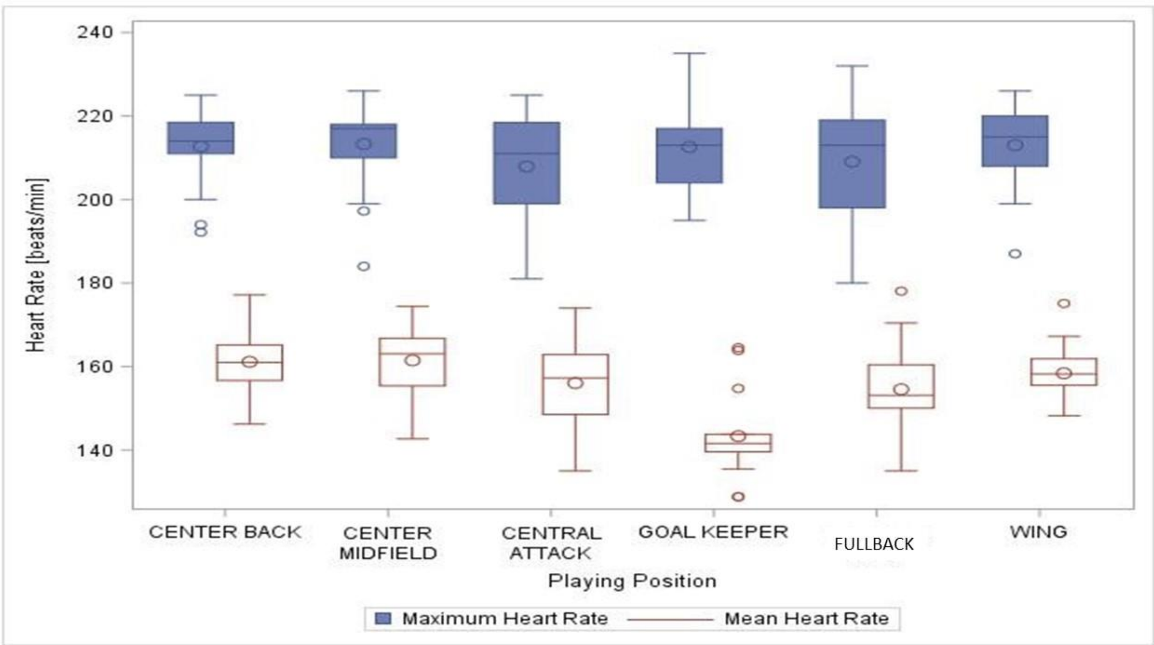

Figure 4.1: Box plot: HR response of second division soccer players (n=149 player games)

The upper and lower quartiles of the mean heart rate of the GK are lower than the lower quartiles of all the other playing positions, which indicates that the GK had a significantly lower mean heart rate than all the positions. The IQRs of all positions except the GK overlap with reference to the mean heart rate, indicating that there are no clinically significant differences between the CB, CA, CM, FB, and the W. In terms of the maximum heart rate, the upper quartile of the CM is approximately equal to, or higher than, the lower quartiles of all the other positions. Similarly, the upper quartile of the W is approximately equal to, or higher than, the lower quartiles of all the positions except the CM. This indicates that the CM and the W yielded the highest maximum heart rates among all the positions. The IQRs of all the positions in reference to maximum heart rate overlap, which indicates that there are no clinically significant differences between all the other positions.

Table 4.1: Heart rate response: Descriptive statistics

HR Response

Descriptive Statistics

		Playing Position						
		CENTER BACK	**CENTER MIDFIELD**	**CENTRAL ATTACK**	**GOALKEEPER**	**FULLBACK**	**WING**	**All**
Maximum Heart Rate (b/min)	N	28	30	27	15	26	23	149
	Mean	212.7	213.3	207.9	212.6	209	213	211.4
	Min	192.2	184	181	195	180	187	180
	Max	225	226	225	235	232	226	235
Mean Heart Rate (b/min)	N	28	30	27	15	26	23	149
	Mean	161.1	161.5	156	143.3	154.5	158.4	156.9
	Min	146.2	142.7	135	128.8	135	148.2	128.8
	Max	177.1	174.4	174	164.5	178.1	175.1	178.1

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 4.2: Maximum Heart Rate: Mean differences between playing positions

Playing position	**Statistic**	**Comparison with playing position**					
		CB	**CM**	**CA**	**GK**	**FB**	**W**
	Mean (b/min)	212.7	213.3	207.9	212.6	209	213
	SE	2.0348	1.9653	2.0664	2.7113	2.1036	2.2388
CB	Difference	-	-0.6	4.8	0.1	3.7	-0.3
	P-value		0.8311	0.0831	0.9575	0.1817	0.9762
CM	Difference		-	5.4	0.7	4.3	0.3
	P-value			0.0486	0.8169	0.1171	0.8166
CA	Difference			-	-4.7	-1.1	-5.1
	P-value				0.16	0.702	0.1066
GK	Difference				-	3.6	-0.4
	P-value					0.2829	0.9794
FB	Difference					-	-4
	P-value						0.2159
W	Difference						-
	P-value						

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.

The CM had the highest maximum HR (213.3 b/min), with mean differences ranging from 0.3 to 5.4 b/min. The CM's only significant difference (p=0.0486) was in relation to the CA (207.9 b/min), which reported the lowest maximum HR, with differences ranging from -5.4 to -1.1 b/min.

Table 4.3: Mean heart rate: Mean differences between playing positions

Playing position	Statistic	Comparison with playing position					
		CB	CM	CA	GK	FB	W
	Mean (m)	161.1	161.5	156	143.3	154.5	158.4
	SE	2.0348	1.9653	2.0664	2.7113	2.1036	2.2388
CB	Difference	-	-0.4	5.1	17.8	6.6	2.7
	P-value		0.8311	0.0831	0.9575	0.1817	0.9762
CM	Difference		-	5.5	18.2	7	3.1
	P-value			0.0486	0.8169	0.1171	0.8166
CA	Difference			-	12.7	1.5	-2.4
	P-value				0.16	0.702	0.1066
GK	Difference				-	-11.2	-15.1
	P-value					0.2829	0.9794
FB	Difference					-	-3.9
	P-value						0.2159
W	Difference						-
	P-value						

The CM (161.5 b/min) had the highest mean HR among all positions and a significant difference (p=0.0486) compared to the CA, with differences ranging from 0.4 to 18.2 b/min. The GK (143.3), on the other hand, had the lowest mean HR, with differences ranging from -11.2 to -18.2 b/min. There were no significant differences between the GK and the other positions.

4.4. Velocity

Table number 4.4 indicates the velocity ranges in each velocity band and the amount of walking, jogging, running, and sprinting distance covered by each position.

Table 4.4: Distance covered: Mean distance covered [m] in different velocity bands

Movement classification	Velocity Band (m.s^{-1})	CB	CM	CA	GK	FB	W
Walking (m)	0.2 – 1.7	3142.6	2930.8	3279.9	3361.6	3199.3	3322.9
Jogging (m)	1.8 – 3.6	3951.5	5009.3	4659.9	1201.6	4324.7	4680.4
Running (m)	3.7 – 5.3	836.2	1425.3	1484.6	109.7	1261.8	1401.6
Sprinting (m)	>5.4	284.2	343.2	469.6	4.6	418.6	613
Mean Total distance (m)		8241.5	9734.9	9911.5	4692.4	9223.3	10024.9

Mean: Least squares mean from mixed model analysis.

The GK (3361.6m) covered the highest walking distance, closely followed by the W (3322.9) and the CA (3279.9), while the CM (2930.8m) covered the least distance. In contrast, the GK (1201.6m) covered the lowest jogging distance, while the CM (5009.3) covered the highest. The CA covered the highest running distance, with 1484.6m, while the W covered the highest sprinting distance (613m). The GK covered the lowest running (109.7m) and sprinting distance (4.6m).

4.5. Distance covered

4.5.1. Total distance covered

Table 4.5: Total Distance: Descriptive statistics

Velocity Bands: Distance								
Descriptive Statistics (m)								
				Playing Position				
		CB	**CM**	**CA**	**GK**	**FB**	**W**	**All**
Total Distance	N	28	30	27	15	26	23	149
	Mean	8241.5	9734.9	9911.5	4692.4	9223.3	10024.9	8934.1
	Min	6014.4	6267	6498.5	3658.9	8225.7	8325.7	3658.9
	Max	11153.6	11529.8	11221	5644.7	10596.2	10822.7	11529.8
Velocity Band 1 Distance	N	28	30	27	15	26	23	149
	Mean	3142.6	2930.8	3279.9	3361.6	3199.3	3322.9	3184.6
	Min	2691.6	2008.3	2810.5	2952.8	2735.7	3016.7	2008.3
	Max	3662.9	3361.6	3859.1	3792.4	3491.7	3701.5	3859.1
Velocity Band 2 Distance	N	28	30	27	15	26	23	149
	Mean	3951.5	5009.3	4659.9	1201.6	4324.7	4680.4	4193.6
	Min	2385.9	2770.7	2389.3	668	3589.7	3907.4	668
	Max	5791.9	6329.6	5826	1581.6	5274.2	5242.2	6329.6
Velocity Band 3 Distance	N	28	30	27	15	26	23	149
	Mean	524	935.6	936.5	83.7	765	858.8	731
	Min	232	475.2	469.4	31.6	537.6	554.9	31.6
	Max	1145.5	1366.6	1273.1	185.5	1106.4	1052.6	1366.6
Velocity Band 4 Distance	N	28	30	27	15	26	23	149
	Mean	312.3	489.7	548.1	26	496.8	542.7	429.7
	Min	122.7	255.7	259.6	11.1	220.5	340.5	11.1
	Max	703.8	841.7	824.9	70.8	829.6	790.7	841.7
Velocity Band 3/4 Distance	N	28	30	27	15	26	23	149
	Mean	836.2	1425.3	1484.6	109.7	1261.8	1401.6	1160.7
	Min	354.7	871.3	729	48.1	758.1	905.7	48.1
	Max	1849.3	2023.1	2098.1	256.3	1936	1843.3	2098.1
Velocity Band 5 Distance	N	28	30	27	15	26	23	149
	Mean	176.8	242	294.3	4.2	272.1	354.6	237.9
	Min	53.9	61	46.4	0	107.4	113.4	0

