Time Motion Analysis in the South African Premier Soccer League using GPS Technology

by

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DECLARATION

I, Kopano Melesi, hereby declare that this dissertation and the work on which this assignment is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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(Signature)

Kopano Zabulon Melesi

30-01-2020__________

(Date)

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ABSTRACT

Introduction: The game of soccer is an intermittent sport characterised by aerobic and anaerobic periods. TMA research on soccer in South Africa is lacking when compared with international counterparts, even though scientific-based soccer research can equip Strength and Conditioning Coaches in soccer with the precise knowledge to aid the development of individualised conditioning programmes for soccer players.

Objectives: The purpose of this study was to quantify the physical demands of different positions in the Premier Soccer League (PSL) in South Africa.

Methods: GPS data on 26 players were collected, 46 matches and 459 observations and entries were analysed for the study. Minimax X4 Catapult GPS units were used to determine the physical and physiological demands made on soccer players. The following variables were recorded: Distances covered runs, run distance; number of runs, sprints, sprint distance and number of sprints in a match play. The quantitative variables were compared between playing positions using a mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect. Fitting the random effects allowed for the correlation of data within matches and for a given player. For each variable analysed, the overall F-test for playing position and the associated P-value are reported. Furthermore, the pairwise mean differences between playing positions, 95% confidence intervals for the mean differences, and associated

P-values are reported. A so-called “lines” display is used to indicate which pairwise differences between the various playing positions are statistically significant.

Results: All playing positions combined covered a mean total distance of 8494m (7197m-9200m) during a match which is notably lower than total distances reported from international soccer leagues which range from 10.180m- 11.680m. The CAM covered the highest total distance (9200.63m), closely followed by the WB (8724m) and CM (8621m). The ST, in contrast, covered the lowest total distance (7197m), closely followed by CB (7741m) and WA (8301m). The same positions made the greatest number of runs CAM (78m) and WB (72m). The WA covered the highest sprinting distance (299m), narrowly followed by the WB (278m). The lowest sprint distance was registered by CM (99m) and CB (101m). The WA performed a greater number of sprints (19) closely followed by the WB with a total of (17). CM and CB listed the lowest number of sprints in a match (7).

Conclusions: In order to optimise soccer performance and to construct appropriate conditioning programmes, it is critical to have an understanding of the physiological demands placed on PSL players during a match. Our findings emphasise the differences in physical demand between the playing positions in soccer. Coaches can apply the findings of this study to develop position-specific strength and conditioning programmes for PSL players. For example, programmes for the CAM, should pay attention on improving aerobic capacity (extensive continuous low intensities) and aerobic power (intensive high intensity training, 2v2). The total distance covered by the W positions suggests that the W should have a balanced programme that switches between aerobic and anaerobic intensities. WA covers the highest sprinting distance among all positions; training regimens should focus on improving the W's anaerobic capacity and anaerobic power ability. The WB training would consist of anaerobic modalities to help prepare the WB for the high intensity of speed endurance demands associated with the position. However, the WA must concentrate on anaerobic power as the sprints in this position consist of lower distances, so speed endurance production is essential in this position. To perform at high intensity throughout the duration of the match, soccer players should improve both aerobic and anaerobic endurance using high-intensity training modalities. This study can also help aspiring soccer players from club level to understand the physiological demands to play at PSL level and the physical demands at International level.

Key words: GPS, Premier Soccer League; physiological demand, performance.

DEDICATION

I wish to dedicate this thesis to my entire family. You remain my pride and joy and the completion of this dissertation would not have been possible without your patience, understanding and love throughout the duration of this dissertation. Thank you so much, love you always.

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
CAM	Central attacking midfielder
CB	Centre back
CDM	Central defensive midfielder
CM	Central midfielder
CONCACAF	Confederation of North, Central America and Caribbean Association Football
CVO_{2max}	Central venous oxygen content/saturation
EA	Energy availability
EB	Energy balance
EEE	Energy expended in exercise
EI	Energy intake
EPL	English Premier League
EPO	Erythropoietin
FASA	Football Association of South Africa
FIFA	International Federation of Association Football/ Fédération Internationale de Football Association
GPS	Global Positioning Systems
HIA	High intensity actions
HIR	High intensity running
HR	Heart rate
HSR	High-speed running
IFAB	International Football Association Board
WB	Wing back

WA	Wing attack
OFC	Oceania Football Confederation
PC/PCr	Phosphocreatine
Pi	Phosphate
PSL	Premier Soccer League
RSA	Repeated sprint ability
RWB	Right wing-back
SAFA	South African Football Association
SAID	Specific Adaptations to Imposed Demands
SAIFA	South African Indian Football Association
SASF	South African Soccer Federation
ST	Striker
TEE	Total energy expenditure
THSR	Total high-speed running distance
TMA	Time-motion analysis
TSD	Total sprint distance
UEFA	Union of European Football Associations /Union des Associations Europeanness de Football
UFS	University of the Free State
VHI	Very high intensity running
VO_2max	Maximal oxygen uptake

UNITS OF MEASUREMENT

%...........Percentage
G……..... Gravitational force
Hz………Hertz
m……….Meter
min……. Minute
$m.min^{-1}$...Meters per minute

s………...Seconds
$km.h^{-1}$…. Kilometers per hour

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CHAPTER 1:

INTRODUCTION AND PROBLEM STATEMENT

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

1.1 INTRODUCTION

Association of football or Soccer as it is famously known is amongst the most popular, if not the most popular sport in South Africa and across the globe. It started in 1863 in England and since then it has developed throughout the various continents and countries. A soccer match usually lasts for 90 minutes with two 45 minutes played per half. Depending on the format of the competition approved by the “South African Football Association (SAFA) and the Premier Soccer League (PSL)” an additional 30 minutes can be added to determine the winner, this period is better known as extra time (IFAB, 2020-21).

To constitute a match, there needs to be a referee, assistant referees, fourth official, match commissioner and the VAR (Video assistant referee) team (optional). Referees are there to enforce and uphold the laws of the beautiful game. Soccer laws of the game are universal throughout the world; however, they are subject to change from season to season. Throughout the history of soccer, it has been played by ten outfield players, a goalkeeper and an option of three substitutions being made in a single match but due to the pandemic Covid-19, an amendment to this rule was made and a maximum number of five substitutions in a single match is now allowed. Teams have three opportunities to make these substitutions during a match (IFAB, 2020-21). Substitutions could be based on an injury or a tactical reason (Dallaway, 2013).

Throughout the years, the sport has evolved from the days of showing up at the fields and playing, “to the modern-day era of players and coaches requiring scientific knowledge and research about the game to have more control, preparation, accountability and most importantly measurable progress" (Meyers, 2006 p.90). It is imperative to understand that different sporting codes have their own specific physical and physiological demands which the coaching staff (sport scientist, strength & conditioning- and head coaches) need to take into consideration when planning for the season. It is well documented that the demands of modern soccer are influenced by the rules, rule changes, structures of the game, as well as the skill and the tactical flexibility of soccer players involved (Aguiar *et al*., 2012).

Thomas *et al.* (2016) stated it is imperative for the players' strength & conditioning coaches and head coaches to have a comprehensive understanding of these demands and be able to manage these sport-specific requirements to optimise performance. These requirements generally include "jogging, running, sprinting, jumping, tackling, accelerating and decelerating" (Bloomfield *et al*., 2004 p.24). Gathering data of these fundamentals, and analysing it, forces the team, players and their coaches to try to better their team and the sport itself. Then only a player should be exposed to high-intensity training that will allow them to keep up with the technical and tactical aspects of the game. In this sense, a player should be able to maintain the physiological and multi-dimensional demands of a match.

1.2 BACKGROUND AND LITERATURE REVIEW

Sweeting *et al*. (2014) stated that the traditional methods designed to assess player movement, like manual video analysis take too much time and cannot be done in "real-time". Furthermore, these methods are more susceptible to individual error when analysing frequent short, high-intensity movements (multi-dimensional) such as are made in soccer. It is also well known that all over the world, the value of success has dramatically increased over the last decade, providing a need for experts and specialists capable of developing maximum potential of players. Cronin *et al*. (2001 p.168) agree and stated that "athletes, trainers and coaches often need to invest a considerable amount of time researching the physiological demands of their sport while striving for success".

Time motion analysis (TMA) is outlined as a "tool for measuring the physical performance of soccer players; it investigates distance covered in the game set-up by means of a GPS system" (Carling *et al.*, 2008 p.839). GPS technology was initially developed for military use, however according to Cummins *et al*. (2013) its first application in sport, was to track soccer players. The focus was on monitoring various players on the soccer field, using different tracking technology. However, previous research involving TMA in a soccer match was "achieved through the use of video cameras placed near the field, often only capable of following a single player for later analysis" (Carling *et al*., 2008 p.841).

Over the years, soccer has evolved, and the game has become faster and this inevitably led to faster, stronger players in this sport. The sudden interest and induction of modern technologies, such as computer tracking systems, specialised GPS units and video analysis, has provided both the conditioning coach, coach and the performance analyst the ability to simultaneously collect and effectively analyse data relevant to the physical performance of players. Computer-based tracking systems were predominantly utilising digitalised videos to allow player tracking, while new technologies such as Catapult X4 units are worn under the players' jerseys. These units have a harness that is particularly designed for them. These methodologies have been thoroughly investigated and it was reported that they are valid and reliable (Edgecomb & Norton 2006; Castellano *et al*., 2011:b; Akenhead *et al.,* 2013; Rampinini *et al*., 2014) in terms of reporting overall distances covered. Every position in soccer requires different physical attributes and preparation from the players (Dellal *et al.,* 2010). Modern soccer really relies on technology, and using GPS tracking systems, we can track players and their movement on the field, including distance covered, speed, walk, tackles, jumps and jogs (Petersen *et al.,* 2010). According to Bloomfield *et al.* (2007), purposeful movement is necessary to maintain and optimise the physical and physiological status of these players; this will result in the scientist being able to design scientific programmes (monitor, manipulate and incorporate gym, field and competition activities) for individual players.

Carling *et al*. (2008 p.839) argue that the optimum physical preparation of elite soccer players have become a crucial part of the professional game and for success, mainly due to the increased physical demands of "match-play". Monitoring of players work rate and work load during a match and during training is now realistic, through various computer aided and mobile device programs or TMA.

Various studies found that TMA is used to monitor the "work rate" of soccer players and has been comprehensively investigated in training and match set-up (Bangsbo *et al.,* 2006; Di Salvo *et al*., 2007; Mohr *et al.,* 2003). Mohr *et al*. (2003 p.519) summarise top-class soccer players as follows:

- "Top-class soccer players performed more high intensity running during a game and were better at the Yo-Yo test than moderate professional players.
- Fatigue occurred towards the end of matches as well as temporarily during the game, independently of competitive standard and team position.
- Defenders (CB) covered a shorter distance in high intensity running than players in other playing positions.
- Defenders and strikers (ST) had a more reduced Yo-Yo intermittent recovery test performance than Midfielders and Wing backs (WB); and
- Substantial seasonal changes were observed in physical performance during matches."

However, Bangsbo *et al*. (2006) indicated that physical requirements of players during a match would differ because of their physical profiling, match demands and tactics employed by the team. Therefore, individualized programming and nutritional strategies should be taken into consideration and utilized in periodization planning and also in recovery. Di Salvo *et al*. (2007) also found when analysing the different work and training loads of players, significant differences ($p< 0.5$) exist between the different playing positions. Furthermore Di Salvo *et al*. (2007) indicated that more total distance was covered in the first half in contrast to the second half, which could be as a result of fatigue. Mohr *et al*. (2005 p.593) indicated in this regard that TMA and performance measures during match-play, fatigue or diminishing of performance appears at three distinct stages in the game: namely;

- "after short-term intense periods in both halves;
- in the initial phase of the second half; and
- towards the end of the game". Coaches must take note of this in using substitutions (the bench), specific for certain positions in the second half.

However, it is interesting to note that most of the substitutions coming from the bench in French League1 were mainly “tactical substitutions” (midfielders) and this decision was based on physical factors, as the high physical work rate tends to decrease in the last 15 minutes of the match (Chuman *et al.,* 2014). According to Bloomfield *et al.* (2007), work rate analysis between different positions in soccer would show that players in various positions could improve from more individualized conditioning strategies. To conclude, with the number of time players find themselves on the field training and playing, it is essential for sport scientists to monitor the internal and external training load of each player and balance it with rest to allow the players to recover.

As a former national team soccer conditioning coach in South Africa, the researcher must highlight that it is indispensable to utilise sound and scientific standards of physical conditioning as well as to coach to improve performance (Evidence Based Practice). Performance analysts play therefore a key role in providing empirical information from analyses of a performance in a match, this is fundamental to providing a stage whereupon objective choices for preparing and arrangement of training. The main role of conditioning coaches in this process within the professional soccer environment is to apply sound knowledge in relationship of the SAID principle (Specific Adaptation to Imposed Demands). They must be the vehicle for applying sound technology, and research, with training and play with regards to the game for peaking and optimal performance (Petersen *et al.,* 2009), and to reduce the risks of injuries. With the aid of technology and supervision, the most frequent types of soccer injuries like sprains and strains to ankles, knees and hamstrings can be drastically reduced by sound pre-rehabilitation programmes. Simons and Bradshaw (2016) agree that overuse injuries, resulting mostly from repetitive sub-acute impact loading, are a real problem in most high-performance sports. Therefore, proper observation and monitoring of training load or impact loading may significantly aid in the prevention of these overuse injuries. Ekstrand *et al*. (1983) proposed preventative programmes and the application of scientific management strategies of players, by the medical team (doctors, physiotherapists and conditioning coaches), this may significantly reduce soccer injuries.

As the physical demands of the game change over time, it is clear that an accurate and efficient method of TMA is essential in providing physiological and tactical data for modern coaching staff and players. Over many years and through much development, TMA studies of soccer have always strived to provide an accurate description of soccer match performance (O'Donoghue, 2002). According to Clark (2014), the gathering of data for TMA in soccer can be done in various ways, such as hand notation, visual estimations, computer-based tracking, multiple camera tracking and GPS to name a few.

Numerous studies (Ekblom, 1986; Rampinini *et al.,* 2007; Peñas *et al.,* 2009; Vigne *et al.,* 2010; Bradley *et al*., 2010; Bangsbo, 2014) have explored the aggregate distance covered by professional soccer players throughout a match. The minimal mean separation of 10,012km ± 1,024km was found for the Brazilian First Division Championships matches. However, the range for European national teams or leagues are between 10,714km ± 991m (English Premier League) and 11,019km ± 331m, (Rampinini *et al.,* 2007; Peñas *et al.,* 2009; Bradley *et al*., 2010; Vigne *et al.,* 2010). Ekblom (1986 p.52) found that players cover approximately 10km of ground per game, of which 8 to 18% is at the highest individual speed. He also indicated that the average aerobic energy yielded during a national level game is around 80% of individual maximum. In totality, comparing various positions, midfielders should cover more ground on the field because they are involved in both defence and attacking formation of the team. For this reason, midfielders should have higher aerobic fitness levels to maintain high exercise intensity during the match (Strudwick *et al*., 2001). Ekblom (1986) and Bangsbo (2014) also found that midfield players cover more ground than other outfield players in total distance covered by different playing positions. This is important information to apply in conditioning and recovery of players.

Stølen *et al.* (2005) concluded that the profiling of a soccer player is determined by high levels of tactical, psychological, physiological and technical skill to execute elite performance repeatedly. An improvement in profiling perspective can have a positive impact on the achievement of an individual's performance or a team's overall performance. It is subsequently imperative to add to every one of these parts of execution. For this dissertation, however, the attention will be mainly on TMA the physiological demands placed on players in the PSL.

Soccer is an endurance sport in which players perform various movements of different intensities varying from anaerobic to aerobic energy system during a 90-min match. Bangsbo (1994:a) indicated that a soccer match is usually composed of two 45-minute periods per half and various activities take place in that 90 minutes, from performing approximately 1350 events that may include dribbling, tackling, heading and running at varying speeds. However, the level of intensity will vary due to different aspects. Mohr *et al*. (2010) indicate for example that heat stress has a negative effect on a player's ability to perform anaerobic parts of the game more than once. The distance covered is influenced mainly by two main factors, namely periodisation and fatigue threshold. Cortes *et al*. (2012) argue that fatigue inhibits optimal performance, and various studies have displayed this; furthermore, muscle fatigue changes the biomechanical and neuromuscular function of the lower extremity and the body in totality. This results in various positions being affected in different ways. According to Cortes *et al.* (2012) these factors could range from:

- Type of league (professional versus semi-professional);
- The competitive level of opponents (various opponents affecting the psychological and physiological aspects of the team)
- Normal fixture or Cup Final
- Temperature (climate, humidity, heat)
- Tactical (formation 4-4-2, 4-5-1) (Cortes *et al*., 2012).

Most of the TMA research that has been conducted and published is from the English Premier League, Brazilian and Australian leagues, however there are no studies conducted in South Africa thus far, due to various reasons—one of them is possible financial constraints. The interest of this research is to investigate and bridge the differences in physiological demands between South African teams and their European counterparts.

1.3 RATIONALE

Lately, there has been an abundance of research on match performance conducted and sport science in particular has a significant influence in preparing players to perform at the highest level of their abilities. Time Motion Analysis is one of the global leading scientific ways of improving player performance. As stated, there is currently a lack of research using this technology in South African soccer.

Research concerning match performance has been conducted, and GPS information can precisely indicate to coaches and conditioning coaches of the position-specific demands on each of their players (evidence based practice). Furthermore, it can also assist in the development of individual training practices and programmes that mirrors the changing demands of the game. This information will allow players to condition optimally so that they can perform at the highest level of their abilities (Gray & Jenkins, 2010).

To conclude, as previously stated, TMA research on soccer in South Africa is lacking when compared with international counterparts. However, scientific-based soccer research can equip Strength and Conditioning Coaches in soccer with the precise knowledge to aid the development of individualised conditioning programmes for soccer players (evidence based practice).

1.4 FORMULATING A PROBLEM

O'Donoghue (2010 p.2) concludes that the "analysis of sports performance can be summarised as the actual investigation of performance during sport or during training". Time motion analysis is one of the scientific ways of improving player performance in soccer. As stated, TMA of the physical demands and movement characteristics of international soccer is well documented on an elite level. However, there is little research available on the activity and movement patterns of the Premier Soccer League (PSL) players using global positioning system (GPS) technology. The PSL is the premier competition for soccer players in South Africa and is perceived by the soccer fraternity as a stepping-stone towards the national team (Bafana Bafana). Therefore, this research aims to describe the physical demands experienced by players during PSL matches.

1.5 AIMS OF THE STUDY

Despite the need for accurate and current data regarding the physiological demands of elite soccer players in South Africa, as stated, there is limited information pertaining to TMA of soccer players in South African PSL. Therefore, the primary aim of this study was:

- to assess the physiological demands on PSL players during soccer matches using an accelerometer (Catapult Minimax X4) in an effort to characterise the differences between different positions in soccer and to provide coaches and conditioning coaches with scientific updated data (evidence based practice) to produce individual training programmes and recovery protocols.