	Max	292.8	404.3	441.6	19.5	449.6	536.8	536.8
Velocity Band 6 Distance	N	28	30	27	15	26	23	149
	Mean	107.4	101.2	175.2	0.5	146.4	258.4	137.8
	Min	16.6	5.8	41	0	0	92.9	0
	Max	239.2	221.8	451.9	7.1	311.5	414	451.9
Velocity Band 5/6 Distance	N	28	30	27	15	26	23	149
	Mean	284.2	343.2	469.6	4.6	418.6	613	375.7
	Min	71.4	66.8	161	0	107.4	220.8	0
	Max	491.5	626.1	893.5	23.5	750.9	947.6	947.6

The W covered the highest total distance covered with a mean of 10024.9m, followed by the CA, which covered 9911.5m on average and the CM with a mean of 9734.9m covered during match play. In contrast, the GK and CB covered the least amount of distance during match play with means of 4692.4m and 8241m, respectively. The W (10024.9m) covered significantly more distance ($p<0.05$) than the CB, GK, and the FB, with mean differences ranging from 113.4m to 5332.5m. Furthermore, the difference in distance covered by the CM and the CA was significantly less ($p<0.05$) than all the other positions (CB, GK, FB, W). The mean differences between the CM and the CA, CB, GK and W range from -176.6 to 5042.5m and the mean differences between the CA and the CM, CB, GK and W ranged from 176.6m to 5219.1m. The difference in distance covered between the CM and the CA was not significant. Table 4.4 also illustrates that most of the total distance covered is covered between 0.2 – 3.6 $m.s^{-1}$ (velocity band 1 and velocity band 2). The GK (3361.6m) covered the most distance in velocity band 1 ($p<0.05$) than all the positions, which accounts for 71% of the GK's total distance. The GK was closely followed by the W (3322.9m) and the CA (3279.9m), which accounted for 33% of the total distance of both positions. The CM, with 2930.8m, covered the least distance in velocity band 1, which was 30% of its total distance. In velocity band 2, the CM (5009.3m) covered a significantly higher distance ($p<0.05$) than all the positions except the CA. In fact, 51% of the CM's total distance was covered in velocity band 2. The W (4680.4m) and CA (4659.9m) followed the CM, both with 47% of their total distance covered in velocity band 2. In velocity band ¾, the CA (1484.6m) covered significantly more distance ($p<0.05$) than the GK, FB, and

CB; this band accounted for 15% of the CA's total distance. The GK (109.7m) only covered 2.3% of its total distance in this band. The least total distance was covered in velocity band 6, where the W (258.4m) covered the most distance ($p<0.05$), which accounted for 2.6% total distance. The W was followed by the CA (175.2) and the FB (146.4), which covered 1.8% and 1.6% of their total distance in velocity band 6, respectively. In velocity band 5/6, which is sprinting, the W (613m) covered more distance than every other position ($p<0.05$), which represented 6.1% of the W's total distance. CA (469.2m) and FB (418.6m) respectively covered 4.8% and 4.5% of their total distance in this band. The GK (4.6m) only covered 0.1% of the total distance in this band.

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

Table 4.6: Total Distance covered [m]: Mean differences between playing positions

Playing position	Statistic	Comparison with playing position					
		CB	CM	CA	GK	FB	W
	Mean (m)	8241.5	9734.9	9911.5	4692.4	9223.3	10024.9
	SE	29.3522	26.8671	27.8413	39.6441	27.9562	30.0007
CB	Difference	-	-1493.4	-1670	3549.1	-981.8	-1783.4
	P-value		<.0001	<.0001	<.0001	0.0047	<.0001
CM	Difference		-	-176.6	5042.5	511.6	-290
	P-value			0.7286	<.0001	0.0175	0.9064
CA	Difference			-	5219.1	688.2	-113.4
	P-value				<.0001	0.0505	0.8415
GK	Difference				-	-4530.9	-5332.5
	P-value					<.0001	<.0001
FB	Difference					-	-801.6
	P-value						0.0426
W	Difference						-
	P-value						

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 4.2, 4.3, and 4.4 display the distributions of distance covered in the different velocity bands (movement classifications) for the different playing positions. The results of the statistical comparison of the different playing positions are presented in Tables 4.6, 4.7, 4.8, 4.9.

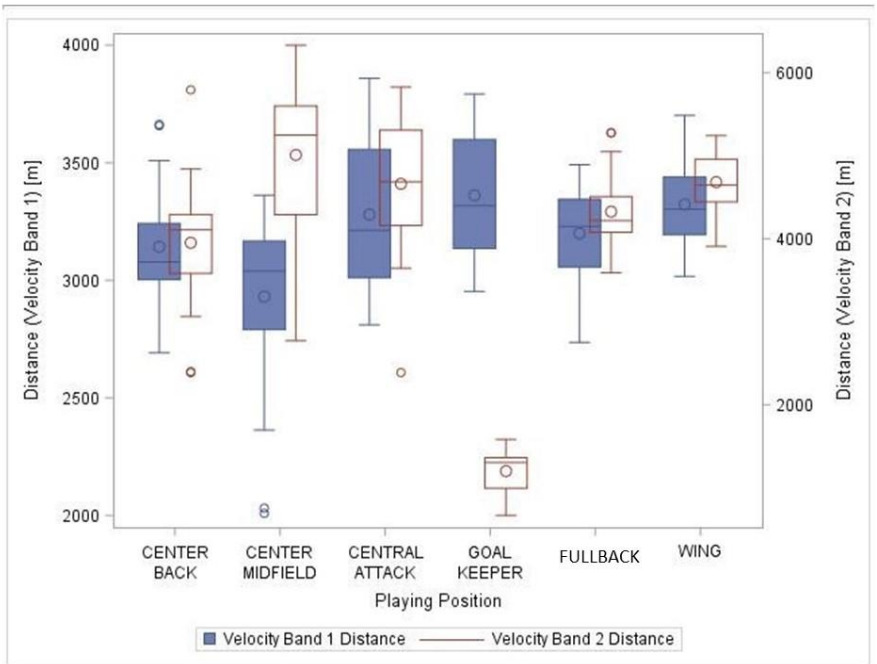

Figure 4. 2: Box plot: Distance covered in Velocity band 1 and Velocity band 2 (n=149 player games)

The upper and lower quartiles of the distance covered in velocity band 1 by the GK are approximately equal to, or higher, than the lower quartiles of all the other playing positions, which indicates that the GK positions covers more distance in velocity band 1 than all the positions. In contrast, the upper and lower quartiles of the distance covered in velocity band 2 by the GK are approximately equal to, or lower, than all the other positions, which indicates that the GK covers less distance in velocity band 2 than all the other positions.

Table 4.7: Distance covered: Mean differences between playing positions in Velocity band 1

Playing position	Statistic	Comparison with playing position					
		CB	**CM**	**CA**	**GK**	**FB**	**W**
	Mean (m)	3142.6	2930.8	3279.9	3361.6	3199.3	3322.9
	SE	66.4501	57.9915	60.4024	94.7823	60.746	66.6023
CB	Difference	-	211.8	-137.3	-219	-56.7	-180.3
	P-value		0.0346	0.2757	0.1562	0.6227	0.0582
CM	Difference		-	-349.1	-430.8	-268.5	-392.1
	P-value			0.0002	0.0042	0.0046	<.0001
CA	Difference			-	-81.7	80.6	-43
	P-value				0.5192	0.5147	0.2811
GK	Difference				-	162.3	38.7
	P-value					0.2664	0.9192
FB	Difference					-	-123.6
	P-value						0.1217
W	Difference						-
	P-value						

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

In velocity band 1, the mean distance covered by the GK (3361.6) was significantly higher than the CM, with a mean difference of -430.8m. With a mean difference of -392.1m, the mean distance covered in velocity band 1 by the W was significantly higher ($p<.0001$) than the CM.

Table 4.8: Distance covered: Mean differences between playing positions in Velocity band 2

Playing position	Statistic	Comparison with playing position					
		CB	CM	CA	GK	FB	W
	Mean (m)	3951.5	5009.3	4659.9	1201.6	4324.7	4680.4
	SE	155.12	143.46	148.22	205.25	148.71	158.57
CB	Difference	-	-1057.8	-708.4	2749.9	-373.2	-728.9
	P-value		<.0001	0.0004	<.0001	0.0434	0.0026
CM	Difference		-	349.4	3807.7	6846	328.9
	P-value			0.0759	<.0001	0.0003	0.038
CA	Difference			-	3458.3	335.2	-20.5
	P-value				<.0001	0.0537	0.5745
GK	Difference				-	-3123.1	-3478.8
	P-value					<.0001	<.0001
FB	Difference					-	-355.7
	P-value						0.182
W	Difference						-
	P-value						

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.

In contrast to velocity band 1, the GK (1201.6m) covered the lowest mean distance in velocity band 2, with mean differences ranging from -2749.9 to -3807.7. The mean distance covered by CM was significantly higher (<0.05) than all the other positions except CA (p=0.0759), with mean differences ranging from 328.9m to 3807.7m.

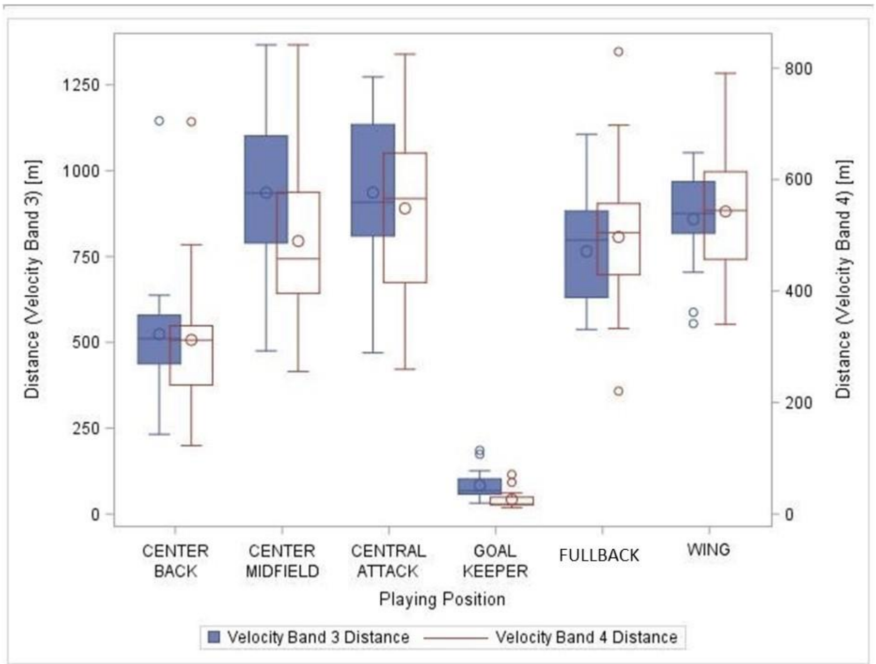

Figure 4.3: Box plot: Distance covered in Velocity band 3 and Velocity band 4 (n=140 player games)

The boxplot in Figure 4.3 shows definite differences between distances covered by the different positions in velocity bands 3 and 4. The GK covered significantly lower distances than all the other positions, as the upper and lower quartiles of the GK in velocity bands 3 and 4 are significantly lower than the lower quartiles of the other positions. Similarly, the CB also covered less distance than the other positions, except GK, in velocity bands 3 and 4. This is evident due to the CB's upper and lower quartiles being lower than the lower quartiles of the other positions except the GK. The IQRs of the CB and GK in velocity bands 3 and 4 do not overlap with the IQRs of the other positions, which suggests that there are significant differences ($p<0.05$) between these two positions and the CB, CM, CA, FB, and W.

Table 4.9: Distance covered: Mean differences between playing positions in Velocity band 3/4

Playing position	Statistic	Comparison with playing position					
		CB	**CM**	**CA**	**GK**	**FB**	**W**
	Mean (m)	836.2	1425.3	1484.6	109.7	1261.8	1401.6
	SE	67.8194	61.1522	63.3613	92.8727	63.6477	68.6869
CB	Difference	-	-588.8	-648.4	726.5	-425.6	-565.4
	P-value		<.0001	<.0001	<.0001	.<0001	<.0001
CM	Difference		-	-59.3	1315.6	163.5	24
	P-value			0.3003	<.0001	0.1172	0.7505
CA	Difference			-	1374.9	222.8	83
	P-value				<.0001	0.0183	0.1926
GK	Difference				-	-1152.1	-1291.9
	P-value					<.0001	<.0001
FB	Difference					-	-139.8
	P-value						0.2736
W	Difference						-
	P-value						

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.

The CA, CM, and W covered the highest mean distance ($p<0.05$) in the combined velocity bands 3 and 4, with 1484.6m, 1425.3 and 1401.6m during matchplay, respectively, while the CB (836.2) and the GK (109.7) covered the lowest distance in both bands. A combination of velocity bands 3 and 4 details mean differences between the CA and other positions ranging from 59.3 to 1374.9. In this combination, mean differences between the CB ($p<0.05$) and other positions range from -425.6 to -565.4 and from -726.5 to -1374.9 between the GK and other positions

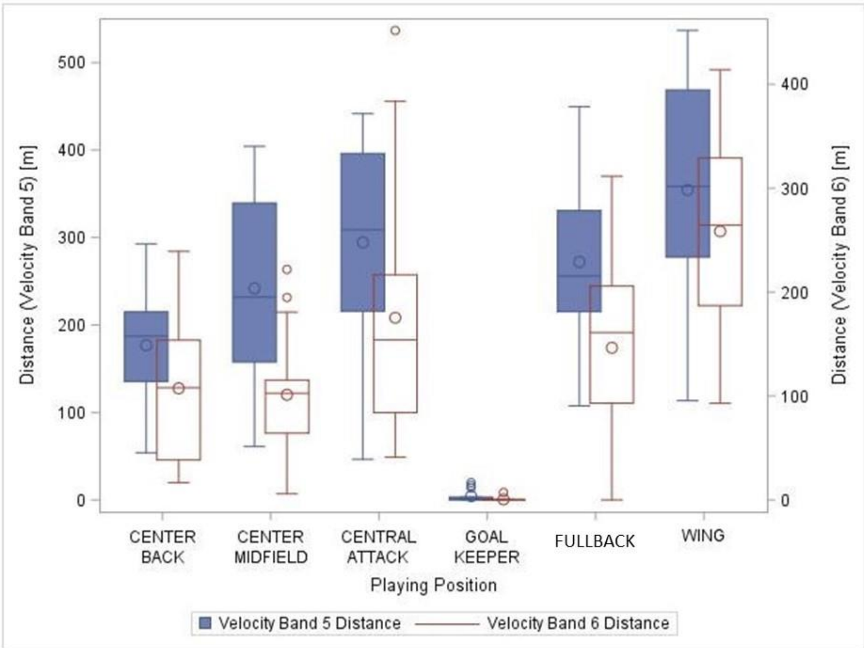

Figure 4.4: Box plot: Distance covered in Velocity band 5 and Velocity band 6 (n=149 player games)

In velocity band 5, the W covered the highest mean distance, which is indicated by the upper quartile of the W being approximately equal to, or higher, than the lower quartiles of the other position. This observation was replicated in velocity band 6, indicating that the W covers the highest sprinting distance (258.4m). The GK, on the other hand, covered the lowest distance in both velocity bands 5 and 6. This is illustrated in both the upper and lower quartiles of the GK being lower than the lower quartiles of the other positions. The IQRs of all positions except the GK in velocity band 5 and 6 overlap, which suggests that there are no significant differences between the other positions; however, these positions covered significantly higher distances ($p<0.05$) than the GK in velocity bands 5 and 6.

Table 4.10: Distance covered: Mean differences between playing positions in Velocity band 5/6

Playing position	Statistic	Comparison with playing position					
		CB	CM	CA	GK	FB	W
	Mean (m)	284.2	343.2	469.6	4.6	418.6	613
	SE	35.7522	33.6155	34.8287	46.9044	34.8629	37.0361
CB	Difference	-	-59.2	-185.4	279.6	-134.4	-328.8
	P-value		0.1989	0.0003	0.0003	0.0039	<.0001
CM	Difference		-	-126.4	338.6	-75.4	-269.8
	P-value			0.0017	<.0001	0.0545	<.0001
CA	Difference			-	465	51	-143.4
	P-value				<.0001	0.2606	0.0036
GK	Difference				-	-414	-608.4
	P-value					<.0001	<.0001
FB	Difference					-	-194.4
	P-value						0.0004
W	Difference						-
	P-value						

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.

The W covered the highest distance ($p<0.05$) in the combined velocity bands 5 and 6, while the GK covered the lowest distance. A combination of velocity bands 5 and 6 shows mean differences between the W (613m) and other positions ranging from 143.4 to 608.4 and from -279.6 to -608.4 between the GK (4.6) and other positions.

4.6. Player load (PL)

4.6.1. Total PL

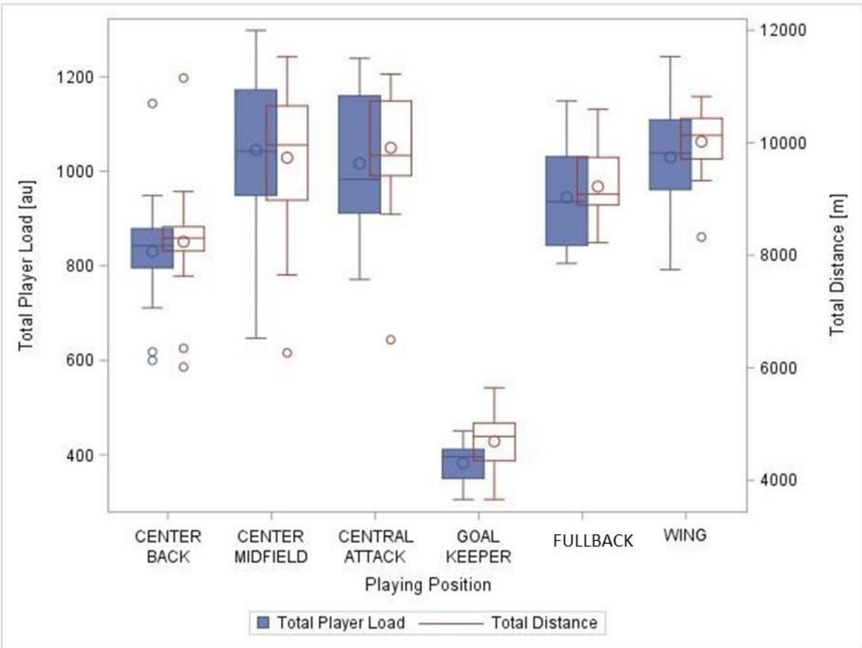

Figure 4.5: Box plot: Total player load and total distance (n=149 player games)

The boxplot in figure 4.5 details the distributions of the total player load and player distance as covered by the different playing positions. The results of the statistical comparison of the different playing positions with regard to player load, player load per meter, and player load per minute are presented in Tables 4.11, 4.12 and 4.14 respectively.

The upper quartile of CM's total player load is approximately equal to or higher than the lower quartiles of all the other positions, which indicates that CM yielded the highest total player load. In contrast, the lower and upper quartiles of the GK's total player load are lower than the lower quartiles of all the other positions, indicating that the GK yielded the lowest total player load among the positions. The IQR of the total player load for CB, CA, CM, FB, and W overlap, which suggests that there are no significant differences between these positions.

Table 4.11: Mean differences in total player load

Playing position	Statistic	Comparison with playing position

		CB	CM	CA	GK	FB	W
	Mean (au)	830.4	1044.5	1016.4	383.1	944.9	1029.8
	SE	29.3522	26.8671	27.8413	39.6441	27.9562	30.0007
CB	Difference	-	-214.1	-186	447.3	-114.5	-199
	P-value		<.0001	<.0001	<.0001	0.0047	<.0001
CM	Difference		-	28.1	661.4	99.6	14.7
	P-value			0.7286	<.0001	0.0175	0.9064
CA	Difference			-	633.3	71.5	-13.4
	P-value				<.0001	0.0505	0.8415
GK	Difference				-	-561.8	-646.7
	P-value					<.0001	<.0001
FB	Difference					-	-84.9
	P-value						0.0426
W	Difference						-
	P-value						

The CM (1044.5 au) had a higher mean player load than the other positions, with mean differences ranging from 14.7 to 661.4. The CM's mean player load was significantly higher than the other positions except the CA and the W. This was closely followed by the W (1029.8au) and the CA (1016.4au), with mean differences ranging from 14.7 to 646.7 (au) and from 28.1 to 561.8 (au), respectively. On the other hand, the GK (383.1 au) recorded the lowest player load among all the positions, with mean differences ranging from -447.3 to -661.4 (au).