1.6 PRIMARY OBJECTIVES

The specific objective of this study:

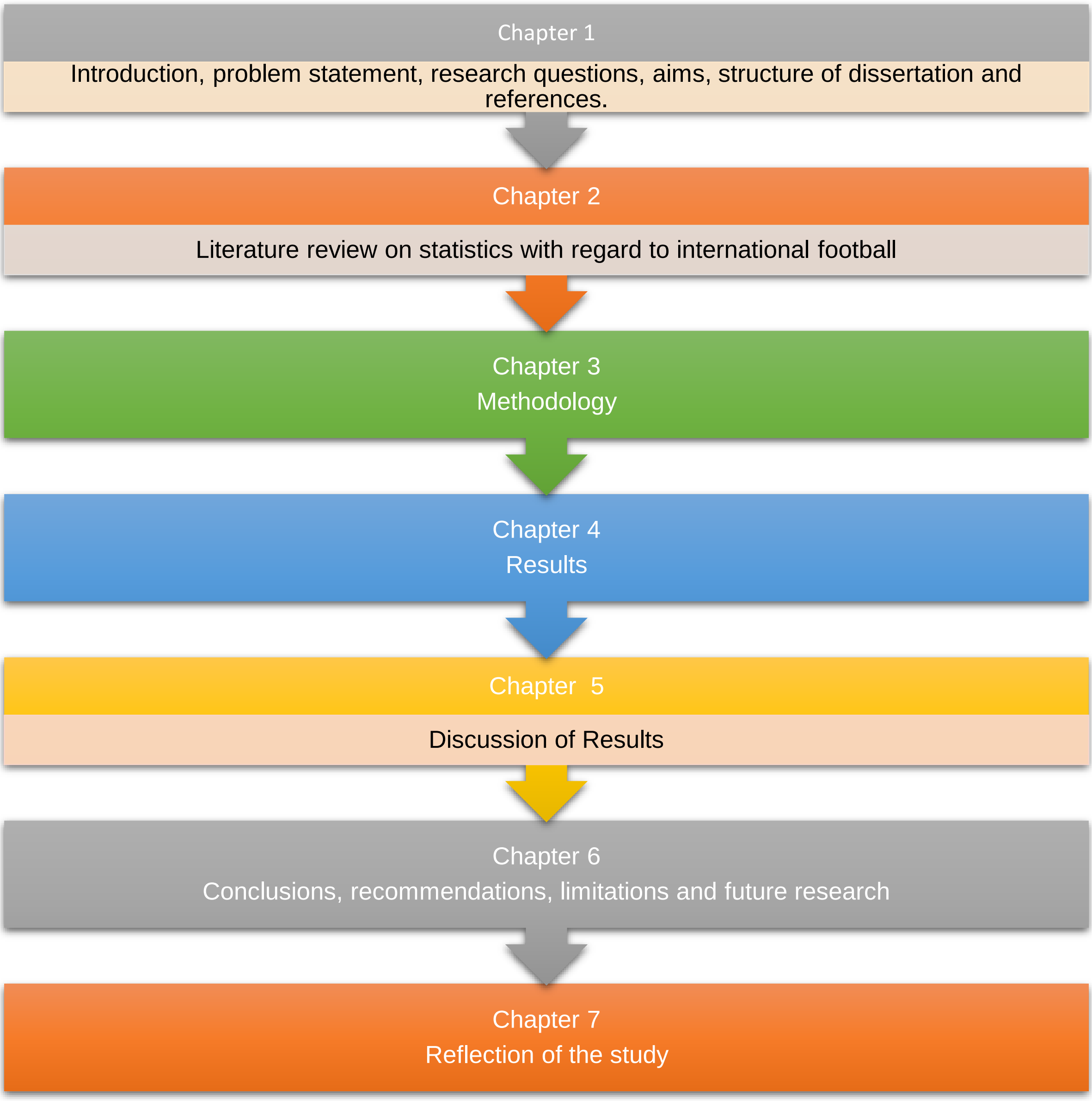
1. To determine the total distance covered (km) of PSL players and investigate the differences amongst various playing positions**,**

   1.1. To determine the distance covered (km**)** during the individual player movement patterns of elite soccer players and to investigate the variances between the various positions (Distances covered**:** total distance covered; number of runs; run distance; run distance per run; number of sprints; sprint distance and sprint distance per sprint).

1.7 MOTIVATION FOR THE STUDY

Soccer players are determined by high levels of tactical, psychological, physiological and technical skill to execute elite performance repeatedly (Stølen *et al.,* 2005). According to Abdelkrim *et al.* (2007), understanding of the physiological demands of soccer players during a match is a principal necessity in order for conditioning coaches to develop a sport-specific conditioning programme. Furthermore, Deutsch *et al*. (2007) emphasised that evidence-based theories and methods of training should reflect the understanding of physiological and physical demands of the sport. The information that comes from TMA can and should be utilised by coaches and conditioning coaches to better prepare the squat as well as individuals for matches. A significant number of studies have been conducted worldwide by various researchers who considered the conditions of their environment, yet despite all these studies, there are no studies from South Africa. As mentioned before, soccer is one of the most recognised sports across the globe, as it is in South Africa too. However, research pertaining to the physiological demands of the game in South Africa is lacking, hence the study was conducted on the South African PSL players in order to minimise the gap between Africa and the rest of the world.

1.8 STRUCTURE OF THE DISSERTATION



CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

This chapter reviews and describes soccer in the South African Premier Soccer League (PSL) competition. It reviews the physiological demands and capacities of soccer players and the role of TMA through GPS in soccer. Time Motion Analysis is used to quantify and provide general information about the movements players execute during a match that contributes to total distance. These movements include standing, walking, jogging, running, sprinting and side/backward movements (Drobnic *et al.,* 2016).

According to Boone *et al*. (2012) soccer is a physical sport that requires a heightened level of fitness, alongside specialised and strategic skills. Furthermore, soccer is primarily an aerobic sport, coupled with anaerobic elements of intermittent short high intensity plays, that requires a high rate of the anaerobic system. A professional soccer player must be able to run "9.5 – 12km" during a regular match (Boone *et al.,* 2012). Even though a soccer match is dependent on the aerobic glycolytic pathways, the most memorable moments in a game and those that are game deciding moments are plays that are created from the use of the anaerobic activities like sprints and jumps. During a match, many of these anaerobic actions occur, resulting in players working towards their anaerobic threshold. Boone *et al*. (2012 p.2051) concluded that the "aerobic capacity, anaerobic capacity, strength, agility and speed are some of the most important attributes to have as a professional soccer player".

It is therefore essential for soccer players to possess a solid base of both components of aerobic and anaerobic capacity to be able to perform at their best in the professional level. However, the importance of the above-mentioned variables will differ because of the specific demands of various positions on the soccer field and by the playing formation. To conclude, the conditioning of a soccer player should be well tailored and organised to improve the player's performance without the risk of overtraining.

Abdelkrim *et al*. (2007) accentuated that, in order to design efficient sport-specific conditioning programmes for individual players, the physiological demands of sport must be understood.

The use of GPS has become increasingly popular in sport, in terms of tracking and monitoring players. In recent years, the mother body of soccer (FIFA) has improved the rules and agreed to the use of electronic performance tracking systems such as GPS devices to be worn in a competitive match (FIFA 2015). This helps in terms of quantifying and justifying variables which is vital in soccer, such as the total distance covered in a soccer match, accelerations and decelerations during a match, the ability to change direction and various speed distances covered by professional soccer players (Dellaserra *et al*., 2014; Vickery *et al.,* 2014). Akenhead *et al*. (2013) and Neville *et al.* (2010) emphasised that these technologies permit monitoring of individual movements and energy costs to be quantified and limit the risk of overtraining or undertraining, and this allows for a better sense of the physiological qualities that are required to perform at an elite soccer level. Time motion analysis can aid and provide feedback to the technical team, the coaches and players (Liebermann *et al.,* 2002) and highlight any discrepancies in performance amongst players in their various positions (Davidson & Trewartha, 2008).

Buchheit *et al*. (2014) argue that even though TMA tracking demonstrates great potential for developing a far better understanding of soccer science, it is important to note that the researcher could not find any study conducted on PSL players in South Africa. However, Table 2.1 provides a summary of the total distance covered by different Confederations in the Soccer World Cup and Table 2.2 provides a summary of positional total distance covered by different leagues internationally.

Table 2.1: Total distance covered ($m \cdot min{-1}$) by different Confederations.

Source	Competition	Confederation	Total Distance $m \cdot min{-1}$
Tuo *et al*. (2019)	FIFA World cup 2018	UEFA	107 ± 12
		CONMEBOL	105 ± 12
		AFC	102 ± 11
		CAF	102 ± 11
		CONCACAF	100 ± 11

Table 2.2: Positional total distance covered by different leagues

Source	Competition	Position	Total Distance (m)
Mallo *et al*. (2015)	Friendly matches	CB	10206
		WB	10452
		CM	11154
		WA	11321
		ST	10726
Di Salvo *et al*. (2007)	Spanish & Champions League games	CB	10627
		WB	11410
		CM	12027
		WA	11990
		ST	11254
Bradley *et al*. (2009)	English FA	CB	9885
		WB	10710
		CM	11450
		WA	11535
		ST	10314
Rampinini *et al*. (2007)	Elite soccer	CB	9995
		WB	11233
		CM	11748
		WA	N/A
		ST	10233
Dellal *et al*. (2011)	English FA	CB	10617
		WB	10777
		CM	11555
		WA	11040
		CAM	11779
		ST	10802
	La Liga	CB	10496
		WB	10649
		CM	11247

		WA	11240
		CAM	11004
		ST	10718
Barros *et al*. (2007)	First Division Brazilian	CB	9029
		WB	10642
		CM	10476
		WA	10598
		ST	9612
Peñas *et al*. (2009)		CB	10070
		WB	11056
		CM	11541
		WA	11659
		ST	10626
Andrzejewski *et al.* (2012)	UEFA Europa League	CB	10932
		WB	
		CM	11770
		WA	
		ST	11377
Andrzejewski *et al.* (2014)	UEFA Europa League	CB	10335
		WB	11063
		CM	11760
		WA	11745
		ST	10939
Djaoui *et al.* (2013)	French First League	CB	10212
		WB	10581
		CM	11373
		WA	10838
		CAM	12784
		ST	10477
Bradley *et al.* (2013)	English League	CB	9816
		WB	10730
		CM	11445
		WA	11612

		ST	10320
	English Championship	CB	10732
		WB	11426
		CM	11878
		WA	12200
		ST	11256
	English League	CB	10980
		WB	11474
		CM	12277
		WA	12043
		ST	11391
Modric *et al*. (2019)	Professional	CB	9319.5
		WB	10368
		CM	11155
		WA	10264
		ST	9796

The intent of the literature review was to examine the current research that has been conducted on the physical and physiological demands of soccer, the utilisation of TMA in soccer, and the utilisation of (GPS) to quantify the separation canvassed by soccer players in various situations during a match.

2.2 SOCCER

Due to the number of participants and spectators associated with soccer or federation of football, Insight (2017) report that it makes it the most popular sport in the world. For the sport to be called "the beautiful game" it is supposed to have a universal language that is basic in its standard rules, basic equipment, and people can play, from any official soccer field to an indoor gymnasium, streets, school play areas, parks, or beaches. It is so popular that 211 associations are registered and are financially supported by FIFA. These associations are categorised as, AFC (Asia), CAF (Africa), CONCACAF (North America), CONMEBOL (South America), OFC (Oceania), and UEFA (Europe) (Insight, 2017). Soccer/Football's governing body, FIFA (Fédération Internationale de Football Association), estimated that in the 21st century 250 million soccer players and over 1.3 billion people interested in the sport; in 2010 more than a billion fans and supporters gathered and watched the FIFA World Cup finals that was hosted in South Africa (Insight, 2017).

2.2.1 SOCCER IN SOUTH AFRICA

According to Goldblatt (2007 p.91) British soldiers initially introduced soccer in South Africa (SA) through exploitation/colonialism in the late 19th century, it was a popular form of recreational sport within the British soldiers. From inception of the sport in SA up until the cease of apartheid, uniformed soccer was once influenced by way of the country's system of racial segregation. It was difficult to imagine it free from all the conflicts brought by segregation until in March 1991 when South African Football Association (SAFA) was founded by four units, "Football Association of South Africa (FASA), the South African Soccer Association (SASA), the South African Soccer Federation (SASF) and the South African National Football Association (SANFA)", which later renounced from the process only to return again two years later. These four units paved the way that set South African soccer on the road back to international stage and worldwide competitions after a lifetime of being banished by FIFA (SAFA, 2020).

In June 1992, CAF and FIFA accepted South Africa as a member of the world governing body, at the FIFA Congress held in Zurich. As part of the celebrations, South Africa hosted one of the giants in African soccer, Cameroon, to play three international friendlies. In September 1992, South Africa u16-17, Amajimbos as they are known, played the first junior international match against Botswana and until today, the country's teams have participated in all of FIFA and CAF's tournaments, from under-17 all the way up to Bafana-Bafana and Banyana-Banyana (SAFA, 2020).

When compared to other soccer nations, South Africa has made exceptional progress, and succeeded with qualifying for the prestigious FIFA World Cup finals in France 1998, Korea-Japan 2002 and finally South Africa 2010 as the host nation. In 1996

Bafana Bafana were crowned as the champions in the Africa Cup of Nations finals (CAF) hosted in South Africa, the team took second place in Burkina Faso in 1998 and third place in Nigeria 2000.

On the other hand, the women's senior national team – Banyana-Banyana, "The Girls" – is one of the most consistent teams in women's soccer. They have been ranked as the top three nations in CAF competitions. In August 2011, they qualified to participate in the 2012 London Olympic Games. During 2011, the team took fourth place in the 2011 All-Africa Games in Mozambique, in what was their triumphant year to date. Most recently, in December 2018, they were runners-up to Nigeria in the Africa Women's Cup of Nations hosted in Ghana. Their second place saw the team qualify for the prestigious women's FIFA World Cup in France 2019 (SAFA 2020).

The country's junior teams from the U20s Amajita and Under-23s Amagluglug, have been doing relatively well at junior level. In 1997, the U20s were runners-up in Morocco, in 2017 they saw fourth place in Zambia and 2018 they took third place in Niger at a youth CAF competition. These top four placings have seen the under 20s competing in a number of FIFA youth World Cups. U23s had a tough campaign in 2011 in a quest to try and qualify for both the All-Africa Games and London Olympic Games in 2012. They participated in 2016 Brazil Olympic Games and they have qualified for the upcoming 2021 Tokyo Olympics that were scheduled from 2020. They have taken a silver medal in the 2011 All-Africa Games in Mozambique and recently in December 2019, the team competed in the CAF competition and achieved third place (SAFA, 2020).

Two teams, at club level, have managed to bring success into the country in the form of Orlando Pirates FC and Mamelodi Sundowns FC. In 1995, Orlando Pirates were crowned triumphant champions in African Champions Cup and thereafter in 1996 the CAF Super Cup (Pirates, 2017-2020). Most recently Mamelodi Sundowns has repeated what Pirates achieved twenty-one years ago and won the CAF Champions League in 2016 (Sundowns, 2018-2020). Sundowns has become a respected team coming from the southern region of Africa.

SAFA has worked tirelessly to provide the structures to take soccer to all parts of the South African people. Education of the sport has come to the forefront as there are "more than 7,000 qualified coaches working around the country and nine provincial structures, who are further divided into 52 Regions. Additional Regions are planned in line with the changes made to municipal demarcations by the Municipal Demarcation Board" (SAHO, 2011).

SAFA (2020) stated that, "in 1996 when the PSL was established, it was made up of eighteen teams, and due to congestion and trying to manage the league, the number of these teams were later reduced to sixteen teams. The framework of the South African football consists of National First Division, SAFA ABC Motsepe League, and the SAFA SAB Regional League"; these 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 currently around the globe (Harris, 2014).

2.2.2 STRUCTURE OF THE GAME

Structure of the game is made up of tactics employed by the team. According to OXFORD DICTIONARY (2020) a tactic is "an action or strategy carefully planned to achieve a specific end". Regarding performance soccer, normally the focus at the end of the match is to win the match. Gréhaigne and Godbout (1995 p.4) explained there's a distinction between the "game strategy and game tactics". However, the team strategy describes the decisions made before the game with respect to how the team wants to play, whereas the tactics are the result of the ongoing interactions between the two opposing teams.

Da Costa *et al.* (2010) argue that tactical advances in soccer have changed the way teams set up and approach matches. The organisation and performance of players can therefore be influenced by the tactical principles applied by the coaching staff (Da Costa *et al.,* 2010). However, according to Van Winckel *et al.* (2014) there are certain tactical behaviours and patterns that the coach wants to be executed during the game, such as collective (i.e. the whole team), inter-sectorial (e.g. defenders and midfielders), sectorial (e.g. defenders), and individual actions (See Figure 2.1).

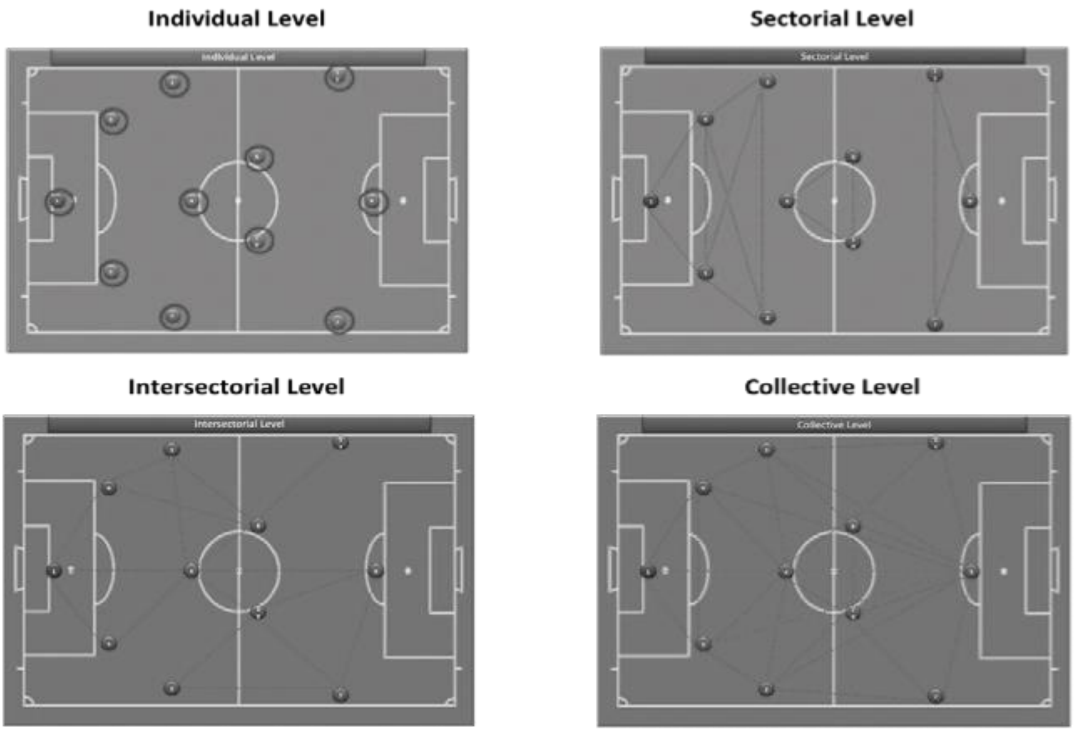


Figure 2.1: Tactical relationship levels. (Van Winckel *et al*., 2014)

In soccer the tactical plan of a team is in relation with the phases of play and ball possession, i.e. the defensive transition and offensive transition. These tactical structures mainly allude to how teams are setting-up on the field across time and unscientifically are considered as accountable for increasing or decreasing the general productivity of the players (Memmert *et al.*, 2017). Recently, teams are playing more dynamic soccer, that requires interchanging of possessions, meaning players are not static.

Figure 2.2 illustrates the different formation levels applied by Spain (1-4-3-3), Germany (1-4-3-3) and France (1-4-3-2-1)

2010: Spain formation 1-4-3-3(FIFA, 2010).

2014: Germany formation 1-4-3-3 (FIFA, 2014).

2018: France formation 1-4-3-2-1 (FIFA, 2018).

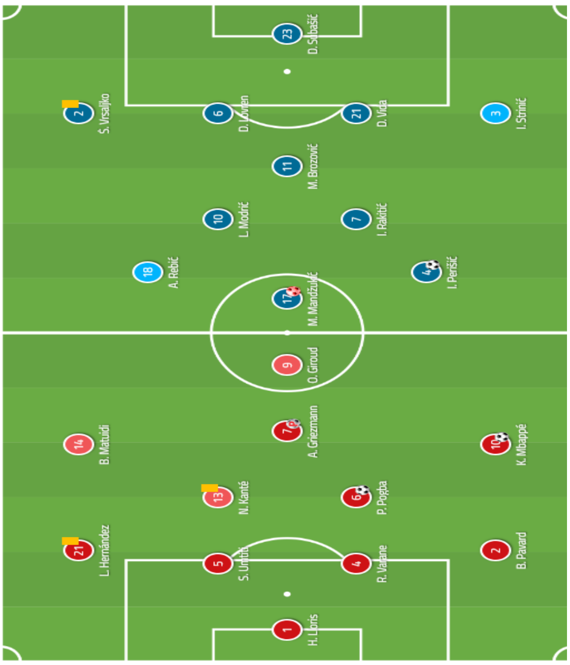


Figure 2.2: Tactical relationship levels.