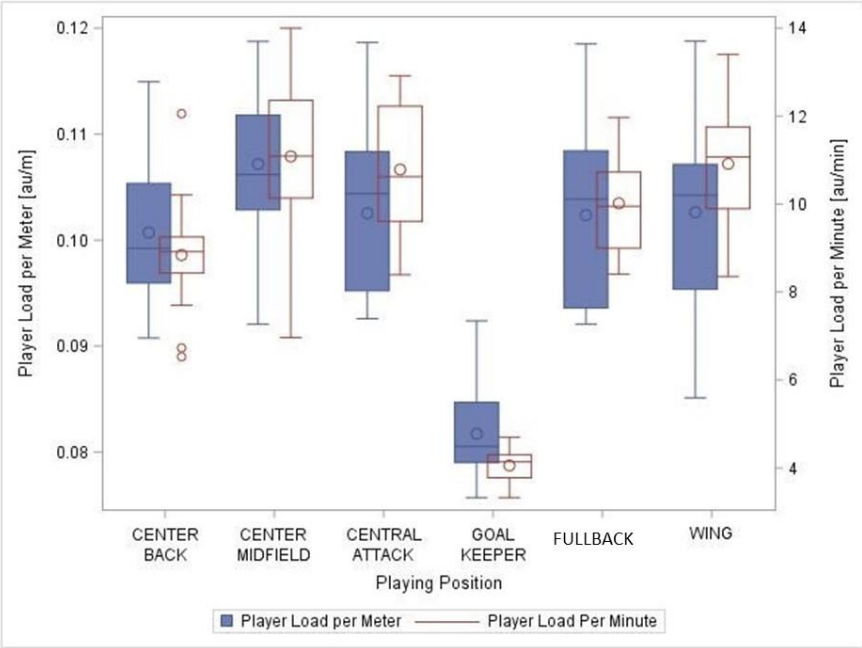

Figure 4.6: Box plot: Player load per minute and Player load per meter (n=149 player games)

The boxplots illustrate that the CM had a higher player load per meter and per minute than the CA, CB, GK, FB, and W. On the other hand, the GK had a significantly lower ($p<0.05$) player load per meter than the other positions, as the GK's upper and lower quartiles are lower than the lower quartiles of the CA, CB, GK, FB, and W. Similarly, the GK's player load per minute was significantly lower than the other positions, as the upper and lower quartiles are lower than the lower quartiles of the other positions. The IQR for player load per meter and per minute of the CB, CA, CM, FB, and W overlap, which indicates that there are no clinically significant differences between the positions. In contrast, the GK's IQR is far lower than the other positions, which indicates that the GK's player load per meter and per minute is significantly lower ($p<0.05$) than the other positions.

Table 4.12: Player load per meter and player load per minute: Descriptive statistic

Descriptive Statistics								
	Statistic	Playing Position						
		CB	CM	CA	GK	FB	W	All
Player load per meter (au/m)	N	28	30	27	15	26	23	149
	Mean	0.101	0.107	0.103	0.082	0.102	0.103	0.101
	Min	0.091	0.092	0.093	0.076	0.092	0.085	0.076
	Max	0.115	0.119	0.119	0.092	0.119	0.119	0.119
Player load per minute (au/min)	N	28	30	27	15	26	23	149
	Mean	8.84	11.085	10.786	4.054	10.017	10.916	9.689
	Min	6.528	6.965	8.393	3.325	8.408	8.353	3.325
	Max	12.056	13.999	12.917	4.699	11.971	13.405	13.999

Table 4.13: Total player load per meter: Mean differences between positions

Playing position	Statistic	Comparison with playing position					
		CB	CM	CA	GK	FB	W
	Mean (au/m)	0.101	0.107	0.103	0.082	0.102	0.103
	SE	0.002062	0.001737	0.001815	0.003013	0.001828	0.002033
CB	Difference	-	-0.006	-0.002	0.019	-0.001	-0.002
	P-value		0.4101	0.9995	<.0001	0.9992	0.5672
CM	Difference		-	0.004	0.025	0.005	0.004
	P-value			0.3178	<.0001	0.3261	0.8487
CA	Difference			-	0.021	0.001	0
	P-value				<.0001	0.9535	0.4744
GK	Difference				-	-0.02	-0.021
	P-value					<.0001	<.0001
FB	Difference					-	<.0001
	P-value						0.5066
W	Difference						-
	P-value						

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.

The CM (0.107au/m) had the highest player load per meter, with mean differences ranging from 0.004 to 0.0025. Following this, the CA and W (0.103au/m) had identical player loads per meter, with mean differences ranging from 0.004 to 0.021. The GK (0.082au/m), on the other hand, had the lowest player load per meter, with mean differences ranging from 0.019 to 0.025 (au/m).

Table 4.14: Total player load per minute: Mean differences between positions

Playing position	Statistic	Comparison with playing position					
		CB	**CM**	**CA**	**GK**	**FB**	**W**
	Mean (au/min)	8.84	11.085	10.786	4.054	10.017	10.916
	SE	0.3	0.271	0.2817	0.4144	0.283	0.3059
CB	Difference	-	-2.245	-1.946	4.786	-1.177	-2.076
	P-value		<.0001	<.0001	<.0001	0.0059	<.0001
CM	Difference		-	0.299	7.031	1.068	0.169
	P-value			0.7514	<.0001	0.0153	0.9579
CA	Difference			-	6.732	0.769	-0.174
	P-value				<.0001	0.0429	0.8106
GK	Difference				-	-5.963	-6.862
	P-value					<.0001	<.0001
FB	Difference					-	-0.899
	P-value						0.0339
W	Difference						-
	P-value						

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 Pos

The CM (11.085au/min) had the highest player load per minute, with mean differences ranging from 0.169 to 7.031. The W (10.916au/min) and the CA (10.786au/min) closely followed with mean differences ranging from -169 to 6.862 and from -0.174 to 6.732, respectively. The GK (4.054au/min), on the other hand, had the lowest player load per minute, with mean differences ranging from -4.786 to 7.031au/min.

CHAPTER 5: DISCUSSION OF RESULTS

5.1. Introduction

Even though the use of TMA to study the physical and physiological demands of sport has become commonplace globally, its use in South African sport remains relatively rare. Even though there are few studies that investigate the physical and physiological demands of South African soccer, several teams have recently invested in GPS systems as a way of conducting TMA, as can be witnessed during some PSL matches. The results of such studies are currently not available in the public domain. The current study involved 24 participants from one team taking part in the ABC Motsepe League and the Nedbank Cup (one match). The average age of the team was 22, with the youngest being 18 and the eldest being 29 at the beginning of the study. Only full match data was utilised; that is, substitution information was not used in the analysis of the data. Full match data, for the purpose of analysis in this study, entailed match duration that was within five minutes of the total match duration. Moreover, the participants played in their specialist positions in some matches. However, the coaching team deployed some players in several positions during a match and the season. Caution is recommended when comparing current data with older studies, as different instruments and sample sizes may have been used to conduct these studies (Buchheit *et al.,* 2014). Furthermore, the influence of playing formation should be considered, as it can influence the distance covered by players (Hennessy & Jeffreys, 2018). Moreover, the understanding of various playing styles is imperative in the analysis and interpretation of performance data (Lago-Peñas *et al.,* 2018). Over and above, it is worth noting that the players in the current study were students during the study while they took part in a professional league, entailing that their academic commitments could likely have impacted their performances.

5.2. Heart rate (HR) response

Heart rate responses have historically been used to estimate training and performance intensity in soccer (Esposito *et al.,* 2004), as well as differentiate between various training methods (Duarte *et al.,* 2010). Krustrup (2005) reported that soccer players perform at a mean heart rate between 152 and 186 b/min. In this study, the mean HR of all participants was 156.3 b/min, while the mean maximum HR of all participants was 209.8 b/min. Contrastingly, university level Belgian players were recorded performing at a mean heart rate of 167 b/min (Van Gool, 1998).

The participants in the current study performed at 75% of the maximum HR, which was lower than the 86% reported by Krustrup (2005). The CM had the highest mean HR (161.2 b/min), while the GK had the lowest mean HR (143.3 b/min). The difference in mean HR was only significant between the CM and the CA (p=0.0486) The CM had the highest mean maximum HR (213.3), with no significant differences between the CM and the other positions, while the CA had the lowest maximum HR (207.9). Through the relationship between HR and VO_2, energy expenditure and VO_{2max} can be estimated (Gilman, 2006). The players in the current study performed at an energy expenditure that is lower than the 75% reported by Reilly (1997) for elite soccer players. Even though this difference could be due to this study being conducted in 2nd division of South African soccer, considering that the players can be expected to perform at a lower energy expenditure than their elite counterparts, this is not always the case. Bradley *et al.* (2013) indicated that players in lower divisions may yield superior results in certain indicators such as distance covered, as well as high-intensity running distance. Reilly (1996) reported that although midfielders and fullbacks cover the highest distances, they experience less fatigue than the other positions. This could be attributed to their superior aerobic capacity, as previously reported by Reilly (1996). However, although fullbacks in the current study covered the second highest distances, they surprisingly recorded the third lowest mean HR. Furthermore, heart rates can be used to indicate the intensity of performance (Gilman, 2006). Considering that CB and CM had the highest mean HR and, higher energy expenditure, therefore, they would be more likely to be performing at a higher physiological level than the

other positions. In relation to the CB, however, there is a contrast to Reilly (1997) declaring that a higher energy expenditure was linked to superior distance covered because the CB covered the second lowest total distance in the current study.
GKs in the current study recorded the lowest mean HR (143.3 b/min), which could be attributed to their low to moderate intensity activities. Furthermore, GKs rarely exit their 18-yard box, except when they must clear the ball after all defenders have been beaten or when they take an indirect free kick just outside their box. However, Sever and Zorba (2017) reported that GKs in their study had a final HR of 192.1 b/min. Unfortunately, it is not readily clear if final HR is synonymous with maximum HR, which was 212.6 b/min for GKs in the current study.

The HR results from the current study and others suggest that the GK experiences the lowest physiological demands, while the CM performs at the highest physiological level than every position during matchplay. These differences may be attributed to the responsibilities of each position, the player's physical profile and playing style, as well as the tactical approaches of each team.

5.3. Velocity

Aughey (2011) and Rampinini *et al.* (2009) categorised velocity bands as low-intensity running (LIR), moderate-intensity running (MIR) and high-intensity running (HIR), running, while the current study grouped the velocity bands into walking, jogging, running, and sprinting. The velocity ranges were based on Dwyer *et al.* (2012), who classified them as 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}. [1]. The GK (3361.6m) covered the highest walking distance, but yielded the lowest distance in the other velocity bands. This can likely be attributed to the GK's role, which comprises low-moderate intensity activities. The highest jogging distance was covered by the CM (5009.3m). Possibly due to the task of meeting through balls and crosses to score goals, the CA covered the highest running distance (1484.6m). The constant requirement to sprint down the wing was the likely reason for the W covering the highest sprinting distance (613m).

5.4. Distance covered

Total distance covered is a commonly-used measure to guide coaches and trainers in effective conditioning programme design. Several studies (table 2.1) have indicated that outfield soccer players cover between 10 to 13km during match play, while goalkeepers cover about 5.6km (Di Salvo *et al.,* 2008). Bangsbo (2001) reports that the distance covered in the first half of the match is usually 5% greater than that covered in the second half, which may be due to fatigue. The current study did not investigate performance differences between the first and second halves. The distance covered by soccer players exceeds several field sport players, including rugby union, who cover between 3km and 7km during match play (Roberts *et al.,* 2008; Gabbett *et al.,* 2012), which could be due to the greater length of a soccer match and differences in match activities. However, any comparisons between the current study and older studies should be conducted with caution, particularly due to the use of video analysis in some studies and GPS in others. This makes a direct comparison challenging and potentially inaccurate. During the 2018 World Cup, the highest total distance was covered by Croatian winger Ivan Perisic with 72,5km (average mean distance of 10.4km) over 632 minutes (average duration of 90.3 min/match) played in 7 matches (FIFA, 2018). As mentioned earlier, none of the matches in the current study went into extra time, as they were played in a league format. The CM in the current study covered less distance than those in other studies. In table 2.1, the CM covered between 10 and 12km, while those in the current study covered a mean distance of 9734.9m and a maximum distance of 11529.8m. These differences could be due to differences in individual playing styles and tactical approaches. For instance, some of the players deployed in central midfield were versatile to the point that they were, in some matches, played at central defence and fullback. This could affect the way they perform in certain positions. Similarly, none of the central defenders depicted in table 2.1 covered less than 9km, whereas those in the current study covered a mean distance of 8241.5m and a maximum distance of 11153.6m. The CA (strikers/forwards and central attacking midfielders) covered a mean distance of 9911.5m and a maximum distance of 11221m in the current study, while those in table 2.1 covered between 9.6km and 11.8km mean distance. Outside backs and wingers covered mean distances of 9223m and 10024.9m, respectively, with maximum distances of

10596.2m and 10822.7m. The FB in other studies, however, covered between 10.1km and 11.5km. Similarly, the W in other studies (table 2.1) covered greater mean distances than in the current study, ranging from 10.3km and 12.2km. A corresponding study (Bradley *et al.,* 2013) conducted on League One players, which is the third tier of English soccer, yielded superior distances in all positions. For example, while central defenders in the current study covered a mean total distance of 8241.5m, those in the comparative study covered a mean distance of 10980m. However, it is worth noting that players in League One had covered superior total distances than their counterparts in the Championship and Premier League at central defence, fullback, central midfield, and attack. This may indicate several points of caution. Firstly, the assumption that players at the highest level of play cover greater distances is dispelled with these comparisons. Secondly, it may bring light to the point earlier made by Bangsbo *et al.* (2014) that high intensity efforts set apart quality players from their average counterparts. In fact, the Premier League players covered the least total distance in all positions. Consequently, coaches of teams from lower divisions may benefit from improving high intensity training in preparation for matches against opposition in higher leagues.

The differences between the current study and previous studies could be due to player identity, individual and team playing styles, as well as tactical approaches. As previously stated in chapter two, playing style can influence the distance covered in a match. To illustrate, a team that attacks mostly through their right flank is likely to influence the distance covered by the right full back and right winger. Similarly, the tactics of the opposition may influence distance covered by particular positions. For instance, if the team A's attacks are mostly from the right flank, team B's left full back may cover a lot more distance than in matches where the opposition does not overuse the right flank. Furthermore, some players covered irregular distances between matches. This could be attributed to the in-game positional changes, in which a player may have been moved from central midfield to fullback, for instance. This was a common practice during this study, where in some of the matches studied, one of the central midfielders changed his position mid-game after a substitution, moving to fullback in most cases. Subsequently, one of the central midfielders would switch to a central attacking midfield position, which could likely affect his total distance covered in that match. Central defenders, who consistently covered the lowest distances among the outfield players, typically confine themselves to defensive duties, with occasional attacking moves. This may be the reason behind their relatively lower distances. Over and above, a player's individual playing style may influence their total distance covered. A pair of central midfielders in a team may cover different average distance due to individual playing style. One player may rely on positional intelligence to intercept the opposition's attacks, while the central midfield partner may rely on speed and agility to fulfil the same duty.

In velocity band 1 (walking), the GK covered the most distance (3361.6m), with a significant difference compared to the CM (p=0.0042). However, the GK covered the least distance among the playing positions in the rest of the velocity bands. This can be attributed to the in-match responsibilities of a goalkeeper. To illustrate, the goalkeeper spends a large period of the match organizing and commanding the defence, taking goal kicks, and intercepting attacks from the opposition, which are tasks mostly executed at low velocity. CMs covered the least walking distance (2930.8m) in velocity band 1, which could be due to their linking role between attack and defence requiring them to spend limited periods in low velocity. The GK's distance covered in this band accounts for 71% of the GK's total distance covered, which is similar to the GK's walking distance (73%) reported by Di Salvo *et al.* (2008). Even though the GK's activities are primarily carried out at low intensity, training regimes should primarily focus on enhancing the GK's high-intensity actions, as these may be vital to the match result (Di Salvo *et al.,* 2008). These high-intensity actions may include saving, controlling, clearing the ball (De Baranda, Ortega & Palao, 2008). The W (3322.9m) and the CA (3279.9m) both covered 33% of their total distance in velocity band 1, while the CM (2930.8m) only covered 30% of its total distance in this band. The CM's linking role may explain why the CM (5009.3m) covered the most distance in velocity band 2, with significant no differences compared to all positions except the CA (p=0.0759). The CMs may be required to be in constant motion to fulfil the dual responsibility of attack and defence. By virtue of their position on the field, CMs provide support for the defence, particularly through intercepting attacks from the opposition. On the other hand, CMs are also tasked with the responsibility of creating scoring chances by moving the ball into the opposition half. The distance covered in this band accounted for 51% of the CM's total distance, while the W (4680.4m) and the CA (4659.9m) both covered 47% of their total distance in velocity band 2. Central attackers (1484.6m) covered the highest distance running (velocity band 3/4), which could be attributed to one-on-one scoring opportunities, as well as the meeting of through balls coming from the midfield. There were no significant differences between the CA and the CM (p=0.3003) and the W (p=0.1926). The CA's superior running distance over the other positions was in contrast to Carling (2012), who reported that CMs covered the highest running distance, while the centre forwards covered the lowest running distance. However, it is worth noting that the current study combined central attacking midfielders and forwards into one positional category (CA), which calls for caution when making this comparison between the two studies. In order to score goals from crosses, CAs need to possess high running ability and capacity. Of the total distance covered by the CA and the CM (1425.3m), 15% was covered running. The CM's high running distance could be due to the responsibility of intercepting opposition attacks and forward runs to join the attack in creating goalscoring opportunities. Furthermore, the CM typically functions in tandem with the CA in attack, which could explain their similar distances covered in this band. The most sprinting distance (velocity band 5/6) was covered by the W (613m), with no significant differences, who are tasked with offensive and defensive responsibilities. The Ws are expected to sprint down the wing and dribble past the opposition's wingers and fullbacks and cross the ball for the central attackers, who had the second highest sprinting distance (469.6m). The W covered 6.1% of total distance in sprinting activity. In Bradley *et al.* (2009) and Di Salvo *et al.* (2010), W yielded similar results to the current study, as they covered superior high intensity running and sprinting distances than the CB, CM, CA, GK, and FB. As stated earlier, the role of the GK could explain why only 109.7m and 4.6m were covered by the GK in running (velocity band 3/4) and sprinting (velocity band 5/6), respectively. The GK's running and sprinting distances amounted to a total of 2.4% of the GK's total distance covered, which was slightly higher than the 2% high intensity distance reported by Di Salvo *et al.* (2008). Furthermore, GKs in the current study cover a similar distance (72%) in the walking band as those reported by Di Salvo (2008). This could imply that a difference in leagues and playing levels plays a minimal role in GKs playing demands.

In the current study, players covered over 70% of their total distance in low to moderate intensity activities. Even though most of the distance is covered in walking and low-intensity running, high-intensity activities are more vital in soccer. In fact, the amount of high-intensity running acts as a distinction between high-level players and those playing at a lower level (Bangsbo *et al.,* 2014). Moreover, Mohr *et al*. (2013) reported that professional players at a low-level cover 28% less high-intensity running (1.90 vs 2.43km) and 58% less sprinting (410 vs 650m) than their counterparts at a higher level. Ingebrigtsen *et al.* (2012) went further by reporting that bottom teams in the Danish League covered 30-40% less high-speed running distance than their opponents at the top of the log. In contrast, players in the Championship (English second tier) slightly exceeded their Premier League counterparts in high-speed running and sprinting distances (Di Salvo *et al.,* 2013). Similarly, Bradley *et al.* (2013) reported that players in the Championship and League 1 (English third tier) covered more high-speed running (>19.8 km h^{-1}) and sprinting (≥25.1 km h^{-1}) than Premier League players. While players in the championship and league 1 averaged 803m and 881m of high-speed running, Premier League players only averaged 681m. In the same vein, while Championship and League 1 players sprinted for 308m and 360m respectively, Premier League players only sprinted for 248m on average. The differences in distances may likely be due to different playing styles, as Premier League teams typically favour possessional tactics over long-ball approaches favoured by teams at lower levels (Bradley *et al.,* 2013). Although these comparisons are valuable, they may not be fully applicable in a South African context, considering that there are few published TMA studies across all levels of South African soccer. Future TMA studies in the different divisions of the South African soccer system would provide an opportunity to draw more applicable comparisons to aid in the training of South African soccer players.

5.5. Player load (PL)

Monitoring training load can indicate whether players are aligned to the training and performance goals as prescribed by coaches and trainers (Scott *et al.,* 2013). Traditionally, various methods have been used to determine the player load of sport players. Scott and colleagues (2013) divide the training load based on the methods used. Internal training load can be derived through heart rate monitoring, rate of perceived exertion after a session (sRPE), and older methods such as Banister's TRIMP and Edwards' TRIMP. External training load, on the other hand, can be determined through Global Positioning Systems (GPS) and accelerometer technology, with metrics such as distance covered. Previous research (Impellizzeri *et al.,* 2004; Alexiou & Coutts, 2008; Boressen & Lambert, 2008) has indicated favourable correlations between the various methods (Banister's TRIMP, Edwards' TRIMP, and sRPE method) of quantifying internal training load. Although the capability of GPS and accelerometer technology in determining external training load was previously doubtful (Gomez-Piriz *et al.,* 2011; Scott *et al.,* 2013), latter studies (Hollville *et al.,* 2015) indicate an improvement in quantifying player load through GPS and accelerometer technology.