To conclude, in the 2010, 2014 and 2018 FIFA World Cups, the most successful teams were flexible, and able to adapt their style of play from 4-4-2, 4-2-3-1 and 4-3-3 based on the match situation (FIFA, 2010; FIFA, 2014; FIFA, 2018).

2.2.3 TIME MOTION ANALYSIS (TMA)

Soccer is an exciting, high intensity, multi-directional game and can be played in any form or on any surface, indoor or outdoor, at competitive or social level. It is well known that most sports in the world are progressively adopting a scientific approach to optimising team and individual performances. This has brought about the utilisation of GPS devices in various sporting codes and the data results coming from these devices. Soccer is no different; in fact, GPS technology has become a standard in both training and competition in professional soccer (O'Donoghue, 2010).

In addition, over the years soccer has been benefiting from these technological advances, some of them being GPS technology and video analysis. Castellano *et al*. (2011: p.415:a) stated that "analysis of movement patterns during match-play has been used to evaluate physical demands in soccer for more than 30 years".

In March 2015, The International Football Association Board (IFAB) decided to permit the use of wearable innovation in soccer. "FIFA invited the industry to Zurich, Switzerland to learn more about how these tracking systems work" (IFAB, 2020-21). That day catapulted various technological usage into the game, from lighter boots, lighter balls, goal line technology, virtual offside line and most recently Video Assistant Referee (VAR). With the amount of money involved in soccer of late, these technologies are there to aid and decrease the element of error in the sport. Global Positional Systems (GPS) tracking or monitoring helps the coaches with documenting and examining all activities taking place during a match. Probably, the main aim of GPS technology is to observe and analyse your own team performance and identify strengths which can then be further developed and weaknesses which means areas of improvement in performance. Likewise, it can also be utilised to investigate opposition performance and use information to distinguish approaches to defend against opposition's strengths and exploit weaknesses during match play. In regard to match analysis, it has been useful in distinguishing the physiological demands of the sport, and in analysing how a specific player compares to the requirements of his position (Peñas *et al.,* 2009).

The way the game of soccer is played, it keeps evolving and the demands are getting higher and higher, so this means training protocols must evolve with the game and the changes it comes with. Di Salvo *et al*. (2007) argue that with detailed focus on movement patterns in sport, various systems such as video analysis and GPS have been developed and used to help understand the physiological load imposed on high level soccer players. These loads are calculated according to their positional responsibilities during competitive matches. This includes the activity profile of the player, the total distance covered, the various intensities met during the game and the energy systems and muscles involved. All these components are important to compile a sport specific training protocol. This is even more relevant in elite athletes. Therefore, to conclude, match analyses is very useful to develop a sport specific training programme that emulates the physiological conditions forced by the game. The closer the simulation of the game, the greater the specific adaptation to imposed demand.

As students of the game, we need to develop instant feedback processes and use them as performance indicators to highlight variables in a match such as the total distance covered during a match, the different intensities using the HR, duration of different movements during match play, work rates, exercise to rest ratio's, energy demands and work load of the players. All these variables must be quantified to create a performance database, meaning performance feedback must be provided to players, coaches and conditioning coaches and with this provision of immediate feedback, players can exercise team evaluation, and bring about an improvement in specific performance areas. All the components that have to do with total distance covered, walking, jogging, cruising, sprinting, backward and shuffling movement can be documented and presented to the players in a form of TMA and we can utilise it further as a form of injury predictor for players. Catapult (2019) indicate that it is important to know when to keep pushing the players and when to back off. With this being said, coaches and conditioning coaches can quantify training programmes and monitor players loading then tailoring rest or training based on the player's specific needs, and even prevent injuries before they occur.

With the increase in the popularity of TMA, FIFA finally perceived the significance of innovations and GPS in soccer, both on and off the pitch, and in the World Cup in Russia, FIFA permitted electronic performance and tracking systems in official matches, and various top teams utilised this technology. Top teams like Germany, Brazil, EURO champions Portugal, Belgium, England, Poland, Denmark and Morocco all utilized STAT-Sports innovation during the World Cup. Anusuya (2018) indicated that different teams were utilising several products from organisations such as Catapult, Zepp, FieldWiz, etc. These devices help in finding a competitive edge over your opponents on the field, keeping your athletes at their best throughout the season or a competition, providing detailed and objective feedback, setting benchmarks for individuals and teams and, most importantly, helping in terms of scouting and recruiting.

However, there is a lack of evidence-based practice in South Africa and Africa but this is changing now as Catapult has collaborated with CAF and it has provided 25 units to associations that are affiliated with CAF (Catapult, 2019). Some professional teams can afford these units; teams such as Mamelodi Sundowns, Orlando Pirates, Kaiser Chiefs, SuperSport United, Cape Town City and Ajax Cape Town have invested in TMA systems.

2.3 PHYSICAL CAPACITIES OF SOCCER PLAYERS

Soccer has become so competitive in recent years and the emphasis on winning has increased the level of competitiveness. This in turn demands higher levels of both physical and mental planning as well as refined technical and tactical preparation of athletes (Simiyu, 2012). Reilly *et al.* (2000) reiterated that in order to compete at the most significant levels in soccer, players must adjust to the demands placed on their bodies. These high physical attributes or demands from these players will provide the capabilities needed to carry out the tactical and technical skills throughout a match or tournament and eventually will determine the measure of success or failure in the season. Reilly *et al*. (2000) found that soccer players are heterogeneous and some of the players are still predisposed to certain positions. “The defenders were generally older and more experienced than both the midfielders and attackers”. The “midfielders were the shortest players in the team. The attackers were taller and heavier than the midfielders, and the attackers were taller than the defenders” (Sporis *et al.,* 2009 p.1949). Sporis *et al.* (2009 p.1949) also indicate that at elite level, goalkeepers were the “heaviest on the field, while central defenders were the tallest; full-backs and midfielders were slightly shorter and lighter than forwards”. A short overview of the physical characteristics and energy demands of soccer players are presented, for better understanding of the demands placed on soccer players in different positions. However, in this current study, the physical characteristics of players are not presented and needs further investigation.

2.3.1. ANTHROPOMETRIC DATA

Drobnic *et al.* (2016 p.8) argued that “physical characteristics, such as height, body mass (BM), muscle mass and body fat levels can all play a role in the performance of sport”. The physical attributes of an athlete are mostly inherited; however, other variables such as conditioning effects of their training programmes and diet can influence a player’s physical attributes. It is well documented (Drobnic *et al.,* 2016) that for some sporting codes, there are explicit physical characteristics, which displays suitability or potential to compete in the sport. Classic examples include, long distance runners, jumpers, and throwers in athletics. Anthropometric traits of athletes have shown to be mindful indicators for co-operation at the largest amount in sports, for instance, soccer. Hazir (2010) highlighted that the ultimate objective is to compete at a world-class level. Soccer players are expected to have morphological and physiological characteristics that are material both for the demands of the game of soccer and even more important for the specific position in soccer. Therefore, continuous anthropometric profiling of soccer players during the periodization cycle is just as important as regular testing of fitness levels.

The information based on anthropometric characteristics can and must be utilised by the conditioning coach to change the player's capacity or even the strategic arrangement of the entire team (Shephard, 1999). Furthermore, Da Silva *et al.* (2008 p.314) stated there are "anthropometric and wellness inclinations for the diverse playing positions inside of soccer".

To conclude, it is clear from the literature that anthropometric profiling is an important component in soccer. Sporis *et al.* (2009 p.1949) highlighted in this regard that goalkeepers are the "tallest and the heaviest players in the team; however, they are also the slowest players in the team when sprinting ability is measured. In turn, midfielders are a lot shorter and with less body fat, and they cover the most distance compared to strikers and defenders while strikers seem to be the fastest players on the team". Table 2.3 summarises the anthropometric measurements of elite and professional soccer players from various parts of the world.

Table 2:3: Comparison between anthropometric variables of elite and professional soccer players (Hassan, 2013).

References	Nationality	Level	N	Age	Height	Weight
Bloomfield *et al.* (2005)	Europeans	Professional Total	208 5	26.4±4.4	1.81± 0.06	75.5±6.3
Dellal *et al.* (2008)	French	Elite	10	26.0±2.9	1.81 ± 5.9	78.3±4.4
Hazir (2010)	Turkish	Elite	161	25.7±3.7	1.78± 5.66	76.1±6.2
Hazir (2010)	Turkish	Professional	144	24.1±4.3	1.78± 5.90	73.9±6.3
Hoppe *et al.* (2012)	German	Professional	11	23.8±3.0	1.79 ± 8.9	76.6±8.6
Kalapotharakos *et al.* (2006)	Greek	Elite	19	26.0±4.0	1.80 ± 5.0	78.0±4.5
Reinhold (2008)	German	Professional	53	24.9±4.3	1.83 ± 7.0	78.6±7.1
Silva *et al.* (2012)	Portuguese	Professional	13	25.7±4.6	1.78 ± 5.7	76.5±9.2
Al-Hazzaa *et al.* (2001)	Saudi Arabian	Elite	154	25.2±3.3	1.77± 0.06	73.1±6.8
Aziz *et al.* (2000)	Singaporean	Professional	23	21.9±3.6	1.75± 0.06	65.5±6.1
Bloomfield *et al.* (2005)	English	Professional	578	26.3±4.8	1.81± 0.06	75.3±7.3
Bloomfield *et al.* (2005)	German	Professional	480	26.6±4.4	1.83± 0.06	77.5±6.4
Bloomfield *et al.* (2005)	Italian	Professional	499	26.4±4.4	1.81± 0.05	74.3±5.4
Bloomfield *et al.* (2005)	Spanish	Professional	528	26.5±4.0	1.80± 0.06	75 ± 5.6
Casajus (2001)	Spanish	Professional	15	26.3±3.1	1.80± 0.07	78.5±6.4

Cometti *et al.* (2001)	French	Elite	29	26.1±4.3	1.80± 0.04	74.5±6.2
Freiwald *et al*. (2012)	German	Professional	14	24± 3.95	1.82± 0.04	80.6±6.4
Matkovic *et al.* (2003)	Croatian	Elite	57	23.2±3.5	1.81± 0.06	77.6±5.7
Modric *et al*. (2019)		Professional	101	23.9±2.9	1.83± 6.7	78.7±7.2
Mohr *et al*. (2003)	Italian	Professional	18	26.4±0.9	1.80± 0.01	75.4±1.5
Ostojic (2003)	Serbian	Elite	30	23.5±3.1	1.83 ± 6.0	76.8±6.1
Hassan (2013)	German	Professional	14	24.6±4.3	1.85± 0.07	83.9±8.5
Rienzi *et al.* (2000)	South American	Elite	11	26.1±4.0	1.77± 0.06	76.4±7.0
Strudwick *et al.* (2002)	English	Elite	19	22.0±2.0	1.77± 0.06	77.9±8.9
Wisløfff *et al*. (2004)	Norwegian	Elite	17	25.8±2.9	1.77 ± 4.1	76.5±7.6

2.3.2 ENERGY DEMANDS AND SUPPLY IN SOCCER

Physiological demands play an important role in modern competitive soccer, therefore, it is imperative for players to be physically fit and have a sound energy system to adapt to the stresses of the game. Soccer being an intermittent sport, "players will experience various intensities at different heart rates e.g. 70-80%, 80-90% to maximum heart rate" (Manzi *et al.,* 2014 p.914). This suggests that average exercise intensities are around the lactate threshold, with periods above and below this threshold during high energy bursts and recovery periods, respectively. With that being said, a soccer player should be able to switch between energy systems when it is required during a match.

Drobnic *et al.* (2016 p.6) indicated that the energy demands are high, so attention must be given to supplying adequate fuel for training and competition. It has been estimated that professional male soccer players "expend about 1,500 kcal per match". These energy requirements by the players are provided through ingestion of food and beverages in their diet. It is clear that energy play a pivotal role in various "fundamental processes including cellular maintenance, thermoregulation, growth, reproduction, immunity and locomotion". Drobnic *et al*. (2016 p.6) and Abernethy *et al*. (1990) also argue that, depending on the type, intensity, and duration of an activity, various energy systems and bioenergetics substrates are utilised to fulfil the needs of these different activities.

Availability of energy in a match allows players to compete at their peak (Gastin, 2001). Drobnic *et al*. (2016 p.6) explain that energy available comprises energy intake minus the energy expended during exercise. "If the total energy expenditure of the athlete, including exercise-related expenditure and the energy required to support daily physiological function, exceeds that of energy intake, the athlete is said to be in negative energy balance". However, if in-taken energy is greater than total energy used, the athlete will be in positive energy balance. Energy requirements during any exercise "are fulfilled by three different energy systems which function simultaneously" (Gastin, 2001 p.725), this will affect the energy availability. Energy expended in exercise will be controlled and influenced by the intensity and extent of the exercise (Drobnic *et al*., 2016). On the other hand, we need to consider there is also a noticeable difference in energy supply according to the muscle type (Van Winckel *et al.,* 2014).

Van Winckel *et al*. (2014 p.55) summarise it as follows:

- "**Type I:** Slow oxidative, characterised by red muscle fibres (due to large amounts of myoglobin) mainly display aerobic energy production with little formation of lactate.
- **Type II:** White muscle cells, are subdivided into:
  Type IIa: These are pink muscle fibre type; they have a mixed aerobic and anaerobic effect and are characteristic of soccer players (they have a crossover effect from type IIb probably being transformed into type IIa).
- **Type IIb:** These are the strongest, but they have a mainly anaerobic metabolism".

During any form of exercise, energy will be provided from two energy sources, namely the aerobic and anaerobic pathways. Table 2.4 supplies an overview of the different energy systems.

Table 2.4: Overview of the different energy systems.

	ATP-CP system	Anaerobic process	Aerobic process
Intensity	95–100%	60–95%	< 60 %
Duration	< 10 sec	30 sec to 30 min	Long duration
Fuel	Creatine phosphate	CHOs (from blood glucose and stored glycogen)	CHOs, fats, proteins
Residual product	None	Lactic acid	Water and carbon dioxide
Recovery	Immediate	20–60 min	Until the fuel reserves have been replenished

(Van Winckel *et al.,* 2014)

Urhause *et al*. (2000) explain that we must take into consideration that a change in energy systems is not sudden; rather, it is a gradual process. Therefore, the aim for the coaches must be to train both the aerobic and anaerobic elements of performance for a soccer player to perform at their best.

2.3.2.1 ATP (ADENOSINE TRIPHOSPHATE)

Adenosine triphosphate (ATP), carries energy biomechanically into a cell and brings about energy for muscle movement. Considering the other roles of a muscle, i refer to movement instead of contraction because of muscular activity having different movement patterns (i.e. isometric, concentric and eccentric movement). This ATP is present in the muscle cell to an extremely limited extent. To restore ADP to ATP, four systems are used: ATP-PC-System, Anaerobic Glycolysis, Oxidative Phosphorylation, and the Kinase Reaction (Van Winckel *et al.*, 2014).

2.3.2.2 ATP – PC SYSTEM

ATP- PC System can be defined as the A-lactic system or phosphate system as the fuel source of ADP (Adenosine diphosphate) and Phosphocreatine (PC) also known as creatine phosphate and is accumulated in the muscle. The ATP-PC system provides energy for high intensity, explosive activities such as jumping, rebounding and short sprints (Corrie & Teesdale, 2004). The ATP-PC system is ideal for maximal bursts lasting up to 10 seconds or less; this is typically in the primary stages of intense or explosive movements (Gastin, 2001). These movements could be anything from a striker or a midfielder going for an explosive run into the penalty area or a defender or goalkeeper contesting for a ball in the air. Van Winckel *et al.* (2014) further stated that ATP is present in the muscle cell to an extremely limited extent, barely sufficient for a few seconds. However, it can be deployed directly. ATP has therefore great power but limited capacity. In chemical terms, it can be described as follows: ATP undergoes hydrolysis in the sarcoplasm, releasing energy that is used by the muscle filaments (actin and myosin activation). ATP + H_2O produces ADP (adenosine diphosphate) + H+ (hydrogen ion) + Pi (free phosphorous) + release of energy that can be used directly by the muscle. Because ATP is the only form of energy that can be used directly by the cells, the small quantity has to be continuously replenished. This is done by converting the ADP by-product back into ATP. This requires energy from the various energy systems, which differ in their speeds of production (their power) and the quantity of energy they can produce (their capacity). Recovery periods lasting 2-3 minutes are required for the replenishment of this energy store (Kenney *et al.,* 2012).

2.3.2.3 ANAEROBIC GLYCOLYTIC SYSTEM

Anaerobic glycolysis produces energy in the sarcoplasm to ensure that the high intensity of an exertion can be sustained for longer than 10 seconds. “Glycogen from these muscles is converted to pyruvate and lactate via a number of chemical steps in which no oxygen is used, releasing a limited quantity of energy; two or three ATPs depending on whether the source of glucose is stored glycogen or glucose coming from the bloodstream” (Van Winckel *et al.*, 2014 p.53). It works as a significant source of ATP for maximal exercise that last between 20 seconds to 3 minutes (Abernethy *et al*., 2005). At high intensity, it is mainly the muscle glycogen that is used and, at lower intensity, the blood glucose coming from the liver glycogen is used. Glycogen stored intracellularly is promptly accessible for energy production, and the rate of energy production far surpasses the flux of glucose into skeletal muscles (Brussow, 2015). The biggest advantage about this ATP-PC system is that it has the largest capacity, which is vital in intermittent sports like soccer (Powers & Howley, 2012). Therefore, “muscle glycogen may have been important for survival during acute emergencies as substrate for fight or flight reactions, whereas accumulated fat has its importance for survival during starvation” (Jensen *et al.,* 2011 p.2). The anaerobic pathways can provide a limited amount of energy and reproduce ATP at high rates (Gastin, 2001). To conclude, when a striker or a midfielder is running at high intensity, the glycogen in the muscle is mainly used and at lower intensities, the blood glucose from the liver is used.

2.3.2.4 OXIDATIVE PHOSPHORYLATION

Oxidative metabolism consist, of the breaking down of carbohydrates, fats and in other instances proteins, using oxygen, Gastin (2001). Gastin (2001 p.730) further reiterated that "it has long been assumed that the aerobic energy system, responds slowly to the demands of high intensity exercise and plays little role in determining performance over short durations". However, it is well documented (Thomas *et al.,* 2016; Carlsohn, 2016; Burke *et al.,* 2011; Kreider *et al.*, 2010) that prolonged exercises lasting more than sixty – ninety minutes usually depletes body glycogen reserves. Therefore, a pre-exercise CHO amount of 1 – 4 g/kg consumed within one to four, before the workout is recommended. This system usually kicks in after two minutes of continuous activity and provides fuel for long duration activities. It supplies most of the energy production (90%) during a soccer match (Bangsbo, 1994:b). The production of this process takes place in the mitochondria, with the glucose and fatty acid substrates converted entirely to water and CO_2. The CHO reserves are limited, while fat reserves are virtually unlimited. Fats become the primary fuel source during low-intensity physical exertion where adequate oxygen is available for the oxidation of lipids (Van Winckel *et al*., 2014). Helgerud *et al.* (2001) and McMahon and Wenger (1998) mentioned that VO_{2max} has been demonstrated to be a significant contributor to repeated sprint ability, total distance, and the quantity of ball touches made during soccer-match. However, Jones *et al.* (2013) further demonstrated that maximal aerobic capacity was a significant factor in assisting recovery between intermittent sprinting in professional soccer players. Reilly (1997 p.261) confirms that "high aerobic capacity is vital in recovery during high intensity intermittent exercise". The capacity to perform and recover from repeated high intensity activities over a prolonged period combined with a decent aerobic capacity is considered an essential physiological requirement for accomplishment in soccer (Jones *et al.,* 2013). The demands of the match will be determined by the playing formation and playing position. In general, midfielders have statistically superior values

VO_{2max} and Blood Lactate were found among the goalkeepers (Sporis *et al*., 2009). However, Bojkowski *et al.* (2015 p.146) stated that the mean of the most distances covered by the defenders of the "best four teams of the tournament was 11,75km. The analysis of these data showed that the Argentine defenders covered the mean distance of 12,49km, the Dutch defenders covered 11,85km, the Germans 11.63km and the Brazilians 11,23km". Table 2.5 shows the total distance defenders covered in a match.