Similar to Sparks *et al.* (2017), who recommended the simultaneous use of multiple methods to determine internal and external player load, the current study employed the use of heart rate monitoring and GPS tracking to determine player load. Players who cover the highest distances typically have the highest player load (Shaw, 2018). However, in the current study, this was not always the case with the total player load, player load per meter, and the player load per minute. The CM, which had the third highest total mean distance covered, the highest total player load (1044,5au), player load per meter (0.107au/m), and player load per minute (11.085au/min). The CM was closely followed by the W and the CA in the categories. The difference in total player load was only significant between CM and the CB (<.0001), GK (<.0001), and FB (0.0175). Similarly, player load per minute displayed a significant difference between the CM and the CB (p<.0001), the GK (p<.0001), and the FB (p=0.0153). On the other hand, the difference in player load per meter was only significant between the CM and the GK (p<.0001).

The GK, on the other hand, reported the lowest results in total player load (383.1au), player load per meter (0.082au/m), and player load minute (4.054au/min). This was congruent with the results reported for total distance covered, where the CB had the second lowest distance covered, after the GK.

Given that the top three positions in total distance covered are the same as those in the total player load, this likely indicates a proportional relationship between total distance covered and player load. That is, the positions that cover the highest distance simultaneously yield the highest player load. This suggests that these CM, CA, and the W would be faced with greater physical and physiological demands. Trainers and coaches should take this into account to ensure that the conditioning programmes cater to these demands.

Dalen *et al.* (2016) reported that accelerations and decelerations are responsible for 12-16% of the total player load. This shows that a major part of match play is dedicated to accelerations and decelerations. In fact, players do not only experience a high metabolic load during high intensity running. A high metabolic load is experience in every instance where acceleration is increased, including at low speeds (Osgnach *et al.,* 2010).

In their study, Dalen *et al.* (2016) revealed that the FB and W accelerate the most in relation to other positions, while the CB and the CM decelerate the least. However, similar data is not available in the current study, making a direct comparison impossible. This could likely be attributed to the role of the FB and W, which entails constant high-intensity running on to create opportunities for the forwards.

The similarities in player load between the CM, CA, and the W suggest that the positions have similar physiological demands, with the CM being the most taxed during matchplay. The GK and the CB can be presumed to have the lowest physiological demand among all positions, as exemplified by lower player load in all categories and lower total distance covered. However, the CB yielded a higher mean heart rate than the CA, FB, and the W, which likely suggests that the use of player load and heart rate in determining physiological demand should be a cautious process, as the two variables are not always proportional. These differences are likely due to player identity and style of play, tactical approaches, and space may influence the physical demand of each position per match. While it is well established that a team's tactical approach may influence the performance of a player, the opposition's tactical approach may also influence the player's performance. In fact, some formations often limit the space a player must execute movements. Tactical approaches such as counter pressing or *gegenpressing*, which entail the attempt to re-gain lost possession in the shortest time possible (Andrienko *et al.,* 2018), may limit a player's space and reaction time. A player on the receiving end of such a system may be forced to pass the ball as soon as he receives it in order to avoid losing it. Such a player may, thus, run less than one who is playing against a team that sits back and absorbs pressure.

CHAPTER 6: CONCLUSION, RECOMMENDATIONS, LIMITATIONS, AND FUTURE RESEARCH

6.1. Introduction

The aim of this research study was to quantify the physical demands of different positions in second division soccer. The main focuses included calculating the total distance covered, distance covered in high-intensity, and velocity of the different positions by players playing in the ABC Motsepe League and to compare these results to higher level leagues. Furthermore, player load and heart rate were measured to determine the physiological demand of each position.

TMA has garnered substantial interest as a research area, attracting studies in top and lower leagues across the globe. These studies have investigated differences between playing levels, playing positions, and playing intensities. However, none of these studies have been conducted on the African continent. Consequently, those studies may not necessarily be comparable with the current study and may not be applicable in the African context. The current study was conducted on one team taking part in the ABC Motsepe League, which is the second division of South African soccer, for a total of fourteen (14) league matches and one (1) Nedbank Cup match. Through the current study and future studies, it is envisioned that the standard of performance and the design of conditioning programmes will be enhanced. Furthermore, the improved conditioning programmes should prepare aerobic and anaerobic fitness levels of players to withstand the rigours of elite soccer.

6.2. Conclusion and recommendations

In line with earlier studies, the current study further confirmed what has long been established: different playing positions possess different physical and physiological demands. Consequently, the design of conditioning programmes should encompass these differences to ensure maximal match preparation. The current study revealed that South African second division soccer players perform at 75% of the maximum HR, which aligns with several other studies conducted on elite soccer players. The CM and the CB yielded the highest mean HR, while the GK yielded the lowest HR. Similarly, the CM had the highest maximum HR, while the CA had the lowest maximum HR.

Players in the current study cover distances that are within the range of global studies depicted in table 2.1. Outfield players in the current study covered between 8241.5m and 10024.9m mean total distance during matchplay, while the players in the GK position covered 4692.4m mean total distance during matchplay. The W covered the highest total distance, closely followed by the CA and the CM. However, comparing the current study with other studies (table 2.1) reveals that players in the current study covered inferior distances in each outfield position. While wingers in other studies covered between 10024m and 12200m mean total distance, wingers in the current study covered only 10024.9m mean total distance. Similarly, CMs in other studies covered between on 10476m and 12277m on average, while CMs in the current study only covered 9734.9m mean total distance. TMA studies conducted on GK, however, are scarce, making comparisons challenging. Nonetheless, GKs in the current study covered inferior distances in comparison to their counterparts from other leagues around the world. Di Salvo *et al.* (2008) reported that goalkeepers cover 5,6km mean distance during matchplay, which is superior to the GK (4692m) in the current study. There were also positional differences in distance covered in different velocity bands. In velocity band 1 (walking), the GK covered the highest distance, while the CM covered the lowest distance. The GK, however, covered the lowest distance in the remaining velocity bands. The CM, which is tasked with defensive and offensive duties, covered the highest jogging distance (velocity band 2). The CM and the CA covered the highest running distance (velocity bands 3 and 4), possibly due to the CA’s need to run into the box to complete goalscoring opportunities and the CM’s role in intercepting the opposition’s attacking moves. In order to cross the ball into the opposition box, the W is required to run past the opposition FB and W, which could justify the W covering the highest sprint distance among all the positions in the current study. The differences in playing levels are an important note to remember when making comparisons between studies and designing conditioning programmes.

In contrast to total distances covered, the CM yielded the highest total player load, player load per meter, and player load per minute. The implication is that the CM is physiologically taxed more than the other positions, which could be attributed to the CM's role of linking attack and defence. This suggestion can possibly be supported by the CM also having the highest mean HR among all the players. On the other hand, the GK yielded the lowest total player load, player load per meter, and player load per minute, which could largely be due to the GK spending 71% of the match duration in walking intensity. Furthermore, the GK also had the lowest mean HR, which could solidify the suggestion that the GK experiences the lowest physiological strain among all the players. Even though the GK primarily performs low-intensity actions, the GK's training should enhance high-intensity actions such as clearing, saving, and controlling the ball, as these may determine the match result. Similarly, the CB's explosive actions such as last-minute tackles, headers, and interceptions, should be incorporated into the training regimens. The CM's training, on the other hand, should be aimed at enhancing aerobic capacity to prepare the CM for the demands of the position. Training of the W, which spent the most time sprinting, should focus on the enhancement of repeated sprint ability and anaerobic capacity to align with the demands and role of the position. While the W sprints during the attacking phase of the team, the FB sprints while defending, even though the roles may overlap. Consequently, the FB's training should also focus on repeated sprint ability and anaerobic capacity. The CA, which yielded the highest running distance, should be trained to enhance aerobic capacity to ensure the ability to cope with constant running during the attacking phase. Furthermore, repeated sprint ability should be incorporated into the CA's training as preparation for crucial sprints that may lead to goalscoring opportunities.

In summary, key findings include:

- Total distance covered is commensurate with global studies.
- Distance covered in different intensities by all positions was generally lower than other studies.

- Even though the CM yielded the highest total player load, player load per minute and player load per metre, the CM did not cover the highest total distance.
- GK yielded the lowest total distance covered, which was lower than results reported in a previous study. Total player load, player load per minute and player load per metre were also the lowest for the GK, which can be attributed to the GK's low-moderate intensity activities.
- Players in the current study perform at 75% maximum HR, which is in line with other studies.

In order for the players to cope with the physical and physiological demands imposed on them, it is recommended that training regimens mimic the match demands of each position. This is in line with the SAID principle, which advocates for training approaches that are specific to the needs of match performance situations (Hoff & Helgerud, 2004)*.* Through sport-specific and position-specific training approaches, coaches may be able to gauge the player responses to the training and lead to necessary adjustments (Borresen *et al.,* 2008). The differences in the above-mentioned performance indicators can be attributed to the different roles each position is given. Furthermore, individual playing styles, tactical approaches, and different playing levels may have an influence on the differences between playing positions. Considering that comparable studies were conducted outside the African continent, differences between those studies and the current one may be due to environmental and climatic conditions, as well as playing standards and team playing styles. Furthermore, these differences could be attributed to the use of different methodologies and equipment. In fact, Coutts (2008) recommended a cautious approach to the interpretation of data gained through different GPS devices, particularly in relation to high-intensity running. Insight gained through the current study and similar studies can assist coaches and trainers in designing programmes that not only respond to the demands of soccer, but the specific positions within the sport. Given that this study was conducted within a South African context, coaches may find it relatively easy to apply the insight gained to their training and match preparations. Consequently, this may aid in improving overall performance on an individual and team basis, which coaches and trainers may achieve by:

- Prioritising high-intensity running in training, as this may be crucial in definitive moments such as tackles, interceptions, and conversion of goal-scoring opportunities.
- Enhancing repeated sprint ability in the CA, FB, and W to respond to the activities inherent in the roles.
- Augmenting the anaerobic capacity of the FB and W to prepare the players for the high-intensity running demands of the positions.
- Improving the CM's aerobic capacity to enable players in the position to cope with the dual role of attacking and defending.
- Ensuring that players train at 75% maximum heart rate or higher, to adequately prepare them for the rigours of elite competition.