Table 2.5: Defenders total distance covered

Number	Team (Strikers)	Number of players	Distance (meters)	Min (meters)	Max(meters)
1	**Argentina**	5	12,492	10,576	14,089
2	**Netherlands**	5	11,851	10,618	12,991
3	**Germany**	5	11,630	6,607	14,115
4	**Brazil**	7	11,225	9,527	13,780

(Bojkowski *et al*., 2015).

Table 2.6 demonstrates that the midfielders of the best four teams of the competition had a mean maximum running distance of 12.02km. Players from Germany covered the highest mean distance of 13.76km, trailed by Brazil with 12.15km; Netherlands had 11.53km and Argentina came in at 11.05km. The midfielders of the top four teams in the World Cup who individually covered distances above 15km in one match were from Germany, with 16.39km and Netherlands, with 15.01km respectively. However, Table 2.6 shows the total distance covered by midfielders during a match.

Table 2.6: Midfielders total distance covered

Number	Team (Strikers)	Number of players	Distance (meters)	Min (meters)	Max(meters)
1	**Germany**	5	13,758	11,261	16,388
2	**Brazil**	5	12,145	10,949	13,906
3	**Netherlands**	7	11,527	5,143	15,012
4	**Argentina**	6	11,047	8,481	14,513

(Bojkowski *et al.,* 2015).

Table 2.7 shows that the mean of the most running distance in the group of strikers was 11.2km. However, among the offensive playing position of the teams (which qualified to the semi-finals), the mean value for the offensive players from the highest distance was Germans, 11.73km, Brazilians 11.14km, the Dutch, 11.00km, and for the Argentines 10.34km. Table 2.6 summarises the total distance covered by strikers in a match.

Table 2.7: Strikers total distance covered

Number	Team (Strikers)	Number of players	Distance (meters)	Min (meters)	Max(meters)
1	**Germany**	4	11,728	8,942	15,180
2	**Brazil**	5	11,142	9,186	13,581
3	**Netherlands**	5	10,995	6,949	13,855
4	**Argentina**	6	10,342	6,464	13,519

(Bojkowski *et al.,* 2015).

Bradley *et al.* (2009) further confirmed that there are differences when evaluating the five most universal positions. The central and wide midfielders cover more total distance than any other position, while the wide midfielders (wing attackers) and fullbacks (wing backs) also displaying superior high-intensity activity profiles. However, the attackers and central defenders consistently show the lowest physical performances during a game. Helgerud *et al*. (2011) established that there is a noteworthy contrast in VO_{2max} amongst the top and lower ranked teams in elite soccer, consequently success in team sports like soccer may depend greatly upon a very well developed aerobic energy system among players. Wilmore and Costill (1999) further cited that a soccer match is characterised by a long duration, i.e. one and a half hour or two hours or more in instance of knockout tournament. In this way, a player's groundwork for a competition ought to be adjusted accordingly in preparation for these intensities. With that being said, a player should be able to adapt to any form of energy system required on a soccer field because of the intermittent nature of the game.

To conclude, Di Salvo *et al*. (2007) argue that these discoveries have suggestions for creating position-specific training exercises that simulates the attributes of each position by taking into account the distinctive tactical, technical and physical demands of different playing positions in the team.

2.3.2.5: CONTRIBUTION OF EACH ENERGY SYSTEM DURING A SOCCER MATCH

During a match, intensities vary from very high to low, so it would be logical to think all three of the energy systems should be and would be engaged throughout the duration of 90 or 120 min; the most intriguing part is the difference in contribution from various energy systems during a soccer match. Soccer is portrayed by an irregular movement profile with high-intensity anaerobic endeavours superimposed on a foundation of aerobic activity. This varying intensity places high metabolic demands on the energy delivery pathways (Drust *et al*., 2000). Bangsbo (1994:a) highlighted that the main metabolic pathway utilised throughout a soccer match is aerobic pathway, where only 10% of the average distance covered is at high intensity (Stølen *et al.,* 2005) and with goalkeepers only covering 2% at high intensity (Di Salvo *et al*., 2008).

Gastin (2001) explained that ATP-PC system is responsible for high-intensity runs and the aerobic system is for prolonged low to moderate intensity efforts, while intense muscle power outputs can be immediately supported by the anaerobic system.

Mohr *et al*. (2003 p.526) indicated that "elite Italian League players performed at least 28% more high intensity running than sub-elite Danish League players". Similarly, Ingebrigtsen *et al.* (2013 p.1342) indicated that distance covered in "high intensity running was 31–38% greater in players in top-ranking Danish teams when compared with middle- and bottom-ranking Danish teams". Reilly (1994) reported that the normal work rate is estimated as percent of maximal heart rate, during an hour and a half match is near to lactate threshold, or 80-90% of the maximal heart rate. This implies that during a soccer match, players are switching back and forth between aerobic/anaerobic metabolic systems, in correspondence to intense technical and tactical situations.

2.3.2.6 SUBSTRATE UTILISATION

Carbohydrates and fats are the primary sources of energy for metabolic processes. While protein can supply energy, it is not its primary function. Protein (or its sub-components, amino acids) are known as the "building blocks of cells, so the body prioritizes them as an available substrate for building and repairing muscles and other tissues" (Van Winckel *et al*., 2014 p.46). Hulton and Edwards (2012) explained that the availability and burning of micronutrients is important in a habitual state of functioning, e.g. mental functioning and physical movement. The contribution or allocation of these micronutrients in sport is influenced by the "type of activity, duration of activity, glycogen stores and the prescribed pre-exercise meals containing carbohydrates (CHO) which are recommended to athletes, prior to exercise have a favourable impact to exercise" (Hulton & Edwards 2012 p.165).

The consumption of body starch stores is the primary source of fatigue or performance impairments during the game, especially during delayed (90 min or longer) match of sub-maximal or intermittent high-intensity activity. Subsequently, methodologies for athletes incorporated expending starch (carbohydrates) before, during and in the recuperation period between exercise sessions (Drobnic *et al.,* 2016). Taking into consideration that the timing of events is used to distinguish between meals on match days, generally pre-meal is consumed 3 hours before kick off. We can conclude that there are benefits from consuming greater "amounts of CHO in both the pre-match and post-match meals so as to increase CHO availability and maximize rates of muscle glycogen re-synthesis, respectively" (Anderson *et al.,* 2017 p.5).

2.3.2.7. FATIGUE

Soccer players tend to experience high physiological stress during an exhausting soccer match or even during a hard training session. These changes come as a result of fatigue and according to Marqués-Jiménez *et al.* (2017) can decrease performance. Phillips (2015 p.4) explained and defined fatigue as a "diminution of the expected muscle force to continue working at a given exercise intensity". Gibson and Edward (2012) further explained fatigue as a self-protective component against harm of contractile machinery of muscles. Reilly *et al.* (2008) conclude that one of the result of keeping consistent exercise for an hour and a half or more, as it occurs in soccer, is that the ability of muscle to produce force decreases. This inability is reflected in the decrease of work-rate towards the end of the game and this phenomenon is known as "fatigue". In soccer, fatigue is characterised as a decrease in the ability to continue muscular work that is showed as a decrease in work rate towards the end of the match

(Reilly *et al.,* 2008). Sahlin (1992) further clarified that fatigue is a mind boggling and multifaceted marvel, which has all sorts of possible mechanisms such as inability to keep the required power output. Fatigue can also be affected by the various components such as type of stimuli (this can be voluntary or electrical), the contraction type (isometric contraction or isotonic contraction, and intermittent or continual, the interval, recurrence and intensity of the exercise, and the type of muscle. The physiological and training status of the player and the environmental conditions may likewise essentially influence fatigue. Mohr *et al*. (2005 p.593) mentioned fatigue is caused by "low glycogen concentrations in muscle fibres in a hot and humid environment, dehydration and a reduced cerebral function may also contribute to the deterioration in performance". Smith *et al.* (2015) revealed that mental fatigue also impairs both physical and technical performance of soccer players. However, there are other factors contributing to fatigue during match day, such as environmental conditions, high altitude, and high lactate build-up (Hargreaves, 2000).

Alghannam (2012 p.65) explained that most of the recent studies indicated the "importance of the comprehension of the energy demands in soccer to aid in the understanding of substrate utilisation during a single match". Research demonstrates that physical performance decreases between the first and second halves of professional match play (Di Salvo *et al*. 2009). Reilly *et al*. (2008) agree and stated that in terms of performance, a decrease in work rate in the second half was constantly discovered regardless of the level of competition or the physical fitness of players. Bangsbo *et al.* (1991) also agree and highlighted that Danish players in the second half decrease compared to the first, a total decrease of 5% in the total distance covered. With that being said, in recent years we've seen the demand for soccer has increased, especially in the professional world, this in turn resulting in high competition loads such as the world cup every four years, UEFA and CAF Champions League, as well as other competitions from different leagues and this results in an accumulation of 90 minutes and less time to recover. In modern soccer, teams use various styles of periodization, depending on the number of matches played during a week. Table 2.8 and Table 2.9 illustrate the types of in season micro-cycles used in the PSL in South Africa.

Table 2.8: Type 1 of in season micro-cycle Saturday to Saturday.

	Match	Recovery		Loading	Recovery	Tapering		Match	Recovery
Starters >60m	**Sat 0**	**Sun +1**	**Mon+2**	**Tue-4**	**Wed-3**	**Thur-2**	**Fr-1**	**Sat**	**Sun+1**
	Match day	Off	Light training	Training Strength	Off	Training Remedial	Training	Match day	Off
	Match	Recovery	Loading		Recovery	Tapering		Match	recovery
Bench <60m	**Sat 0**	**Sun+3**	**Mon+2**	**Tue+1**	**Wed-3**	**Thur-2**	**Fri-1**	**Sat**	**Sun+1**
	Match	Off	Training	Training Strength	Off	Training Remedial	Training	Match	Off

Table 2.9: Type 2 of in season micro-cycle Tuesday to Saturday.

	Match	Recovery		Match	Recovery		Tapering	Match	Recovery
Starters >60m	**Sat 0**	**Sun +1**	**Mon-1**	**Tue-4**	**Wed-3**	**Thur-2**	**Fr-1**	**Sat**	**Sun+1**
	Match day	Regeneration	Light training	Match day	Regeneration Or Off-Day	Light Training	Training	Match	Off
	Match	Loading	Tapering	Match	Recovery		Tapering	Match	Recovery
Bench <60m	**Sat 0**	**Sun+1**	**Mon+2**	**Tue+1**	**Wed-3**	**Thur-2**	**Fri-1**	**Sat**	**Sun+1**
	Match	Training	Training	Match day	Training	Training Remedial	Training	Match	Off

Dupont *et al.* (2013) mentioned that soccer teams like Mamelodi Sundowns, which have competed in every prestigious competition in the continent for the past four to five years, have been affected with regard to the normal pre-season regime of six weeks and it is becoming an increasingly shorter period for teams that are crowned as champions. Even during the season, teams try to manipulate training times and focus on the duration of training rather than the volume of training. Teams get to plot the pre-season two to three weeks after most teams have started with the pre-season. It forces the medical team and the technical team to carefully plan the season ahead and put recovery strategies in place. Dupont *et al.* (2013 p.9) highlighted strategies such as “hydration, diet, sleep, cold water immersion and compression garments as effective to try and accelerate the recovery process”.

2.3.2.8 TRAINING LOAD

Training load is made up of internal and external load training (Bourdon *et al*., 2017), and if we investigate the relationship of workload (internal-external load) between performance and injury, we will see why athlete monitoring is so popular in modern sport. Internal and external load relationship is made of a group of prescribed exercises put together to provoke a response from the body. It is a "Dose-Response relationship" and in this manner, it permits us to improve our insight into how a player may react to a specific training dose. We can become increasingly proactive in future when controlling the dose, as opposed to only responding to the reaction (Van Winckel *et al*., 2014 p.167). A more consolidated approach, which takes into consideration the two variables of training load (internal and external), can provide a more consistent outlook on training (Bourdon *et al*., 2017).

As referenced above, there are various reasons why observing training load has come to the forefront of a scientific way to deal with understanding athletes' relationship between training responses and match day readiness. Observing of training load can give a logical and scientific clarification for changes in performance. This can aid in building up an understanding and confidence in relation to any possible reasons related to change in performance and decrease the degree of uncertainty related with the changes (Van Winckel *et al*., 2014). From this information, it is not just conceivable to reflectively look at load–performance relationships, but also to allow detailed planning for training loads and games. Significantly, load monitoring is also utilised to try to decrease the risk elements e.g. injuries, illness, and non-functional overreaching. This set of data is important as it may also influence team selection and determining which player is ready for the demands of a match (Halson, 2014).

Figure 2.3 shows the relationship between internal and external workload.

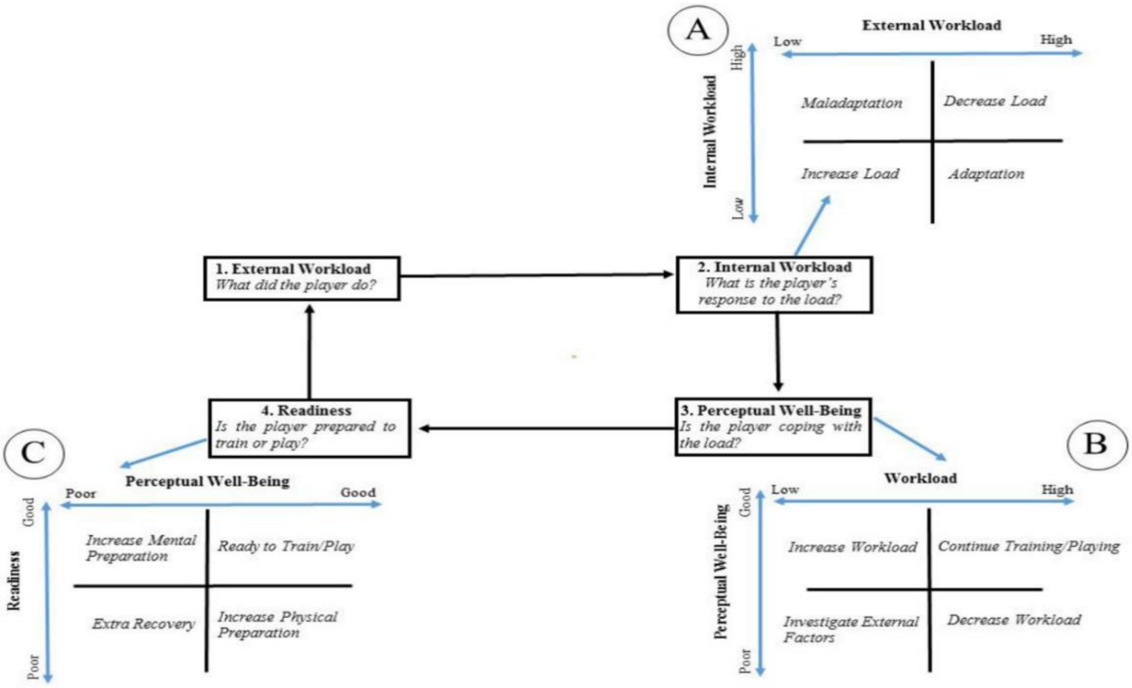


Figure 2.3: Schematic presentation of internal and external workload (Gabbett *et al*. 2017).

External Load is made up of prescribed exercises from the coaches, such as total distance covered or sets/repetitions. Kyprianou and Farioli (2018) stated these two attributes can be accurately monitored or measured using Global Positioning System (GPS). It is well known that conditioning coaches integrated GPS data with the physical capacity (fitness test score of athletes), also with game-specific tasks, tactical and strategic information as well as injury prevention strategies. It is clear that the future of GPS analysis will involve "further reducing of devices, longer battery life, and integration of other inertial sensor data to more effectively quantify the effort of athletes" (Aughey, 2011 p.295). A good and reliable device can help the coach with various coaching interventions.

Internal Load can be seen as the players' physiological adaptation to the external training load. Malone *et al*. (2014) added that internal loading will evoke or give guidance to training adaptation. Foster *et al*. (2001) explains it as the simplest way to measure aerobic and anaerobic activity, this is executed via session rating of perceived exertion (sRPE). Training load measured by the sRPE represent a subjective way of measuring the load an athlete was exposed to. This system includes multiplying a player's RPE (on a 1–10 scale) with the time of the session (in minutes) (Van Winckel *et al*., 2014). A more consolidated approach using the sRPE method has been the object of researches that analysed its validity assuming as construct HR techniques (Impellizzeri *et al*., 2004), and which has been "correlated with other internal and external training load" (Haddad *et al.,* 2017 p.3). Haddad *et al*. (2017 p.3) further stated that "this basic technique has been demonstrated to be valid and reliable, with individual correlations between session RPE and summated HR zone scores ranging between R = 0.75 and R = 0.90". Hopkins (1991) also recommended Heart Rate (HR) monitoring, and using HR zones as one of the most common means of assessing internal load in athletes and the objective measurement of intensity. The utilisation of HR monitoring during any activity depends on the linear correlation between HR and the rate of oxygen utilised during consistent exercise. A caution by Gilman (1996) states that in certain conditions such as thermal stress and cardiac drift, heart rates do not accurately align with the VO_2 and in this case, selected heart rates can be used as indicators of training intensity. However, data obtained from maximum HR can be utilised to both prescribe the intensity and monitor the required intensity (Borresen & Lambert, 2008). Due to day by day variation in HR, which might be up to 6.5 % for submaximal HR (Bagger *et al.,* 2003), controllable factors for example hydration status of the player, environment temperatures, and medication are important.

To conclude, after analysing the data (via HR, sRPE and GPS), the conditioning coach or physical trainer should supply the head coach with the analysed data, where upon the coach can adjust the intensities of the training sessions or even rest some players as a form of injury prevention strategy. Players get instant feedback and that will help improve their performances.

2.3.2.9 ANAEROBIC POWER AND MUSCLE STRENGTH

The need of specific strength training for a soccer player is highly determined by the constraints placed on them during a match (Gamble, 2010). In most parts, strength is viewed as being crucial in sports that include speed. Considering the importance of strength in soccer, the strength & conditioning coach together with the player must recognise how improving strength can have a positive effect on performance, in the same breath the necessity to understand the protocols applicable to strength training to adequately prescribe and enhance performance (Bompa & Haff, 2009). Muscular strength plays various important roles in soccer. Players use muscular strength in various actions during a match, for instance, acceleration, deceleration, change of direction, sprints, jumps, dribbling, kicking, heading and tackling. Strength in the trunk muscles is crucial as it is required during agility, change of direction and tackling the ball (Bisanz *et al.,* 2008). Stølen *et al*. (2005) reiterated that soccer is indeed a strength related sport and it requires both absolute strength and relative strength. Without a doubt muscle strength is an extremely important component of physical element in soccer, in reference to both elite level performance and injuries.

Power development is dependent upon maximal strength, being associated with a change in force abilities (Wisløfff *et al*., 2004). Reilly and William (2003) expressed strength preparing in soccer players with three viewpoints:

* To build muscle (power) force yield during explosive exercises, for example, tackling, hopping, kicking, accelerating and decelerating.
* To prohibit injuries, and
* To recapture strength post injury.

Wisløfff *et al*. (2004 p.286) showed that strength accumulation in soccer players increases the force velocity, and to execute fundamental actions like jumping and sprinting. They have found a strong correlation amongst, jumping height and squat strength, and also in all the parts of 30m sprint execution in elite soccer players. The outcomes confirmed that,

- "the 1RM correlates with the 10m sprint time ($r = 0.94$, $p<0.001$),
- 30m sprint time ($r = 0.71$, $p<0.01$) and
- jumping height ($r = 0.78$, $p<0.02$).
- vertical jump capabilities are related to both 10m ($r = 0.72$, $p<0.001$) and
- 30m sprint time ($r = 0.60$, $p<0.01$)".

Based on the results, it will be valuable for a soccer player to possess a high level of muscular strength, to help with basic soccer skills that include acceleration, deceleration, speed and change of direction.

Bangsbo (2003) agrees that explosive strength in the lower limb muscles correlates with the velocity of speed within a match, when a player is required to rapidly change direction. Reilly (1996) also emphasised that lower body muscle strength is a vital fitness component for speed, jumping, kicking, tackling and change of direction. Likewise, upper body strength is equally important as it is mainly utilised during throwing and avoid being knocked off the ball by opponents.

A balance strength training between the upper and lower body is essential for elite soccer players. Previous experiments have highlighted the correlation between muscle force and power, and the influence it has on vertical jumping ability; this is an important component of game play and hence is essential to a player's effective execution particularly for defensive players (Reilly & Williams, 2003; Stølen *et al.,* 2005). However, it seems that the smaller and more dynamic players are starting to dominate the midfield and striking positions in soccer. Khazan (2014) concluded in this regard and mentioned that in recent years the world's most celebrated players are compact. According to Khazan (2014) a good example is Xavi Hernández (1,7m) and Andres Iniesta (1.71m); these two players have won more trophies than any other Spanish player ever has, in the domestic league and at international level. In addition to that, the legendary Pele is (1.73m), and Argentina's Diego Maradona is just (1.65m). The fact that all the above-mentioned players are compact gives them an advantage of being close to the ground as midfielders and strikers. Shorter people have a quicker stepping pattern. They can change directions much faster than tall players, and they have better control over their limbs (Khazan, 2014).

2.3.3.1 SPEED

According to Bompa and Haff (2009) sprint speed on the field of play, is viewed as a critical component to the game as most crucial plays in match are usually a consequence of a player’s capacity to move at rapid speed with the ball or towards the ball. Therefore, it would be a great advantage for ST and CB to have remarkable levels of speed. It is notable that agility and speed are fundamental parts, which can impact a match in all type of sports. These elements profoundly associated with the player's muscle strength and power. Actualizing of speed and agility training modalities into the conditioning programme as well as manipulating specific training components can improve performance in sport. Having knowledge of the conditions and variables that impact speed and agility equip coaches to design sport specific conditioning programmes that improves sport performance (Bompa & Haff 2009). Van Winkel *et al*. (2014) explains the different components of speed as follows:

- Reaction/starting speed: The first three or four strides;
- Acceleration: 10–20m;
- Speed endurance: 60–70m;
- Repeated sprint ability: Repeated sprints sometimes with little recovery time in between.

According to Sharma (2018) it is a common practice to test speed in distance zones of 10m, 20m and 40m. This is generally organised in a best-of-two trials and the best one is recorded as a result (Sharma, 2018). Speed and power are acknowledged as essential factors in soccer matches. During a match, players must have the capacity and ability to quickly accelerate to match up to the physical, strategic and technical aspects of the match. Furthermore, soccer players are expected to cover grass adequately while controlling the soccer ball with their feet at high speeds, and simultaneously try to evade tackles from the opponents.

Silvestre *et al.* (2006) also highlight the crucial role speed plays in soccer, the capacity of acceleration which is some times the most important component in success for players during matches, where they need to get to the ball first or to be set up for a counter attack in play. Silvestre *et al.* (2006) also highlight the importance of speed for increasing good defensive positions, to clear a risky play as well as producing opportunities to win a match. Players do not regularly cover more than 25m at once in a match. Therefore, as soccer players are required to deliver high intensity work repeatedly, a heightened anaerobic threshold is crucial in order to compete at high intensity (Bangsbo, 1994:b). Having said that, research shows that leaner-sprint training seems to have practically no impact on the improvement of sprinting that includes change of direction. Young *et al*. (2001) and Tsitskaris *et al*. (2003) reaffirmed this. However, Faude *et al*. (2012) highlight the fact that two hundred and ninety-eight (83%) goal scoring opportunities were made by one powerful action from the goal scorer or the assisting player. Most runs or movements for the scoring player were straight sprints (n = 161, 45% of all analysed goals, P < 0.001). Faude *et al*. (2012) concluded that acceleration, maximum speed, and agility are explicit characteristics and generally unrelated to one another. They therefore recommend the utilisation of specific testing and training protocols for each speed variable when working with professional players.

2.3.3.2 ACCELERATION

Little and Williams (2003) define acceleration as the rate of change in velocity, that permits a player to attain maximum velocity in the least amount of time. Osgnach *et al.* (2009) further explained acceleration as a metabolically challenging activity that increases both the energy consumption of an activity and muscle fatigue when compared to displacement at a consistent speed. Morin (2018) further indicated that soccer is mostly related to changing of speed; that is accelerating one's body mass. Starting from different speeds (rarely standing still) and positions, a player has to create high amounts of "pure acceleration" past an opponent (offense), get to the ball/position first, or catch up with an opponent (defence).

2.3.3.3 AGILITY

Osgnach *et al*. (2009) argue that agility does not have a worldwide definition but it is regularly perceived as the capacity to change direction, to start and stop rapidly. However, "the ability to sprint, accelerate and decelerate with a change of direction is commonly known as agility. Agility has been, indeed, defined as a rapid whole-body movement with change of velocity or direction in response to a stimulus" (Sheppard & Young, 2006 p.919). Agility is made out of perceptual and decision-making elements, as well as change of direction mechanisms (Young *et al.,* 2015). During any competitive soccer match, players should execute this continuous change of direction to win position functional to game tactics (Stølen *et al.,* 2005). It is imperative to repeat these soccer activities. Bloomfield *et al*. (2007) emphasised that physical match analysis demonstrates that during professional soccer matches, players execute a great deal amount of change of direction bouts at high intensity using a wide scope of turning angles. Furthermore, change of direction were considered to affect the outcome in professional soccer match. These actions will be dependent on where and what action you are about to execute on the field of play. Faude *et al*. (2012) concluded that there were two hundred and ninety-eight goals scored in the German national league and 6% of the goals were created from change-in-direction sprints.

2.3.3.4 MAXIMUM SPEED

According to Malý *et al*. (2014 p.155) maximum speed is "the maximal velocity at which a player can sprint". These sprints are customary in many team sports including soccer, rugby, basketball, hockey, etc.

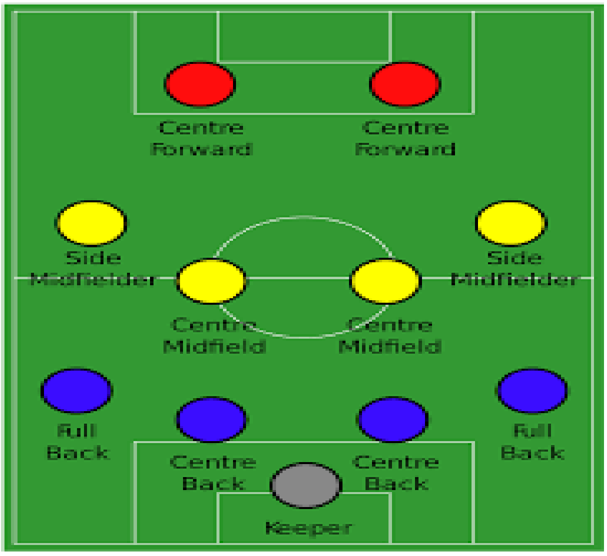
Speed comprises several different components, namely:

- Reaction/starting speed: Known as the first three or four strides. It can be seen as the time interval during which the nerve impulses are conducted to the brain, where they are processed and then sent to the respective muscles. It was further elaborated that the reaction speed is determined by various factors, including age and gender.
- Starting speed: 10–20 meters: As was discussed earlier, the energy for this type of exertion is supplied by the ATP still present in the muscles.
- Acceleration: 10-20 meters and the duration for this phase is 2-6 seconds.
- Speed-endurance: 60–70 meters and the duration is 6-10 seconds.
- Repeated sprint ability: Is one of the most important components of the modern-day soccer player. Duration can vary from 1-6 seconds per sprint at 100% effort (Van Winckel *et al.,* 2014).

To conclude, all these mentioned attributes will determine who gets to the ball first or moves away from an opponent and will definitely influence critical match outcomes. With straight line or maximum sprint being the most common action taken before a goal-scoring action, maximum speed is therefore an important attribute for participating successfully in team sport like soccer.

2.3.3.5 POSITIONAL PROFILING

Positional profiling is derived from how a team wants to be positioned on the field, and this will be determined by the skill set of players and how the team wants to set up defensively or offensively (See Figure 2.4 below).



This is one of the most used formations in soccer to date. The main strength of this formation is right balance. The balance from strikers, midfielders and the defence. The 1-4-4-2 is possibly the initial formation you will come across as you start to play.

Figure: 2.4: Shows 1-4-4-2 formation (Anon, 2019).

The 1-4-3-3 emphasis on triangular midfield, putting a central midfielder in-front of the back four with two CAM behind the centre forward and two wingers. The wingers are the workhorses of this formation as it is a dynamic formation between a 4-3-3 on attack and 4-5-1 on defence.

Figure: 2.5: Shows 1-4-3-3 formation (Anon, 2019).

The 3-5-2 is one of the current formations in modern soccer and is primarily related to German soccer. The formation was popular during the World Cup in Italy (1990) where Germany won the competition. The system was also practiced successfully during the European Cup (1996) by Germany.

Figure 2.6: Shows 1-3-5-2 formation (Anon, 2019).

The 3-4-3 is an offensive minded formation with little defensive thinking and most focus is on offensive part. It is unusual because it makes your team vulnerable to counter attacks. You will not see many coaches using it today without giving clear instructions to the players.

Figure: 2.7: Shows 1-3-4-3 formation (Anon, 2019).

Table 2.10: Playing positions explained.

CB	• Central Defender
WB	• Wing-back
CM	• Central Midfielder
CAM	• Central Attacking Midifielder
WA	• Wing Attack
ST	• Striker

As mentioned before in section (2.2.2 structure of the game) most of the successful teams from 2010, 2014 and 2018 FIFA World Cups, were able to be flexible and adapt their style of play from 4-4-2, 4-2-3-1 and 4-3-3 based on the match situation. (FIFA 2010, FIFA 2014, FIFA 2018).

2.4. COMPONENTS OF IMPORTANCE FOR SOCCER FITNESS

2.4.1 DISTANCE COVERED BY A SOCCER PLAYER

The physical needs of distance covered by outfield players is being extensively researched, using a couple of distinct systems, which includes video analysis, hand documentation and trigonometry (Bangsbo *et al.,* 2006). According to Ekblom (1986) TMA is applied in soccer because players, coaches, conditioning coaches and even spectators are passionately invested in the sport. Finally, the use of TMA in matches has permitted detailed data of match activities.

It is interesting to note that in the 90's, Reilly *et al*. (1990) suggested that top division players secured an aggregate mean distance of only 8.6km. However, in modern soccer, we could label that as an outlier, because the physiological demands of the game have extended over the span of the last quarter of a century, this increase can be seen in total distance covered in a single soccer match (Jansen *et al*., 2010). Stølen *et al*. (2005) indicated that today's soccer players cover an aggregate running distance of around 7 to 13km with repeated short high intensity running activities during a match. This suggests the normal soccer player's physical condition has heightened in recent years. Midfielders seem to be covering a lot of distance because they act as a link between the defenders and the strikers (Rienzi *et al*., 2000). They can cover up to 11,5km-12km or even more compared to the defenders and strikers who cover relatively the same distance (10km-10.5km) per game (Bangsbo, 1994:a). There are a few reasons that contribute to such changes in distances covered, for example, changes in strategies (pressing high, medium or low, counter attacking), playing position and playing styles (formation 1-4-4-2, 1-3-5-2, 1-4-2-3-1 or 1-4-3-3). Bradley *et al*. (2011) concluded that distance covered during a game will be influenced by the formation. Table 2.11 and 2.12 show the distance covered influenced by formation. It is clear that the 1-4-3-3 formation needs even more top conditioned players.

Table 2.11: Distance covered influenced by formation

"Formation	Distance covered
1-4-4-2	(10697-945m)

1-4-3-3	(10786-1041m)
1-4-5-1	(10613-1104m)"

(Bradley *et al.,* 2011).

Table 2.12: Distance covered by various positions in different formations

"Defenders in various formations	**Distance covered**
1-4-4-2	(10452 -755m)
1-4-3-3	(10073- 852m)
1-4-5-1	(10123- 875m)
Midfielders in various formations	**Distance covered**
1-4-4-2	(11505 -783m)
1-4-3-3	(11586- 494m)
1-4-5-1	(11606- 722m)
Strikers in various formations	**Distance covered**
1-4-4-2	(9982-769m)
1-4-3-3	(11130- 999m)
1-4-5-1	(10012- 946m)"

(Bradley *et al*., 2011).

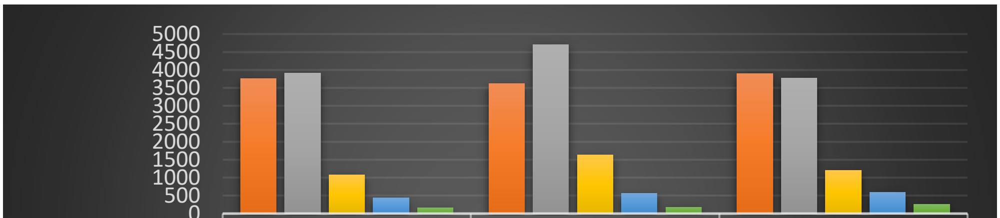
Peñas *et al*. (2009 p.224) categorised 5 levels of intensity which dominate a match. "The overall distance covered by soccer players during a match consists of 58.2–69.2% walking and jogging (0–11km/h) corresponding to 6626–6996m, 13.3–15.7% low-speed running (11.1–14km/h) corresponding to 1336–1809m, 12.3–17.1% moderate-speed running (14.1–19km/h) corresponding to 1238–1999m, 2.9–5.8% high-speed running (19.1–23km/h) corresponding to 333–682m and 1.8–4.2% sprinting (> 23 km/h) corresponding to 184–490m".

The different movements involved in a soccer match included backward, sideways and diagonal movements, as well as running and walking activities. It also include a few other movement patterns like tackling, jumping, shooting, dribbling, as well as acceleration and change of direction. However, most of the total distance attained during a soccer match, is by walking and low-intensity running. However, it is important to note that mainly the high-intensity exercise periods (which are vital moments) that determines the results of the match. To conclude, low-intensity actions make up more than 70% of the game.

2.4.2. HIGH-INTENSITY DISTANCE COVERED

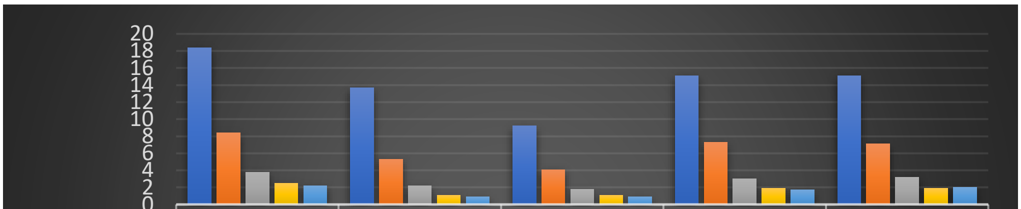
Bangsbo *et al*. (1991) and Mohr (2003) indicate that the total distance covered by a top-level outfield male soccer player during a match is 10–13km. This is much higher as reported by Reilly *et al.* (1990). However, it is important to note that most of the total distance is covered by walking and low-intensity running. It must be highlighted again that the high-intensity exercise periods- that are really important. Carling *et al*. (2005 p.104) mentioned that “during an intermittent, high-intensity sport, performance can be heightened through improving players’ ability to perform high-intensity work repeatedly”. This can be explained due to the timing of anaerobic efforts, (distance, duration) and the capability to repeat these efforts. Di Salvo *et al*. (2007) conclude that soccer players execute at least 3 to 40 sprints in a single match. However, the mean distance and interval of a sprint run are reasonably short. Sprinting distances seldom exceed 20m and are no longer than 4 seconds (Di Salvo *et al*., 2007).

Figure 2.8, 2.9 and 2.10 show the positional differences for each of the five distance categories and at different intensities.



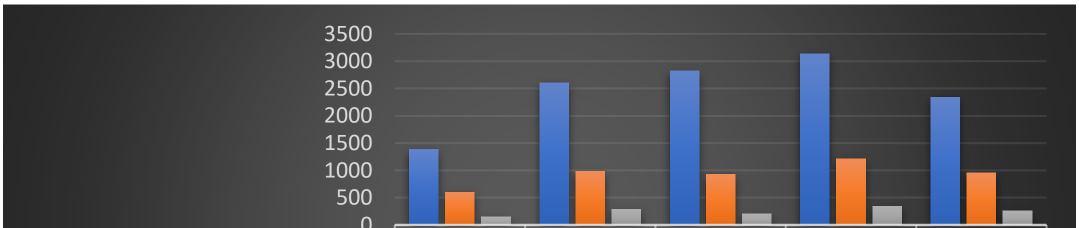
	Defenders	Midfielders	Strikers
Zone 0-7km	3760	3621	3906
Zone 7-15km	3907	4710	3770
Zone 15-20km	1086	1629	1210
Zone 20-25km	433	566	591
Zone 25+km	165	182	254

Figure 2.8: Positional differences for each of the five distance categories in a World Cup 2018 knockout stage (Peeve *et al.* 2019).



	Wide Midfielders	Central Midfielders	Central Defenders	Wide Defenders	Attackers
0-5m	18.4	13.7	9.2	15.1	15.1
5.1-10m	8.4	5.3	4.1	7.3	7.1
10.1-15m	3.8	2.2	1.8	3	3.2
15.1-20m	2.5	1.1	1.1	1.9	1.9
>20m	2.2	0.9	0.9	1.7	2

Figure 2.9: Positional differences for each of the five distance categories (Di Salvo *et al*. 2010).



	Central Defenders (92)	Fullbacks (84)	Central Midfielders (80)	Wide Midfielders (52)	Attackers (62)
High-Intensity Running (m)	1384	2605	2825	3138	2341
Very High-Intensity Running (m)	603	984	927	1214	955
Sprinting (m)	152	287	204	346	264

Figure 2.10: Differences of speeds in soccer positions (Bradley *et al.* 2009).

Furthermore, Redwood-Brown *et al*. (2012) concluded that soccer players' work rate was higher when losing than winning a match. Redwood-Brown *et al*. (2012) argue that this could be because players are trying to repossess the ball and to get on equal terms with their opponents. Gómez *et al*. (2012) emphasised that the match activity of winning teams is more specific, in terms of the winning team not losing the ball more often and this consequently results in them having more shoots and goals. Randers *et al*. (2007 p.161) elaborated that players in "successful teams competing within the same elite league were reported to perform more high-speed running and sprinting in the most intense periods of the game and more sprinting over the whole 90 minutes than less successful teams".

2.4.3. PERCENTAGE WORK-RATE/RATIO AT HIGH-INTENSITY

Sprint-profile is considered to be "an imperative element of performance but only contributes a small proportion to the overall motion activity during competition; accounting for approximately 10% of the total distance covered over the course of matches" (Carling *et al*., 2008 p.852). Rampinini *et al*. (2007) found that at least 8% of the average distance covered in soccer is in high intensity, while Rienzi *et al*. (2000) indicate that sprinting can vary from 1-12% of the total distance covered in a soccer match. Data shows that, in a game, elite soccer players execute 150–250 intense movements (Mohr, 2003; Bangsbo, 2003) and perform a high-intensity run (>19.8 km · h^{-1}) every 72s (Bradley *et al.*, 2009).

However, Di Salvo *et al*. (2007) found that among outfield players, (CB) spend considerable time walking and jogging (0– 11 km/h) covering a longer distance in this activity category, when compared to other playing position. Rampinini *et al.* (2004) agreed that CB covered the lowest distance in reference to high intensities. However Midfield players (CM and WA), were reported to be spending less amount of time walking and jogging, but covered significantly greater distance in low- and moderate-speed running. Furthermore, Wing Attack (WB) spent the highest percentage of time and covered the greatest distance in high-speed running and sprinting. Di Salvo *et al.* (2007) also indicate that time spent, and distance covered by (WA) players was not significantly different from wing backs and strikers (Rampinini *et al*., 2004; Di Salvo *et al.,* 2007). Important to note that the above-mentioned possessions are always combining between the defenders or with attackers trying to score, and these could be match defining moments.