6.3. Limitations and future research

As is the nature of research, there were limitations within the current study. Firstly, the lack of studies similar to the current study conducted on the African continent makes comparisons with similar studies challenging. As a result, the only comparisons that could be made are with studies conducted in Europe and the Americas. Differences in climate, altitude, performance standards and playing approaches entail that comparisons should be made cautiously. Furthermore, while the data gained from this study can be used to improve conditioning programmes, the study was conducted in the second division of South African soccer; data in the highest level of South African soccer remains unavailable. Comparisons with other studies, thus, may not offer a clear picture of the South African standard of soccer in relation to global studies. On a more practical level, the heart rate monitors used in the current study caused some discomfort for some of the players, possibly affecting their performances. However, there were no complaints as far as the GPS devices were concerned.

Due to the limited research on South African soccer TMA, the researcher recommends future research to focus on the following elements. Firstly, TMA should be conducted across all professional levels of South African professional soccer to ensure more valuable comparisons with global studies. Such research can provide insight into the readiness of players in the lower levels to transition into the highest level of South

African soccer. Secondly, future studies should consider the influence of acceleration and deceleration (Russel *et al.,* 2014), as well as other performance actions such as dribbling (Sparks *et al.,* 2017), as these may have an effect on energy expenditure.

Furthermore, the physical demands of soccer referees remain relatively obscure; therefore, a TMA study on South African referees should be conducted to determine whether they can withstand the rigours of elite soccer. Additionally, a TMA study on women's soccer in South Africa could provide valuable insight into the gendered differences in performance standards, which can prove to be imperative in the design of conditioning programmes. Due to the CA position being a combination of the striker and central attacking midfield positions due to their overlapping roles, the results of the position may not provide a clear indication of the demands of the two positions. Consequently, future studies should seek to separate the positions to gain clear insight of their demands. The influence of playing formations and in-game formational changes on the distances South African soccer players cover should be investigated. Equally important, research should be conducted on the differences in distance covered between the halves of a soccer match in order to gain a better understanding of the dynamics of fatigue in the South African game. Lastly, data on substitutions and in-game positional changes could provide valuable insight into the influence of tactics on the physical and physiological demands that are placed on South African soccer players.

CHAPTER 7: REFLECTION OF THE STUDY

7.1 Introduction

Like most worthwhile processes, research can be daunting, time-consuming, and mentally challenging. In true novice fashion, I underestimated the reality of potential challenges tied to the research process. Even after being taxed in all possible ways (mostly mentally), I cannot overemphasise the value of rigorous research. It prepares one for a competitive world where in-depth knowledge is one of the primary currencies, where attention to detail sets one apart from the chasing pack.

7.2 From honours to confusion

Following a turbulent honour's programme, I was unsure of my immediate future. Should I pursue a master's degree, take a much-needed sabbatical, or go into the workplace? Those were the questions I dealt with daily. Prior to completing my honour's in sport science, I had made it into another honour's programme, which I planned to pursue immediately. However, I was encouraged to rather go into a master's programme. In retrospect, the advice was valuable as the other honour's programme would not have provided much value to my overall vision.

7.3 Getting a supervisor and team

After finding out the type of research Dr. Schoeman was interested in and knowing that it was in my region of interest as well, the decision as to who would supervise my work became a rather seamless one. The real challenge, I would soon find out, lay with finding a soccer team to conduct the study with. Right off the bat, the popular teams came to mind. After all, which 21-year-old wouldn't want to work with a Premier Soccer League team? However, after taking time, convenience, and logistics into consideration, and with advice from my supervisor, a more workable solution was settled upon.

7.4 Cold sickness

On a warm Bloemfontein Saturday morning, I completed my usual routine prior to travelling to the Eastern Free State for what was to be, probably, game 12 of my research study. The routine included ensuring that all GPS devices, vests, and heart rate monitors were organised and packed, as well as preparing the data forms for the match. I was feeling under the weather, but chose to travel, nonetheless. Barely 50KMs out of Bloemfontein, we had to pullover as I had serious case of nausea. A quarter of an hour later, I felt better. Thirty minutes before we reached our destination, I realised that we would be playing in overcast conditions. However, none of us had prepared for what was to come after that realisation. Although Bloemfontein was probably a warm 32 degrees on the day, Qwa-Qwa was quite the opposite at what felt like 14 degrees. None of us had gotten the memo to dress warmly. 90% of the team, myself included, was wearing shorts and golfers. No jerseys in sight. 90 minutes of soccer felt like 3 hours.

7.5 Extra time

Much like a cup final that ends in a stalemate after 90 minutes, I also required extra time to get this one over the line. Initially, I had underestimated the volume of work that lay ahead and, consequently, miscalculated the time I would need to complete the degree. Nonetheless, a shave under four years later, here we stand in anticipation of the final whistle.

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Appendix A-1: Information Document

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

INFORMATION DOCUMENT

Research title: Time Motion Analysis of Varsity Cup Soccer

Dear Participant

I, Sam Masingi, am doing research on the physical demands of Varsity cup soccer. In this study, we want to learn more about what happens in a soccer match using GPS as a measuring tool.

I am inviting you to participate in this research study, which will be done on the University of the Free State 1st soccer team during the ABC Motsepe League.

What is involved in the study - Data will be collected from matches played by the University of the Free State 1st soccer team during the ABC Motsepe League. Every player's age, mass, stature and anthropometric data will be collected one week prior to the start of competition to give an indication of the physical differences between players and positions. Every player will wear the GPS unit in a padded protected harness, positioned between his left and right scapula in the upper thoracic spine area underneath their playing shirt. After the match, data will be downloaded to a personal computer and further analysis will be carried out using system software provided by the manufacturer. The following variables will be investigated: total distance covered, high intensity distance covered, and work to rest ratios, velocity and changes of direction experienced by soccer players.

Participation is voluntary: Refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled; the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Possible benefits: The information gathered during the study will provide a better knowledge and understanding of the game which will assist coaches and conditioning staff to improve training and fitness programs for better and more consistent performance for teams and individual players.

Confidentiality: Efforts will be made to keep personal information confidential. All results will be reported as group averages, no individual result will be revealed. All participants will remain anonymous in ant ensuing publication. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.

Researcher: **Supervisor:**

Sam Masingi Riaan Schoeman

Tel: 0712578365 0823736988

Email: samstyrax@gmail.com schoemanr@ufs.ac.za

Contact details of secretariat and Chair: Ethics committee of the Faculty of Health Sciences, University of the Free State – for reporting of complaints/problems:

Telephone number: 051 405 2812

Thank you for your participation in the research project.

Regards,

Sam Masingi

Appendix A-2: Informed consent form

INFORMED CONSENT FORM

Research title: Time Motion Analysis of Varsity Cup Soccer

You have been invited to participate in a research study conducted by the University of the Free State, Exercise and Sport Science Department as a result of your inclusion in the University of the Free State 1st soccer team. This research will investigate the physical demands placed on soccer players during ABC Motsepe League matches. It is hoped that the findings of this study will assist your coaches and conditioning staff to improve your training and fitness programs for better and more consistent performance.

All procedures will be explained to you in an information document as well as a formal information session. You are encouraged to ask any questions regarding the process and equipment used, as well as to disclose any information that you feel the tester needs to know. When you are satisfied that you fully understand and all questions have been answered, you will be asked to sign this informed consent document. You may contact the researchers at any time if you have questions about the research.

Researcher:	**Supervisor:**
Sam Masingi	Riaan Schoeman
Tel: 0712578365	0823736988
Email: samstyrax@gmail.com	schoemanr@ufs.ac.za

You may contact the Secretariat of the Ethics Committee of the Faculty of Health Sciences, UFS at telephone number (051) 405 2812 if you have questions about your rights as a research subject.

- There is no payment for your involvement in this study and no "out of pocket" expenses will be expected of you.
- Your participation in this research is voluntary, and you will not be penalized or lose benefits if you refuse to participate or decide to terminate participation.

Freedom of consent

The research study, including the above information, has been verbally described to me. I have read and understood the above information and the information document. I understand the procedure and have had an opportunity to ask questions. I understand what my involvement in the study means and I voluntarily agree to participate.

Appendix A-2: Informed consent form

________________________	________________________
Name and surname	ID Number
________________________	____________________
Signature of Participant	Date
________________________	____________________
Signature of Witness	Date

Appendix B-1: Permission letter - Head Coach: UFS Men's Soccer

PERMISSION LETTER

205 Nelson Mandela Drive
Park West
Bloemfontein
9300
20 August 2016

Research title: Time Motion Analysis of Varsity Cup Soccer

Dear Mr. Tenoff
Head coach University of the Free State 1st soccer team

I, Sam Masingi and the Department of Exercise and Sport Sciences of the University of the Free State, am doing research on the physical demands of Varsity cup Soccer. In this study we want to learn more about what actually happens in a soccer match using GPS as a measuring tool.

Data will be collected from all matches played by the University of the Free State 1st soccer team during the Varsity cup. Every player's age, mass, stature and anthropometric data will be collected one week prior to the start of competition to give an indication of the physical differences between players and positions. Every player will wear the GPS unit in a padded protected harness, positioned between his left and right scapula in the upper thoracic spine area underneath their playing jersey. After the match, data will be downloaded to a personal computer and further analysis will be carried out using system software provided by the manufacturer. The following variables will be investigated: total distance covered, high intensity distance covered, and work to rest ratios, velocity and changes of direction experienced by soccer players.

205 Nelson Mandela Drive/Rylaan, Park West/Parkwes, Bloemfontein 9301, South Africa/Suid-Afrika
P.O. Box/Posbus 12098, Brandhof 9324, South Africa/Suid-Afrika, T: +27 0 51 401 2580, F: +27 0 51 444 3132, www.ufs.ac.za

KovsieSport
UFS·UV

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

Participants will not be placed at risk by wearing the device and it will not have any effect on the player's performance on the field.

With this letter, I would like to request permission from you to do my research on the players of the University of the Free State 1st soccer team during the Varsity Football or the SAB Regional League.

Your assistance in this matter will be greatly appreciated.
Please contact me with any questions or suggestions.

Sincerely

Sam Masingi
Tel: 0712578365
Email: samstyrax@gmail.com

Permission

I, Godfrey Tenoff, ID nr., 0868688
Head coach of the University of the Free State 1st soccer team, hereby give permission to Sam Masingi to collect GPS date from the University of the Free State 1st soccer team players during the Varsity Football competition or the SAB Regional League.