2.4.4. WORK-REST RATIOS

Reilly and Thomas (1976 p.88) indicate in their study that the total distance covered by outfield players during a match comprises of: "24% walking, 36% jogging, 20% cruising, 11% sprinting, 7% moving backwards and 2% moving while possessing the ball". In modern soccer it is imperative to analyse and quantify the athlete's performance by the use of motion analysis. O'Donoghue (2002) agrees that the utilisation of TMA methods permits information including "sprinting, jogging and walking movements alongside total distances covered and maximum velocities to be gathered". Dupont *et al.* (2004) also agree and stated that the analysis with the point of evaluating the athlete's work to rest ratios and the periods of recovery can be deemed as important as the active moments. With all the data at the conditioning coach's and coach's disposal, Dupont *et al*. (2004) recommended that coaching staff can try to simulate the actual match-play by incorporating all the submaximal and maximal intensity activity with short and long recovery periods.

O'Donoghue (2002) elaborated that midfielders had a significantly lower average recovery between bursts than defenders which implies that the former executing considerably greater number of bursts than defenders (See table 2.13-2.15). Therefore, midfielders spent significantly more time working than defenders. O'Donoghue (2002) summarise the effect of position on activity profile in table form. The results of the study are depicted in the following tables (Table 2.13 – 2.15).

Table 2.13: Summary of analysis of the effect of position on activity profile.

Measure	Defenders	Midfielders	Strikers	Average
% time spent performed work	9.2 ± 2.4	11.0 ± 2.5	10.4 ± 1.6	7.7
Number of bursts	28.4 ± 6.4	32.1 ± 6.0	31.4 ± 4.8	4.3
Duration of mean of high intensities burst	3.1 ± 0.5	3.2 ± 0.4	3.2 ± 0.4	1.3
Duration of mean low intensities recovery	31.9 ± 7.9	27.1 ± 5.4	28.2 ± 4.3	6.5

O'Donoghue (2002 p.6)

Table 2.14: Frequency of high intensity bursts of different durations.

Duration of burst	Defenders	Midfielders	Strikers
Under 2s	13.2 ± 3.9	14.6 ± 3.5	14.4 ± 3.0
2s to Under 4s	9.1 ± 2.5	10.3 ± 2.4	10.1 ± 1.9
4s to Under 6s	3.3 ± 0.9	3.9 ± 1.1	3.9 ± 1.2
6s to under 8s	1.9 ± 1.5	2.0 ± 1.5	1.5 ± 0.9

8s to under 10s	0.5 ± 0.6	0.7 ± 0.5	0.7 ± 0.4
10s to under 12s	0.2 ± 0.4	0.4 ± 0.4	0.5 ± 0.6
12s or greater	0.1 ± 0.3	0.2 ± 0.4	0.2 ± 0.3
Total	28.4 ± 6.4	32. ± 1 6.0	31.4 ± 4.8

O'Donoghue (2002 p.6)

Table 2.15: Frequency of low intensity recoveries of different durations.

Duration of burst	Defenders	Midfielders	Strikers
Under 2s	1.5 ± 0.8	2.1 ± 1.2	2.0 ± 1.1
2s to Under 4s	1.7 ± 0.9	2.2 ± 1.4	2.1 ± 1.3
4s to Under 8s	2.8 ± 1.7	3.6 ± 1.8	2.8 ± 1.2
8s to under 12s	3.6 ± 2.1	4.4 ± 2.5	4.3 ± 1.9
12s to under 20s	5.0 ± 2.2	6.4 ± 2.3	5.8 ± 1.7
20s to under 45s	6.2 ± 1.7	6.8 ± 1.3	7.6 ± 1.5
45s to under 90s	5.1 ± 1.5	4.7 ± 1.2	5.0 ± 1.1
90s or greater	1.4 ± 0.8	0.9 ± 0.6	0.9 ± 0.7
Total	27.4 6.4	31.1 6.0	30.4 4.8

O'Donoghue (2002 p.6)

With the data provided above by (O'Donoghue, 2002) we can conclude that there are substantial differences between strikers, midfielders and defenders in reference to work rate, activity profiles and movements.

2.4.5. IMPLICATIONS FOR FITNESS TRAINING

Physical preparation plays a pivotal role in the success of any soccer team at any level. This takes careful planning and understanding of both the physiological and the practical demands of the game (Reilly, 2007). It is essential to plan a season for soccer players; this will take meticulous programming knowledge supported by science. Reilly (2007 p.9) proposed that a programme should include: “planning seasonal training to peak at the right time, training for strength, speed, aerobic and anaerobic fitness, designing appropriate sessions for training and rehabilitation, best methods for recovery from exercise and reducing injury risk, preparation for play in different environmental conditions, evaluating the effectiveness of training programmes and diet, sleep, lifestyle, young players and long-term development”.

Most importantly, sport scientists need to investigate or analyse the duration, frequency, and intensity of movement patterns executed during a match and these need to be taken into account before they can assess the fitness status of players (Dotter, 1998). Furthermore, these professionals need to be considerate of the playing philosophy and flexibility of the playing formations of the team because these will contribute to planning and programming.

Peñas *et al*. (2009 p.218) highlighted total distance covered in five selected categories of intensity: namely;
" (0-11 km/h standing, walking, jogging); 11.1-14 km/h (low-speed running); 14.1-19 km/h (moderate-speed running); 19.1-23 km/h (high-speed running); > 23 km/h (sprinting)".

Bradley *et al.* (2009 p.160) reported more or less the same variables, however it differ slightly: "standing (0–0.6 km/ h), walking (0.7-7.1 km/h) jogging (7.2–14.3 km/ h), running (14.4-19.7 km/ h), high-speed (19.8-25.1 km/h), and sprinting (25.1 km/h). High-intensity running consisted of running, high- speed running, and sprinting (running speed 14.4 km/h). Very high intensity running consisted of high-speed running and sprinting (running speed 19.8 km/h)".

Positional training profile need to be taken into account, considering that midfield players covered greater total distance during a match than the group of defenders and strikers (Peñas *et al.,* 2009). If we consider the performance profiling of a soccer player and the activities such as speed, acceleration, deceleration, walking and jogging, most of these elements can be trained for with or without the ball. Reilly (2007) highlighted, that soccer players are more stimulated and motivated by exercises performed with the ball than organised fitness work such as repetitive runs. Therefore it is important for condition coaches to be creative in using games to do their conditioning. Reilly and Ball (1984) reported in their study that oxygen consumption, heart rate, blood lactate and perceived exertion were raised by the presence of a ball and dribbling compared to typical running. To achieve game intensities in preparation for a match, sport scientists and coaches can try to simulate the match intensities throughout the week. Reilly and White (2005) suggested small-sided games to be used in place of interval training for the purposes of maintaining in-season fitness.

These games require precision, as the conditioning coach wants to load the players appropriately and allow them to peak at the right time in the week. If the professionals get this wrong, they run a risk of overloading players and risk of injuries.

2.5. DIFFERENCES BETWEEN LEVELS OF COMPETITION

Carling (2013) proclaimed that the competitive standard (league ranking) in soccer is related with a more noteworthy physical capacity (or distance covered) in matches are far too simplistic. Bradley *et al*. (2013) agree and found that players in League 1 in English soccer, covered more high-intensity running distance than those in the Premier league and Championship league. However, they also indicate that League 1 players made less passes and also fewer successful completed passes. Despite these highlighted performance contrasts, the physical capacity of players in these leagues were quite comparable. Carling (2013) suggested that it is rather technical instead of physical indicators that separates between different league rankings in elite soccer. Therefore, it will be logical for the top tier leagues to a have slightly heightened technical abilities and there is currently no detailed data in this regard.

2.6. FACTORS AFFECTING MATCH-PLAY

There are various factors that can and will influence a soccer match in various ways. Gomez *et al*. (2013 p.259) mentioned that "different competitive conditions in which soccer matches are played may affect the performance of teams and players at a behavioural level". It could be anything from the location of the match, team selection and quality of the opponents, match status (League or Cup match), other teams results, all these variables could have an effect on soccer match performance (Trewin *et al*., 2017).

2.6.1. MAGNITUDE OF THE GAME

Trewin *et al.* (2017) highlighted that some environmental factors have a strong influence on the variability and differences observed in match-running performances from match-to-match. Therefore, the total distance will differ based on type of competition (league match or a cup match). Rampinini *et al.* (2007 p.1022) concluded that “total distance” and more “high intensity running” is influenced by playing against higher quality opponents.

2.6.2. PLAYING FORMATION

Game formation or a game model is a pattern the team is planning to approach the match and this can change at any point in a match; it can even determine who will succeed or not succeed. Tierney *et al*. (2016 p.1) studied the 5 most familiar playing formations employed in an 11 versus 11 in soccer “(4-4-2; 4-3-3; 3-5-2; 3-4-3; 4-2-3-1)”.

It was found that “3-5-2 formation elicited higher Total Distance (TD) (10528 ± 565m), high speed running (HSR) (642 ± 215m), and high metabolic load distance (HMLD) (2025± 304m) than all other formations and above average acceleration (Acc) and deceleration (Dec) (34 ± 7, and 57 ± 10,) with 4-2-3-1 eliciting the highest Acc and Dec (38 ± 8 and 61 ± 12)”. Positional data showed that “CM in 4-3-3 covered >11% TD than in 4-4-2. Strikers (FW) in 3-5-2 covered >45% HSR than in 4-2-3-1. CM in 4-3-3 covered >14% HMLD than in 4-4-2). FW in 4-3-3 performed >49% accelerations than in 4-2-3-1. WD in 3-5-2 performed >20% more decelerations than in 4-4-2”.

Tierney *et al*. (2016) further argue that for better understanding of various positional physical demands in soccer, the coaches need to understand and study the requirements of playing in various formations during match play.

2.6.3. ENVIRONMENTAL CONDITIONS

Trewin *et al*. (2017) and Chmura *et al.* (2017) identified environmental elements, such as relative air moistness, the temperature and air quality to influence a soccer match performance. Nassis *et al*. (2015 p.2) reported in this regard that “the total amount of sprints executed and the distance covered at high intensity by top male players in the 2014 FIFA World Cup matches under high environmental strain “(at 50% relative humidity, WBGT 28–33 °C or at 75% relative humidity, WBGT 25–29 °C) were significantly lower than under low environmental stress (at 50% relative humidity, WBGT < 24 °C or at 75% relative humidity, WBGT < 20 °C)".

It is important to note that the season in South Africa usually is from August to May; in that period, the environmental conditions change from extremely hot, to hot conditions, and match officials must give water breaks in matches. With that being said, research indicate that the intensities of high-speed running decrease drastically in the second half of a soccer match. Ozgunen *et al*. (2010) indicates in his research that soccer players cover more total distance in the first half on a hot day than in the second half. Therefore, proper hydration strategies and protocols must be implemented by medical staff to ensure that players can perform optimally in the heat.

Nybo and Secher (2004) indicated that research demonstrated that high ambient temperature expanded the rate at which fatigue in the cardiovascular system and the central nervous system would happen. Mohr *et al.* (2010) also emphasised that soccer players fatigue quicker in hot and humid conditions, possibly due to the faster rate of dehydration in such conditions.

However, there are major individual differences and positional differences in the physical demands of players during a soccer game related to physical capacity and tactical role in the team. It is therefore important that these differences should be taken into account when planning the training and nutritional strategies of top-class players, who require a significant energy intake during a week (Mohr *et al.,* 2010). There are also great individual differences in physical demands of players during a soccer match related to the tactical role and physical aspects of a player related to team dynamics, these differences could be anything from the utilisation rate of creatine phosphate (CP), Glycolysis, Muscle glycogen, Fatigue, Blood free fatty acids (FFAs). Bangsbo *et al. (*2006) stress that these differences ought to be taken into consideration when arranging the training and nutritional strategies for elite/professional players, to assist them to perform at their best. To conclude, soccer players should be adequately hydrated through fluids to minimize risks of dehydration, heat stroke and heat exhaustion (Kerksick *et al.,* 2018).

2.6.4. HOME AND AWAY MATCHES

Home advantage in soccer has been investigated and discussed, and it is alleged to influence decision of tactic and strategy in various competitions (Liu *et al*., 2015). However, in South Africa, big teams do not own a home stadium as teams have supporters all across the country and are adamant to take soccer to the people. Liu *et al.* (2015 p.371) further argue that several authors have shown that the "home teams generally play better than the away side, making more shots, shots on target, performing better in shot accuracy and other offensive performance measures that are closely related to match success, meanwhile achieving fewer match actions and events related to defending". With this dominance being cited, it brings about higher ball possession, and passes completed and total distance will be covered at low intensities when compared to the away team (Football science, 2015). Lago *et al*. (2010 p.103) reported that the "home teams covered a greater distance than away teams only during low-intensity activity (<14.1 km/h) in the first division of Spanish soccer league".

2.6.5. ERGOGENIC AIDS

Ergogenic aid can be broadly defined as a "technique or substance used for the purpose of enhancing performance" (Thein *et al.*,1995 p.426). Ivy (1994 p.223) stated that "ergogenic aids are used to help physical performance or improve recovery from physical effort". He further explained that the word *ergogenic* is derived from the Greek word *ergon* meaning "work" and the suffix *-genic* meaning "producing". Therefore, the word ergogenic literally means "work producing" or "tending to increase work". Ergogenic aids are commonly classified into 5 classes in particular.

Mechanical ergogenic aids can be anything from soccer boots, goalkeeper gloves, to altitude training, heart rate monitors, GPS and video monitoring, or any equipment soccer players can use to enhance performance. Recently some players have personal sponsors who can design special clothing or shoes for their bodies. "Various brands have come out with innovative technologies of late. Innovations such as boots with enhanced touch/control are reportedly designed for optimal passing and dribbling (e.g. PUMA EvoTouch, Nike Magista and Adidas Ace)". These skills are acknowledged as an important aspect of the modern game with analysis of FA Premier League matches highlighting dribbling and short passes as the most frequently performed ball handling skills during match play (Kryger *et al.,* 2018 p.1).

Psychological ergogenic aids could be anything from a form of hypnosis, psychotherapy, imagery, music, relaxation or yoga. In South Africa, singing is the most prominent way of relaxing and motivating the team for a match.

Physiological ergogenic aids are not as easy and straightforward as the others because there are legal and illegal methods. Legal methods would include sport massages as a form of therapy for relaxing muscle tension. Players could go through various methods like blood doping and saline infusion. However, "blood doping is illegal because it entails putting extra blood into the body which increases the level of haemoglobin, thereby providing an increased oxygen carrying capacity for delivery to the working muscles. The drug EPO (erythropoietin) stimulates red blood cell production. It causes an increase in the haematocrit and increases $VO_{2\,max}$" (Tokish *et al.,* 2004 p.1547).

Pharmacological ergogenic aids are the same as physiological aids. Before a player can try this method, proper research should be conducted because there are legal and illegal methods like caffeine, growth hormones, B-blockers, steroids, stimulants and amphetamines.

Nutritional ergogenic aids are used as supplementation to energy production, and to delay the onset of fatigue and increase blood oxygen; and these include protein supplements and energy drinks. Morton (2014 p.1) elaborated on various "methods to reduce symptoms of progressive fatigue: pre-game caffeine ingestion may improve cognitive, physical and technical performance. To improve the capacity to perform repeated bouts of high-intensity activity in close proximity to one another, players may benefit from prior loading with β-alanine, creatine and nitrate. Proteins high in leucine consumed post-match and post-training may facilitate recovery and training adaptations by promoting muscle protein synthesis. This can be ingested in a sports nutrition product or as normal foods. Most importantly, supplements should not be administered as a one-size-fits-all approach, given that many players are training for different goals (e.g., body composition issues, injury rehabilitation, etc.) and have different training load".

In conclusion, the use of ergogenic's to improve performance in sport has become a worldwide phenomenon. Athletes and coaches should educate themselves to be able to distinguish between the risk or benefits and, most importantly, the legal and illegal ergogenic aids.

CHAPTER 3:

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This study investigated the physical and physiological demands placed on professional soccer players in South Africa during the PSL, MTN8, Telkom Cup and CAF Champions League competitions and compared the demands to those placed on other professional soccer leagues in the world. This chapter explains the study design, methodology and inclusion/exclusion of participants, data collection, equipment used and reporting on results (data analysis). Subsequently, the reliability and validity of the measuring equipment and the pilot study was discussed. Lastly, the deliberation and the implementation of the findings was presented as well as the ethical aspects. Data was collected using different search engines such as Kovsiekat, PubMed, EbscoHost, Science Direct, academic journals and textbooks to prepare for this study.

3.2. THEORETICAL PERSPECTIVES ON RESEARCH DESIGN AND METHODOLOGY

Research is a systematic method of finding new useful information on a particular topic or idea. It is the science of studying how the procedure is to be completed, the system by which specialists approach their work of describing, clarifying and foreseeing the phenomenon called methodology (Rajasekar *et al.,* 2006). Various studies have upheld that the aim of research is to add to the logical accumulation of knowledge and describe it as "the systematic and rigorous process of enquiry which aims to describe phenomena and to develop and test explanatory concepts and theories" (McCusker & Gunaydin, 2015 p.6).

Research design is considered as a plan for research, managing at least four inquiries: which questions to investigate, which information is relevant, what information to gather and how to dissect the results (William, 2012). This study has investigated a group of individuals that are male professional soccer players, who competed in the PSL in South Africa.

3.3. STUDY DESIGN

A quantitative cross-sectional study utilising GPS and accelerometer technology was conducted to examine the physiological demands placed on PSL players during the matches played throughout the season. The prevalence of the following variables were investigated: total distance covered, high-intensity distance covered, and total speed distance covered. The results of the players were compared to determine positional differences or similarities.

3.4 PARTICIPANTS

This is a group of people selected to be part of the study and they should fit the study's characteristics. The researcher had to consider characteristics such as age, gender, level of training, level of performance, size and a unique type of athlete (Thomas *et al.,* 2015). "There is sampling for quantitative research and sampling for qualitative research. Non-random sampling and random sampling include systematic sampling, Simple random sampling, sampling, cluster sampling, and stratified random sampling, unrestricted random" (Bowling, 2014 p.205).

In this particular study, a non-random convenient sampling. Members of Mamelodi Sundowns Football Club were used in this study. Convenient sampling is explained as a cohort of subjects (such as a squat of football players) that occur to be in the right place at the right time (Polit & Beck, 2008). Permission was obtained from the South African Football Association SAFA (Appendix C), and the Head of Medical of the soccer club in the Premier League (Appendix B); the study assessed the physiological demands during soccer matches played in a cohort of PSL players. The researcher monitored the physiological demands of all the soccer players during each match played during the PSL League tournaments. The study used data on twenty-six (n=26) registered PSL players during the 2018-2019 soccer season. Players were studied according to their playing groups: defenders, midfielders, and forwards. With that transpiring, most of the players had specialised positions on the field; the technical team would eventually decide the positions and formation players would play in a match. Injuries, substitutions, and tactical approaches impacted the positions which the players took up in each game.

Before the beginning of this research, players each received a written information document (Appendix D). Players were requested to sign an informed consent in English before this research commenced (Appendix E). The research was voluntary, and players did not get any financial compensation for their participation. The soccer players had the right to pull out from the study at any time. Players were also informed beforehand that the results of the study would be published.

The researcher made every effort to keep personal information confidential under all circumstances. Data was stored on a password-protected personal computer of the researcher in a cloud-based folder dedicated to the Catapult GPS system and locked in a safe. Only the researcher had access to raw data.

GPS receivers are also widely used in sport and are seen as conventional sportswear. The Catapult GPS pod did not pose any additional risk of injury to the player. Players were comfortable with the GPS unit as they also wear it during team training sessions.

Injured players received professional medical rehabilitation to ensure their triumphant return to competition. Medical staff present at PSL matches included the team medical staff (doctor, physiotherapist and conditioning coach), stadium doctor, nurse and the ER24 medical response personnel with the ambulance being available all the time, during and after matches.

3.4.1. INCLUSION CRITERIA

Study participants had to adhere to the following inclusion criteria:

1. The player was included in the Mamelodi Sundowns squad in the 2018/19 season.
2. The player was healthy and free of illness or any disease which would affect his performance or put his health at risk.
3. The player was able and willing to give consent in English, being the spoken language in the team.

3.4.2 EXCLUSION CRITERIA

Any of the players that required to be excluded or did not adhere to the criteria were removed. Any participant, who displayed any of the following criteria, was excluded from the study:

1. Players who were rehabilitating from an injury involving the lower limbs or an area that may directly affect his performance.
2. Players who were suffering from an illness such as common flu or any disease which may influence outcomes and put the participant at risk was excluded. The player had to be cleared to play by the team doctor.
3. Players who were reluctant or unable to give consent in English.

3.4.3. WITHDRAWAL OF STUDY PARTICIPANTS

Withdrawal of study participants for the most part happened if a participant sustained an injury during the season, and the team Doctor withdrew the player.

3.5 DATA COLLECTION

Data was collected from twenty-six (26) players, playing forty-six (46) matches (home and away) for Sundowns, in the PSL 2018/19 season. Data collection was done in season.

The study concentrated on the physiological prerequisites of individual playing positions in soccer. Playing positions were grouped into striker (ST), wing back (WB), central midfielder (CM), central attacking midfielder (CAM), and wing attack (WA). Information on all players, excluding substitutes, was gathered over each match that formed part of the study. Therefore, data gathered could be individualised for each playing position. The PSL format of the competition consists of a home and away format. There are other knockout competitions like MTN8, TELKOM and CAF Champions League that the team participated in, which equated to a total of 46 matches.

All players were presented with a GPS unit. The GPS unit comprised of “a tri-axial accelerometer with responsive motion sensors used to measure the frequency and magnitude of movement in three dimensions namely, anterior-posterior, mediolateral, and longitudinal" (Krasnoff *et al*., 2008 p.528). The Catapult Minimax X4 unit estimated an increase in speeds in the "frontal-, sagittal- and transverse axes of movement to define a variable called (PL) Player Load" (Dwyer & Gabbett 2012) and had been demonstrated to be highly reliable with a "coefficient of variation of <2%" (Boyd *et al*., 2011 p.311).

The units (worn by all players during the match) were kept in a specially designed harness that prohibits undesirable movement and holds the units in place in the centre of the upper back — therefore constraining any potential hindrance on performance. Team members received the harness, which hosts the accelerometer, prior to the warm-up for the match. Thereafter players went to the changing room to fit the harness before putting on their playing jerseys over the harness. The researcher turned on GPS units, and the second the unit showed it was connected to the GPS signal, it was fitted into the harness. After each member got a GPS unit, the team started with their warm-up and the match. The start and end time of each match was recorded. Therefore, information recorded by the GPS unit during the warm-up and in between the playing halves could be effortlessly cut and did not form part of the data used in the study. Additionally, the scientist recorded time and details of all substitutes as well as injuries that occurred during the match. At the end of the match, all equipment (the GPS units and harnesses) was gathered by the scientist.

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

- Distances covered
    - Total distance covered
    - Number of runs
    - Run distance
    - Run distance per run
    - Number of sprints
    - Sprint distance
    - Sprint distance per sprint

Comparisons were made regarding the variables for the following groups of playing positions.

Table 3.1: Positional Classification.

Positions Abbreviations	Positions Explained
CAM	Central attacking midfielder
CB	Centre back
WB	Wing back
CM	Central midfielder
WA	Wing attack
ST	Striker

3.6. EQUIPMENT- CATAPULT MINIMAX X4 GPS UNITS

As stated, the Catapult Minimax X4 GPS units were utilised to collect data for this study. The device measures 96x52x14 mm with a weight of 67 g. GPS data is recorded at 10 Hz with accelerometer and gyroscope data at 100 Hz each. The device is water-resistant and has a battery life of more than 6 hours (Catapult 2018).

Figure 3.1 Illustrates the representation of the data collection process.

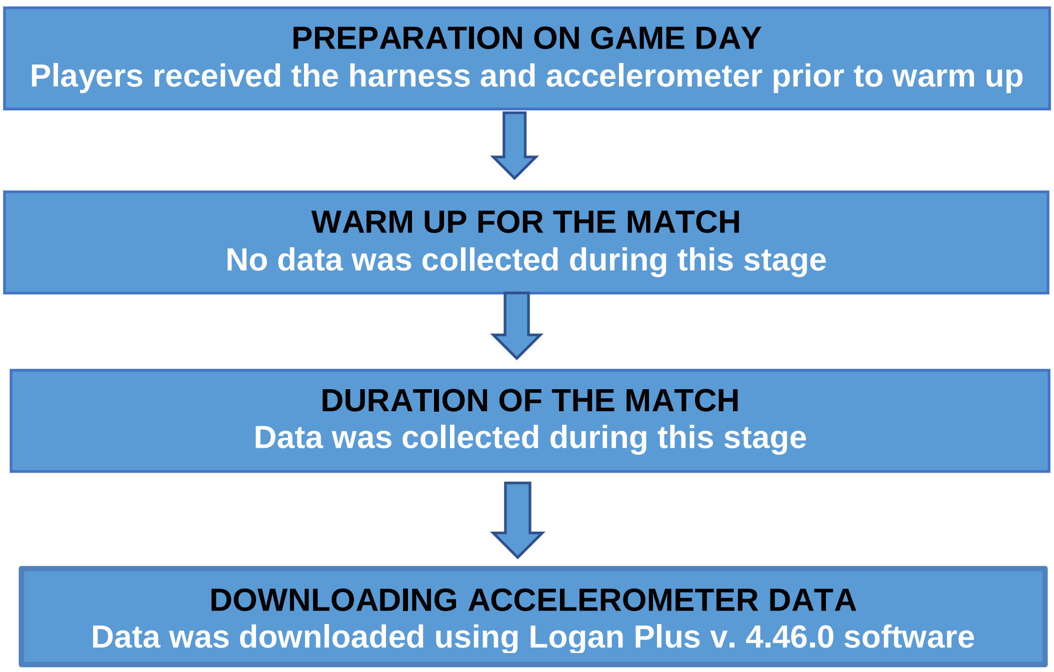


FIGURE 3.1: THE DATA COLLECTIONING PROCESS.

3.6.1. VALIDITY AND RELIABILITY

The global positioning system technology was utilised to measure the physiological demands of athletes training or competing in sports such as cricket, soccer, triathlon and Australian Football. The validity and reliability of these technologies are paramount to the success of a team or individual sport; looking at the 10 Hz GPS for measurements of instantaneous velocity is inversely related to acceleration. Those using 10 Hz GPS should be aware that during accelerations of over 4 m s−2, accuracy is compromised (Akenhead *et al*., 2013). Castellano *et al*. (2011:b) reported improvement in reliability and validity with an increased sampling frequency. Rampinini *et al*. (2014) agree and verified higher validity and reliability of the 10 Hz Catapult units compared to 15 Hz GPS units of other manufacturers. However, most researchers agree that error in GPS units increased as the speed of movement increased. Twist and Worsfold (2015) and Johnston *et al*. (2014) reported that GPS units sampling at a lower frequency (1 Hz and 5 Hz) brought about more critical errors for high intensity running and sprinting, (The 10 Hz and 15Hz units are valid and reliable instruments for quantifying total distance covered and more reliable than 1 Hz and 5 Hz units for measuring movement demands (Johnston *et al.*, 2012).

To conclude, Castellano *et al.* (2011:a) found high intra and inter-reliability in the 10 Hz GPS and accuracy improves with the increase of distance to 15m. Numerous studies have been conducted on the 10Hz the Minimax X4 accelerometer, and all these studies concluded that the 10Hz GPS is reliable on the longer distances rather than the 5m and walking distances (Boyd *et al.,* 2011: Johnston *et al.,* 2014).

3.6.2 PILOT STUDY

A pilot study can be seen as standard logical device for 'soft' research, permitting the researcher to conduct a preliminary analysis before focusing on a full-blown study or experiment. Blessing and Chakrabarti (2009) concurred that a pilot study aims to identify potential problems that may affect the quality of the results. The data of twenty players in two pre-season matches GPS was recorded and analysed to identify possible errors and to ensure that the recorded GPS data was understandable, recorded effectively, and could be analysed. The effectiveness of the data, equipment, and protocols was established in the pilot study.

3.7 STATISTICAL ANALYSIS

The following data for the individual 26 soccer players in 46 matches were available.

- Distance
- Number of runs
- Run distance
- Run distance per run
- Number of sprints
- Sprint distance
- Sprint distance per sprint

All quantitative variables were summarised using descriptive statistics (mean, SD, minimum, Q1, median, Q3, maximum), both by player position, by an individual player, and overall.

The quantitative variables were compared between playing positions using a mixed linear model, suitable playing position as fixed effect and match and (individual) player as a random effect; fitting the random effects allowed for the correlation of data within matches and a given player. For each variable analysed, the overall F-test for playing position and the associated P-value are reported. Furthermore, as regards the pairwise mean differences between playing positions, 95% confidence intervals for the mean differences and associated P-values are reported. A so-called "lines" display is used to indicate which pairwise differences between the various playing positions are statistically significant.

3.8. ETHICAL ASPECTS

Marczyk *et al.,* (2005 p.233) stated that “all studies with human participants involve some degree of risk. The researcher must be aware that these risks present him with an ethical dilemma". Conducting research requires honesty, responsibility, and integrity in order to protect the rights of soccer players, and to render the study ethically. The rights of the players to self-determination, confidentiality, anonymity and informed consent were observed.

Permission to conduct the research was obtained in writing from the following professional bodies:

· The Ethics Committee of the Health Sciences Faculty of the University of the Free State; **UFS-HSD2019/0170/2603** (Appendix A)

· Coaching staff of Mamelodi Sundowns Football Club (Appendix B)

· South African Football Association (SAFA) Chief Medical Officer (Appendix C)

Participants signed informed consent before the study commenced.

The study was voluntary, and it was standard practice in the team to perform GPS analysis. Players were informed beforehand that the results of the study would be published. Every effort was always made to keep personal information confidential and under all circumstances. Written informed consent was obtained from all study participants (see Appendix E), which included all the essential elements of informed consent:

· A fair explanation of the procedures to be followed;

· A description of the value and benefits of their participation;

· An offer to answer any enquiries concerning the processes;

· An indication that participants are free to withdraw consent and to discontinue participation in the project or activity at any time.

· The rights of the participant will be considered by the researcher;

· The right to privacy or non-participation;

· The right to confidentiality; and

· The right to expect experiment responsibility.

3.9. METHODOLOGICAL ERRORS

Systematic methodological errors were minimised by using similar equipment, called Catapult Optima eye X4 GPS units (Catapult Innovations, Melbourne, Australia). All the relevant equipment was calibrated in accordance to the manufacturer's specifications, and the PSL players were observed according to the protocol. Irregular methodological errors that may have occurred consist of change in weather on the various days that the matches were played. Rain or cloudy weather can affect the GPS signal of the GPS sport system. The information may likewise have been affected by external variables that may have prompted early fatigue by players. Variables such as matches played in very hot conditions. Furthermore, tactics may also have varied from one match to the next and could impact the outcomes of the players' physical demand.

3.10. IMPLEMENTATION OF FINDINGS

This study project will give objective data to Mamelodi Sundowns FC and the South African Football Association (SAFA) with respect to the physiological demands placed on players during matches. The outcomes will also provide conditioning coaches with valuable data that can assist with the improvement of physical programmes that are both individualised and specific for soccer.

CHAPTER 4:

RESULTS

4.1 INTRODUCTION

This chapter displays the results of the study, based on its primary aim which was to evaluate the physical and physiological demands of players in the South African PSL, an official competition.

Using a GPS accelerometer with built-in tri-axial (Catapult Minimax X4) the following data was collected:
(1) total distance covered
(2) sprint distance
(3) run distance
(4) number of runs
(5) number of sprints.

These sets of data was collected during the PSL, MTN 8, Telkom and CAF Champions League matches throughout the 2018/2019 season. Since the matches were played in a league and cup format, all the matches were 90 minutes long plus with the referee's optional time. In other words, none of the matches included extra time.

In this chapter, the results of the study will be presented using tables and box plots for additional illustration. This chapter will introduce the results from the study and illustrate them with tables and box plots. Box plots give a realistic representation of the variable that is plotted. The box plots displays the "range between the first to the third quartile of the information; 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" (Shaw, 2018).
The interpretation and the discussion of the findings will follow in Chapter 5.

4.2. DEMOGRAPHIC INFORMATION OF PARTICIPANTS

4.2.1. NUMBER OF PLAYERS AND NUMBER OF PLAYER GAMES ANALYSED

Twenty-six (26) first team players of Mamelodi Sundowns FC formed part of the study. Regardless of a player’s specialised position on the field, the technical team would decide the formation and tactical set-up on the day which determined the player’s position in the match. Injuries, substitutions, and tactical approaches played a significant role in the positions which the players took up in each game. Consequently, it was conventional for any 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 specified below.

Twenty-six participants, five Central Defenders (CB), three Wing Backs (WB), five Wing Attacks (WA), six Central Midfielders (CM), four Central Attacking Midfielders (CAM) and three Strikers (ST) participated in this study. Data from a total of forty-six (46) completed matches were analysed. A total number of four hundred and fifty-nine (459) GPS data sets (player matches) were analysed.

4.3 TOTAL DISTANCE COVERED

The boxplots in Figure 4.3.1 display the total distance covered by players in the different playing positions. Descriptive statistics for total distance are presented in Table 4.3.2.

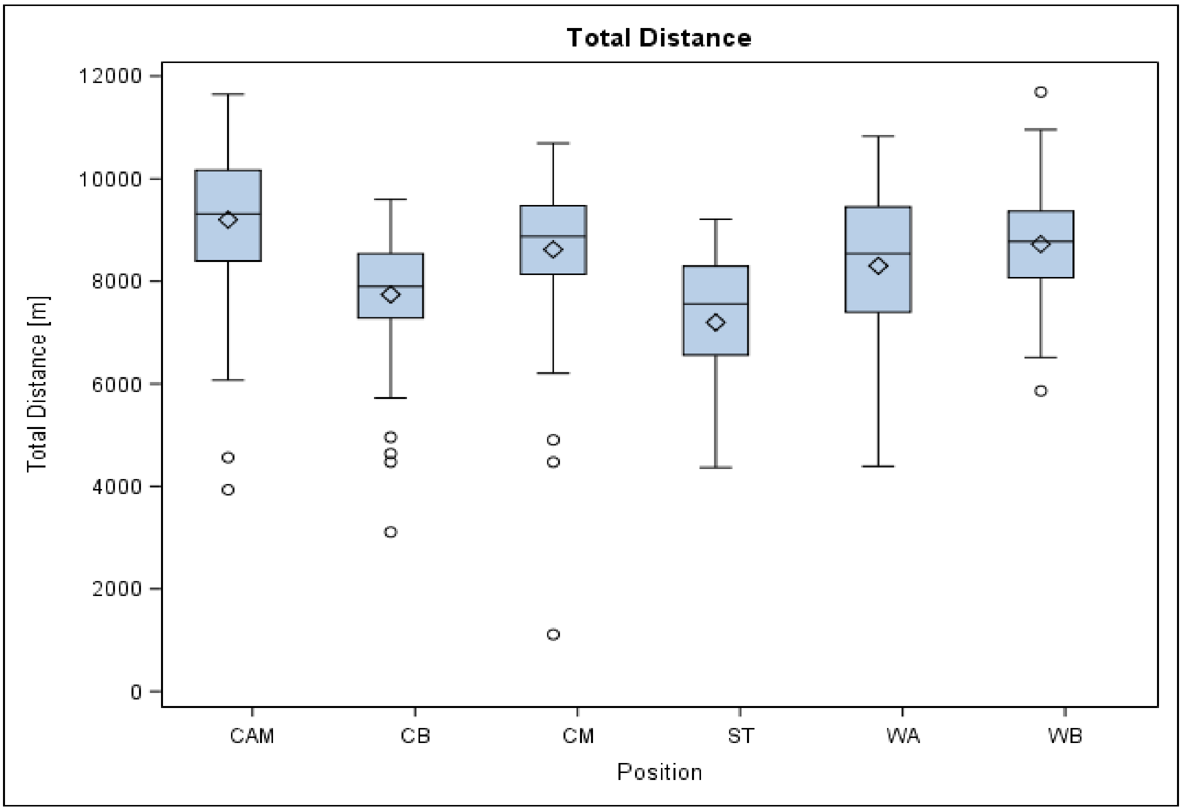


Figure 4.3.1: Box plot: Total distance covered (n=459 player games)

CAM covered the highest total distance on average (total mean of 9200.63m; Table 4.3.1), and the lower quartile in total distance for a CAM is approximately equal to or higher than the upper quartiles of CB and ST, suggesting the CAM covered notably greater distances than defenders and strikers. WB have covered the second most total distance on average (mean 8724.37m), followed by the CM, WA and CB. The ST covered the smallest distance (mean 7197.41m).

Table 4.3.1: Total Distance: Descriptive statistics.

	Positions						
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	9200,6	8621,51	7741,4	7197,4	8301,6	8724,3	8494,1
Min	3930	1108	3109	4366	4392	5863	1108
Q1	8395,5	8135	7284	6560	7398,5	8069	7790
Median	9314,5	8874	7898	7556,5	8540,5	8777	8556
Q3	10165,5	9471	8540	8294	9452,5	9364	9436
Max	11646	10693	9599	9212	10830	11693	11693

The results of the statistical comparison of the different playing positions regarding total distance are presented in Tables 4.3.2 and 4.3.3 and will respectively follow in the next section.

Table 4.3.2: Total distance: Statistical comparison of mean number of runs for various playing positions (pairwise mean differences, P-values and 95% CIs)

Differences of Least Squares Means Between Positions

Position	Position	Estimate	SE	P-value	Lower CI
CAM	**CM**	696.69	517.08	0.1935	-384.62
CAM	**CB**	1143.57	530.67	0.0463	20.8901
CAM	**ST**	1690.07	642.25	0.0170	340.13
CAM	**WA**	951.56	517.17	0.0817	-131.89
CAM	**WB**	581.75	525.17	0.2810	-512,91
CM	**CB**	446.88	457.66	0.3366	-487.58
CM	**ST**	993.38	598.20	0.1104	-244.48
CM	**WA**	254.47	444.66	0.5696	-643.11
CM	**WB**	-114.94	434.41	0.7923	-685.87
CB	**ST**	546.50	611.52	0.3821	-729.07
CB	**WA**	-192.01	476.86	0.6908	-1178.44
CB	**WB**	-561.82	484.70	0.2565	-1555.92
ST	**WA**	-738.51	598.20	0.2299	-1978.19
ST	**WB**	-1108.31	606.76	0.0803	-2360.91
WA	**WB**	-369.81	347.84	0.2891	-1055.90

[a]Least squares mean. Pairwise mean differences and associated statistics from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect

Table 4.3.3: Total Distance: Display of least squares means and summary of pairwise comparisons.

Playing position	Least Squares	Significance of pairwise comparison of playing position[b]	
CAM	9139.09		A
WB	8557.34	B	A
CM	8442.4	B	A
WA	8187.53	B	A
CB	7995.52	B	
ST	7449.02	B	

[a]Least squares mean estimates from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.
[b]Means sharing the same letter are not statistically different from each other at 0.05 significance level; pairs of means that do not share a letter differ statistically significantly.

Table 4.3.2 and 4.3.3 summarize the results of the statistical comparison of mean total distance covered between playing positions. For instance, total distance covered by a CAM is statistically significantly higher ($p<0.05$) compared to the CB and ST.

4.4 RUNS AND SPRINTS

The boxplots in Figure 4.4.1 display runs and sprints made by players in the different playing positions. Descriptive statistics for runs and sprints are presented in Table 4.4.2 and 4.4.3 respectively.