19-4-17

205 Nelson Mandela Drive/Rylaan, Park West/Parkwes, Bloemfontein 9301, South Africa/Suid-Afrika
P.O. Box/Posbus 12098, Brandhof 9324, South Africa/Suid-Afrika, T: +27 0 51 401 2580, F: +27 0 51 444 3132, www.ufs.ac.za

Appendix B-2: Permission letter – Director: KovsieSport

KovsieSport
UFS·UV

PERMISSION LETTER
205 Nelson Mandela Drive
Park West
Bloemfontein
9300
20 August 2016

Research title: Time Motion Analysis of Varsity Cup Soccer

Dear Mr. DB Prinsloo
Director: KovsieSport

I, Sam Masingi and the Department of Exercise and Sport Sciences of the University of the Free State, am doing research on the physical demands of Varsity cup Soccer. In this study we want to learn more about what actually happens in a soccer match using GPS as a measuring tool.

Data will be collected from all matches played by the University of the Free State 1st soccer team during the Varsity cup. Every player's age, mass, stature and anthropometric data will be collected one week prior to the start of competition to give an indication of the physical differences between players and positions. Every player will wear the GPS unit in a padded protected harness, positioned between his left and right scapula in the upper thoracic spine area underneath their playing jersey. After the match, data will be downloaded to a personal computer and further analysis will be carried out using system software provided by the manufacturer. The following variables will be investigated: total distance covered, high intensity distance covered, and work to rest ratios, velocity and changes of direction experienced by soccer players.

205 Nelson Mandela Drive/Rylaan, Park West/Parkwes, Bloemfontein 9301, South Africa/Suid-Afrika
P.O. Box/Posbus 12098, Brandhof 9324, South Africa/Suid-Afrika, T: +27 0 51 401 2580, F: +27 0 51 444 3132, www.ufs.ac.za

Appendix B-2: Permission letter – Director: KovsieSport

KovsieSport
UFS·UV

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

Participants will not be placed at risk by wearing the device and it will not have any effect on the player's performance on the field.

With this letter, I would like to request permission from you to do my research on the players of the University of the Free State 1st soccer team during the Varsity Football or the SAB Regional League.

Your assistance in this matter will be greatly appreciated.
Please contact me with any questions or suggestions.

Sincerely

Sam Masingi
Tel: 0712578365
Email: samstyrax@gmail.com

Permission

I, Daniel B Prinsloo, ID nr., 6104115017083
Director: KovsieSport, hereby give permission to Sam Masingi to collect GPS date from the University of the Free State 1st soccer team players during the Varsity Football competition or the SAB Regional League.

[signature] 2017/04/19
Signature Date

205 Nelson Mandela Drive/Rylaan, Park West/Parkwes, Bloemfontein 9301, South Africa/Suid-Afrika
P.O. Box/Posbus 12098, Brandhof 9324, South Africa/Suid-Afrika, T: +27 0 51 401 2580, F: +27 0 51 444 3132, www.ufs.ac.za

Appendix B-3: Permission letter – University of the Free State Research Desk

APPENDIX F

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

UFS·UV
STUDENT AFFAIRS
STUDENTESAKE
DITABA TSA BAITHUTI

1

08 June 2017

Research Desk Summary and recommendation:

APPLICANT:

PS Masingi
2010106751

NAME OF STUDY:

Time motion analysis of varsity cup soccer

NATURE OF STUDY:

Motion tracking

RESEARCH POPULATION:

UFS 1st soccer team participating in the 2017 varsity cup

RECOMMENDATION;

Recommended for approval

Vhugala Nthakheni
Senior Officer: Student Governance and Professional Assistant to the Dean: Student Affairs

OFFICE OF THE DEAN: STUDENT AFFAIRS
T: +27(0) 51 401 2852
F: +27(0) 51 444 6718
E: sewsankera@ufs.ac.za

STUDENT LIFE CENTER
Thakaneng Bridge
1st floor, Internal Box 4
Bloemfontein 9301
South Africa/Suid-Afrika

205 Nelson Mandela Drive/Rylaan, Park West/Parkwes
Bloemfontein 9301, South Africa/Suid-Afrika
PO Box/Posbus 339
Bloemfontein 9300
South Africa/Suid-Afrika
www.ufs.ac.za

APPENDIX F

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

UNIVERSITY OF THE FREESTATE RESEARCH ETHICS COMMITTEES

APPROVAL FROM UFS AUTHORITIES
FOR PARTICIPATION OF STUDENTS/STAFF IN RESEARCH PROJECTS

Title, Initials, Surname:	MR. P.S. MASINGI	**Staff/Student number**	2010106751
Department/Institution:	EXERCISE & SPORT SCIENCES		
Phone:	071 257 8365	**E-mail address:**	samsisyrak@gmail.com
Supervisor(s):	RIAAN SCHOEMAN	**Phone:**	0823736988

Protocol Title:	TIME MOTION ANALYSIS OF VARSITY CUP SOCCER

Who will be involved in the study? (tick ✓)	☐ UFS Personnel	☒ Students

SECRETARY
OFFICE OF THE DEAN
STUDENT AFFAIRS
09 -06- 2017
UNIVERSITY OF THE FREE STATE

INSTRUCTIONS:

- Please attach the following to this form when requesting approval from the signatories:
  - A short summary of the study protocol;
- Kindly note that it is the responsibility of the researcher(s) to ensure that all relevant signatures are obtained before this signed form is attached to your Ethical Clearance Application's Document Checklist on RIMS.
- Please choose either section A, B **OR** C below.
- *Please note:*
  - *If you are doing research on any students from the UFS you require the permission of the Dean: Student Affairs B (i).*
  - *If you are doing research on students/staff from a non-academic/support service division at the UFS you require the permission of the Director / Snr Director of the Division C (i).*
- Section D is **mandatory** for all research on campus.

Page ***1*** *of* ***3***

FORM: Approval from UFS Authorities v01
Effective date: June 2016
University of the Free State

APPENDIX F

A. FOR RESEARCH ON UFS STUDENTS AND/OR STAFF FROM A SPECIFIC FACULTY, BOTH THE FOLLOWING SIGNATURES MUST BE OBTAINED:

i. HEAD OF DEPARTMENT	☑ Approved	☐ Not Approved
Signature:	**Date:** 01/06/2017	
Comments: Dr Santie v Vuuren se goedkeuring asb nodig		

ii. DEAN OF FACULTY	☑ Approved	☐ Not Approved
Signature:	**Date:**	
Comments:		

Dean: Faculty of Health Sciences
University of the Free State
02 -06- 2017
Dekaan: Fakulteit Gesondheidswetenskappe
Universiteit van die Vrystaat

AND

B. FOR RESEARCH ON INTERFACULTY UFS STUDENTS AND/OR STUDENTS IN UFS RESIDENCES, THE FOLLOWING SIGNATURE MUST BE OBTAINED:

i. DEAN: STUDENT AFFAIRS	☑ Approved	☐ Not Approved
Signature:	**Date:** 08 — 06 — 2017	
Comments:		

Page 2 of 3

FORM: Approval from UFS Authorities v01
Effective date: June 2016
University of the Free State

APPENDIX F

OR

C. FOR RESEARCH ON STAFF FROM SUPPORT SERVICES:		
i. DIRECTOR / SNR DIRECTOR OF SUPPORT SERVICE DIVISION	☐ Approved	☐ Not Approved
Signature:	Date:	
Comments:		

AND

D. ALL RESEARCH ON STUDENTS AND/OR STAFF TO BE APPROVED BY:		
i. VICE-RECTOR: RESEARCH	☑ Approved	☐ Not Approved
Signature:	Date:	
[signature]	19/06/2017	
Comments:		

Prof. Corli Witthuhn
Viserektor:Navorsing - Vice Rector:Research
Universiteit van die Vrystaat
University of the Free State
Hoofgebou K61 Tel. 051 - 401 2116

Die Universiteit van die Vrystaat
The University of the Free State
2017 -06- 19
Prof. R.C. Witthuhn
VISEREKTOR: NAVORSING
VICE RECTOR: RESEARCH

Page 3 of 3

FORM: Approval from UFS Authorities v01
Effective date: June 2016
University of the Free State

Appendix C: Ethical Clearance

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

30 August 2017

MR PHUTI S MASINGI
DEPT. OF EXERCISE AND SPORT SCIENCES
FACULTY OF HEALTH SCIENCES
UFS

Dear Mr Phuti S Masingi

HSREC 84/2017 (UFS-HSD2017/0741)
PRINCIPAL INVESTIGATOR: MR PHUTI S MASINGI
SUPERVISOR: DR R SCHOEMAN
PROJECT TITLE: TIME MOTION ANALYSIS OF VARSITY CUP SOCCER

APPROVED

1. You are hereby kindly informed that, at the meeting held on 29 August 2017, the Health Sciences Research Ethics Committee (HSREC) approved this protocol after all conditions were met.

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

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | 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 D: Data collection form

Date:	Time:	Game #:	Column4	Player	Player2	Subs (time)
Position	**Vest + HR number**	**Pod #**	**5 digit #**			
Subs						
Time stamps	Start	Finish				
Warm up						
First half						
Second half						

Appendix E: Turnitin Report

12/4/2018 Turnitin

Turnitin Originality Report

Processed on: 04-Dec-2018 12:29 SAST
ID: 1050317130
Word Count: 27559
Submitted: 1

TIME MOTION SOCCER By Sam Masingi

Similarity Index	Similarity by Source
10%	Internet Sources: 8% Publications: 5% Student Papers: 4%

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Submitted to Saint Edwards University on 2014-06-26

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Paul S. Bradley, Christopher Carling, Antonio Gomez Diaz, Peter Hood et al. "Match performance and physical capacity of players in the top three competitive standards of English professional soccer", Human Movement Science, 2013

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M. U. Deutsch. "Time - motion analysis of professional rugby union players during match-play", Journal of Sports Sciences, 2007

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Appendix F: Language Editing

ACE MOLOI

In relevance our smartness is born

Subject: Editing and proofreading support

To whom it may concern,

This letter serves to confirm that The AM Writing Centre provided the following services for the document titled *Time Motion Analysis of Varsity Cup Soccer*, as produced by Mr. Sam Masingi:

- Language editing
- Proofreading

Please find all in order.

Regards,

Ace Moloi

Senior Writer and Editor

The AM Writing Centre

Ace Moloi | 89A Hilton Court, Raymond Mhlaba Road, Bloemfontein, 9301
C: +27 (0) 65 927 8303
E: ace.moloi@gmail.com