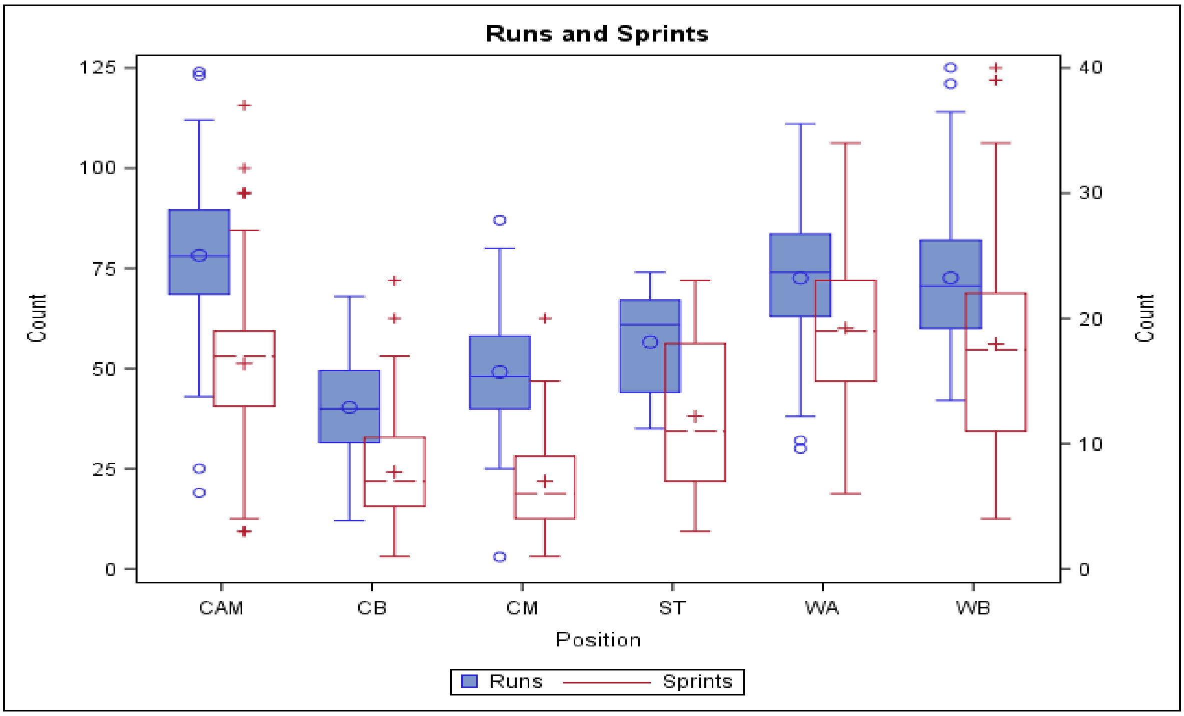


Figure 4.4.1: Box plot: runs and sprints (n=459 player games)

CAM executed the greatest number of runs on average (mean 78,19m Table 4.4.1), the lower quartile of CAM in terms of the number of runs is higher than the upper quartiles of both CM and CB. This suggests that a CAM covers a greater number of runs compared to both CM, CB and ST. CAM are closely followed by WB and WA with average number of runs of (72,59m and 72,52m). The CB covered the least number of runs (mean 40.31m).

Table 4.4.1: Runs: Descriptive statistics.

			Positions				
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	78,19	49,11	40,31	56,55	72,52	72,59	61,8
Min	19	3	12	35	30	42	3
Q1	68,5	40	31,5	44	63	60	45
Median	78	48	40	61	74	70,5	61
Q3	89,5	58	49,5	67	83,5	82	77
Max	124	87	68	74	111	125	125

Regarding sprints, the WA dominates this category; they executed the highest number of sprints on average (mean 19.21m Table 4.4.2). The lower Quartile of sprints for the

WA is higher than the upper quartiles of both CB and CM. This suggests that the WA makes notably more sprints than the CB and CM. Players in this position must sprint inside to support the striker and achieve overlaps or underlaps. WA is closely followed by WB (mean 17,94m Table 4.4.2), while the CM and CB make the least number of sprints.

Table 4.4.2. Sprints: Descriptive statistics

	Positions						
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	16,38	7	7,73	12,18	19,21	17,94	13,1
Min	3	1	1	3	6	4	1
Q1	13	4	5	7	15	11	7
Median	17	6	7	11	19	17,5	12
Q3	19	9	10,5	18	23	22	18
Max	37	20	23	23	34	40	40

The results of the statistical comparison of runs and sprints for the different playing positions are presented in Tables 4.4.3, and 4.4.4.

Table 4.4.3: Runs: Statistical comparison of mean number of runs for various playing positions (pairwise mean differences, P-values and 95% CIs).

Differences of Position Least Squares Means					
Position	**Position**	**Estimate**	**SE**	**P-value**	**Lower**
CAM	**CM**	18,2650	7,1293	0,0175	3,5105
CAM	**CB**	31,2629	7,4291	0,0004	15,7665
CAM	**ST**	15,8537	8,9499	0,0916	-2,8044
CAM	**WA**	7,1715	7,1606	0,3275	-7,6853
CAM	**WB**	4,9563	7,2097	0,4985	-9,9381
CM	**CB**	12,9979	6,0687	0,0382	0,7405
CM	**ST**	-2,4113	8,1559	0,7699	-19,1937
CM	**WA**	-11,0935	5,7746	0,0598	-22,6601
CM	**WB**	-13,3087	5,5361	0,0187	-24,3348

CB	**ST**	-15,4092	8,4355	0,0809	-32,8683
CB	**WA**	-24,0914	6,4638	0,0008	-37,2926
CB	**WB**	-26,3066	6,4868	0,0003	-39,4793
ST	**WA**	-8,6822	8,1841	0,2991	-25,5557
ST	**WB**	-10,8974	8,2421	0,1975	-27,8326
WA	**WB**	-2,2152	4,1793	0,5965	-10,4421

[a]Least squares mean. Pairwise mean differences and associated statistics from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

Table 4.4.4: Sprints: Statistical comparison of mean number of sprints for various playing positions (pairwise mean differences, P-values and 95% CIs).

Differences of Least Squares Means Between Positions

Position	Position	Estimate	SE	P-value	Lower
CAM	**CM**	5,072	2,8	0,0844	-0,751
CAM	**CB**	6,6582	2,9158	0,0345	0,5414
CAM	**ST**	2,1047	3,5111	0,5561	-5,2545
CAM	**WA**	-1,6768	2,808	0,5571	-7,5335
CAM	**WB**	-2,28	2,8322	0,4295	-8,1582
CM	**CB**	1,5862	2,3934	0,5116	-3,2614
CM	**ST**	-2,9673	3,2071	0,3642	-9,593
CM	**WA**	-6,7488	2,2798	0,0046	-11,3242
CM	**WB**	-7,352	2,188	0,0013	-11,7159
CB	**ST**	-4,5534	3,3132	0,1838	-11,4431
CB	**WA**	-8,335	2,5423	0,0028	-13,5472
CB	**WB**	-8,9382	2,5564	0,0014	-14,1464
ST	**WA**	-3,7815	3,2144	0,2516	-10,4369
ST	**WB**	-4,3848	3,2397	0,1884	-11,0677

WA	**WB**	-0,6033	1,6542	0,7156	-3,8601

[a]Least squares mean. Pairwise mean differences and associated statistics from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

Table 4:4:5: Runs: Display of least squares means and summary of pairwise comparisons.

Playing position	**Least Squares Mean[a]**	**Significance of pairwise comparison of playing position[b]**		
CAM	75.1849		A	
WB	70.2286		A	
WA	68.0134	B	A	
ST	59.3312	B	A	C
CM	56.9199	B		C
CB	43.9220			C

[a]Least squares mean estimates from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

[b]Means sharing the same letter are not statistically different from each other at 0.05 significance level; pairs of means that do not share a letter differ statistically significantly.

Table 4.4.5 summarises the statistical comparison of the mean number of runs between playing positions. For example, the number of runs by the CAM, WB and WA are statistically significantly higher ($p<0.05$) than the CM and CB.

Table 4.4.6: Sprints: Display of least squares means and summary of pairwise comparisons.

Playing position	**Least Squares Mean[a]**	**Significance of pairwise comparison of playing position[b]**		
WB	17.1765		A	
WA	16.5732		A	
CAM	14.8964	B	A	
ST	12.7917	B	A	C
CM	9.8244	B		C
CB	8.2382			C

[a]Mean estimates from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

[b]Means sharing the same letter are not statistically different from each other at 0.05 significance level; pairs of means that do not share a letter differ statistically significantly.

Similarly, regarding sprints, Table 4.4.6 shows that the mean number of sprints distance by the WB and WA is statistically higher ($p<0.05$) than for CM and CB.

4.5. RUN DISTANCE

The boxplots in Figure 4.5.1 display total run distance and distance per run covered by players in the different playing positions. Descriptive statistics for the two variables are presented in Table 4.5.1. and 4.5.2.

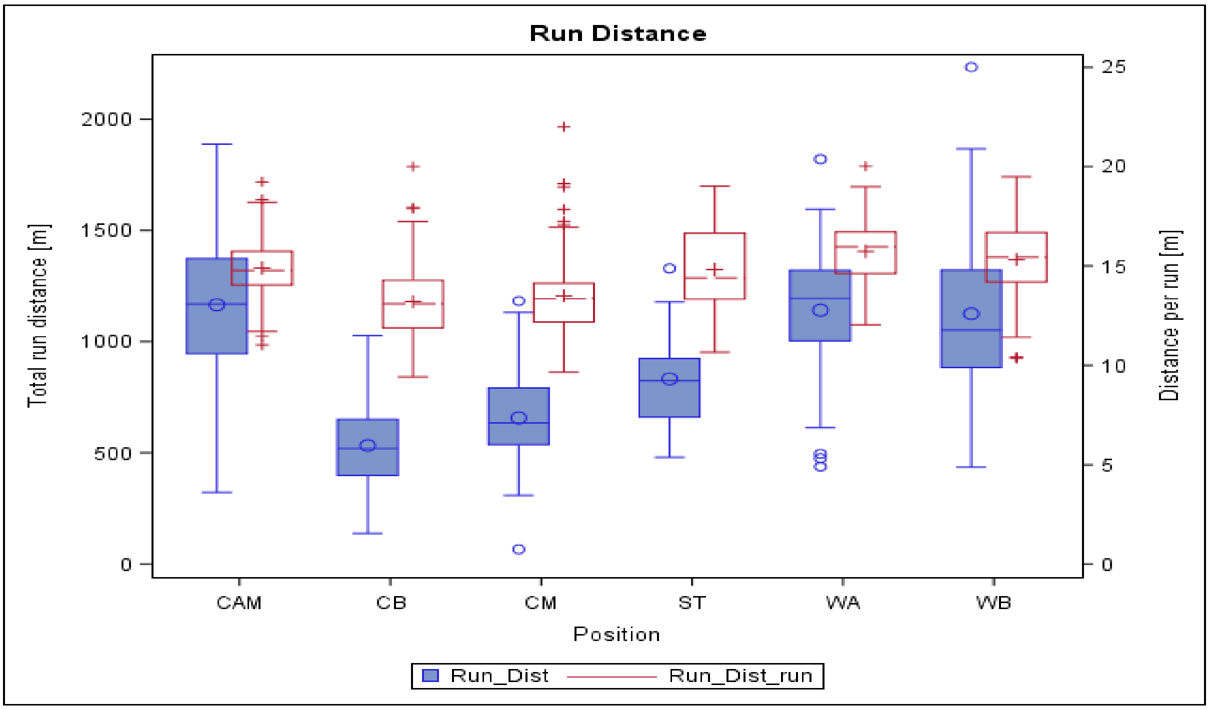


Figure 4.5.1: Box plot: Total run distance and run distance per run (n=459 player games)

CAM covers the highest mean run distance (1165,84m Table 4.5.1). The lower quartile of CAM is higher than the upper quartiles of for CB, CM and ST. This suggests that CAM covered notably higher run distance than the CB, CM or ST. The WA covered the second highest run distance (mean of 1141,63m), followed by the WB; in contrast, the CM and CB covered the smallest run distance of all positions.

Table 4.5.1: Runs distance: Descriptive statistics.

	Positions						
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	1165,84	657,3	532,97	832,41	1141,63	1125,23	905,95
Min	322	66	138	480	438	436	66
Q1	946	538	398,5	660	1003,5	884	590
Median	1169	635	519,5	824	1194,5	1052,5	867
Q3	1374	792	650,5	924	1321	1322	1194
Max	1889	1183	1028	1329	1821	2234	2234

Boxplot 4.5.1 shows that the WA covered the highest run distance per run with an average of 15,73m (see Table 4.5.2); the lower quartile of WA is approximately equal to or higher than the upper quartiles of CM and CB, suggesting that the WA covered notably higher run distance per run than the previously mentioned positions. The WB covered the second highest mean distance per run (15.32m), followed by ST and CM. The CB covered the smallest run distance per run (mean of 13,20 m).

Table 4.5.2: Runs distance per run: Descriptive statistics.

	Positions						
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	14,9	13,5	13,2	14,82	15,73	15,32	14,43
Min	11,03	9,66	9,41	10,67	12,04	10,38	9,41
Q1	14,04	12,17	11,89	13,33	14,63	14,18	13
Median	14,78	13,35	13,1	14,4	15,96	15,46	14,35
Q3	15,73	14,13	14,28	16,65	16,71	16,68	15,73
Max	19,24	22	20	19	20,02	19,49	22

The results of the statistical comparison of these variables from different playing positions are presented in Tables 4.5.3. and Table 4.5.4 respectively.

Table 4.5.3: Run Distance: Statistical comparison of mean run distance for various playing positions (pairwise mean differences, P-values and 95% CIs).

Differences of Least Squares Means Between Positions

Position	Position	Estimate	SE	P-value	Lower
CAM	CM	302.78	122.70	0.0210	49.6692
CAM	CB	518.93	128.31	0.0006	252.45
CAM	ST	235.68	154.58	0.1421	-85.5369
CAM	WA	48.7110	123.37	0.6966	-206.41
CAM	WB	32.0937	124.00	0.7979	-223.33
CM	CB	216.15	103.20	0.0418	8.3334
CM	ST	-67.1028	140.10	0.6359	-354.71
CM	WA	254.47	97.6548	0.0116	-449.24
CM	WB	-270.69	93.1847	0.0047	-455.98
CB	ST	-283.26	145.28	0.0629	-583.03
CB	WA	-470.22	110.62	0.0002	-695.38
CB	WB	-486.84	110.68	0.0001	-710.96
ST	WA	-186.97	140.70	0.1956	-476.38
ST	WB	-203.58	141.47	0.1615	-493.67
WA	WB	-16.6173	69.2621	0.8106	-152.91

[a]Least squares mean. Pairwise mean differences and associated statistics from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

Table 4.5.4: Run distance: Display of least squares means and summary of pairwise comparisons.

Playing position	Least Squares Mean[a]	Significance of pairwise comparison of playing position[b]	
CAM	1106.26		A
WB	1074.17		A
WA	1057.55		A
ST	870.58	B	A
CM	803.48	B	
CB	587.32	B	

[a]Least squares mean estimates from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

bMeans sharing the same letter are not statistically different from each other at 0.05 significance level; pairs of means that do not share a letter differ statistically significantly.

Both Tables 4.5.3 and 4.5.4 show the results of the statistical comparison of the different playing positions with regard to run distance. The distance covered by the CAM, WB and WA is statistically significantly higher ($p<0.05$) compared to the CM and CB.

4.6 SPRINT DISTANCE

The boxplots in Figure: 4.6.1 display total sprint distance and sprint distance per sprint covered by players in their different playing positions. Descriptive statistics for the abovementioned variables are presented in Table 4.6.1. and 4.6.2.

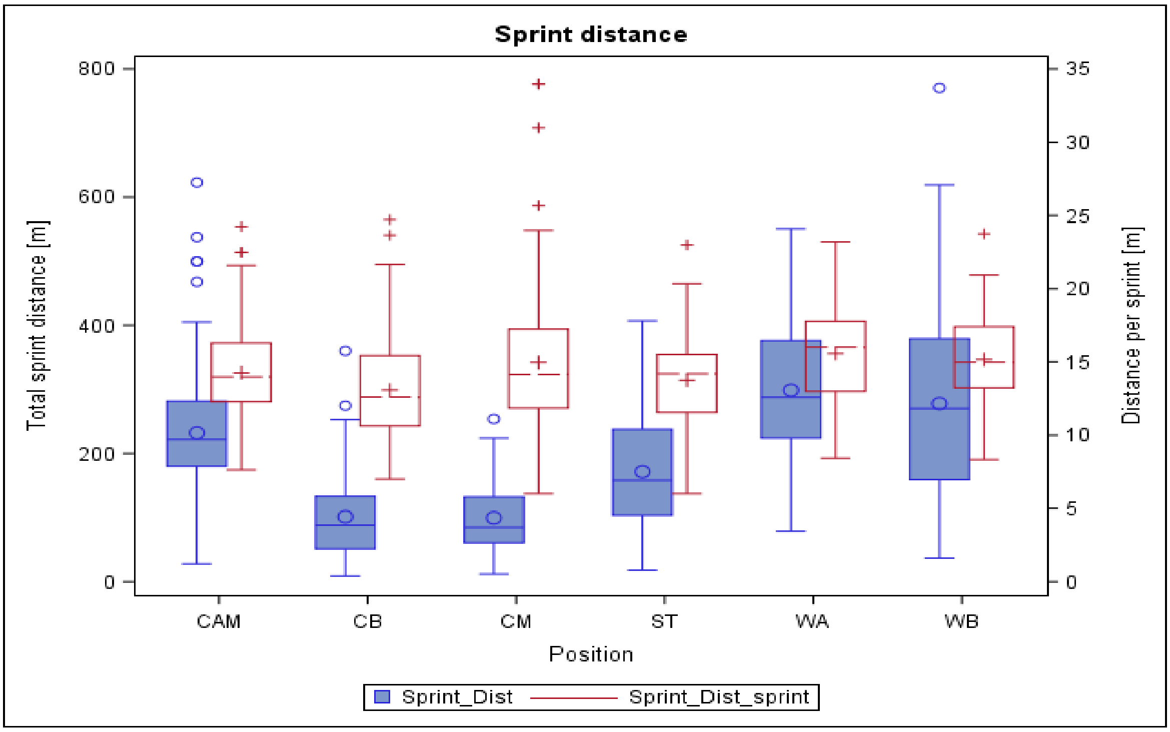


Figure 4.6.1: Box plot: Total sprint distance and sprint distance per sprint (n=459player games)

WA covers the highest mean sprints distance (299,15m see Table 4.6.1), the lower quartile of WA is higher than the upper quartiles of a CB, CM and ST. This means that the wing attack executes more sprints than the Centre back, central midfielders and strikers. WB covers the second highest distance in sprints (mean of 278,28m) followed by CAM, ST, CB and in contrast the CM covered the least sprint distance of all positions.

Table 4.6.1: Total sprint distance per sprint: Descriptive statistics.

	Positions						
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	232,26	99,87	101,45	171,55	299,15	278,28	191,16
Min	28	12	9	18	79	37	9
Q1	180	61	51,5	104	224	159	88
Median	222	85	88,5	158	288	270,5	166
Q3	282	132	133	238	376	379	272
Max	623	254	360	407	551	771	771

The boxplot figure 4.6.1 displays that the WA covered the highest sprint distance per sprint with an average of (15,57m, see Table 4.6.1), the lower quartile of WA is approximately equal to or higher than the upper quartiles of CB and ST, meaning the WA executed more sprint distance per sprint than the centre back and striker. The WB covered the second highest sprint distances per sprint (15.16m), followed by CM, CAM and ST. The least sprint distance per sprint was covered by CB the (mean of 13,10 m).

Table 4.6.2: Sprint distance per sprint: Descriptive statistics.

	Positions						
	CAM	**CM**	**CB**	**ST**	**WA**	**WB**	**All**
N	120	87	100	22	52	78	459
Mean	14,27	14,96	13,1	13,77	15,57	15,16	14,42
Min	7,63	6	7	6	8,43	8,33	6
Q1	12,29	11,86	10,65	11,57	13,01	13,25	11,78
Median	14	14,17	12,62	14,22	16	14,97	14,05
Q3	16,29	17,23	15,42	15,5	17,78	17,4	16,75
Max	24,25	34	24,71	23	23,21	23,76	34

The results of the statistical comparison of these variables from different playing positions are presented in Table 4.6.3. and Table 4.6.4 respectively.

Table 4.6.3: Sprint distance: Statistical comparison of mean total sprint distance for various playing positions (pairwise mean differences, P-values and 95% CIs).

Differences of Least Squares Means Between Positions

Position	Position	Estimate	SE	P-value	Lower
CAM	**CM**	66.4348	45.2912	0.1562	-27.3636
CAM	**CB**	101.57	47.1239	0.0437	3.1773
CAM	**ST**	25.6866	56.7736	0.6558	-92.7276
CAM	**WA**	-58.2005	45.4080	0.2136	-152.49
CAM	**WB**	-46.3676	45.8257	0.3220	-141.09
CM	**CB**	35.1381	38.7783	0.3703	-43.2577
CM	**ST**	-40.7482	51.9176	0.4398	-147.60
CM	**WA**	-124.64	36.9851	0.0014	-198.77
CM	**WB**	-112.80	35.5832	0.0022	-183.63
CB	**ST**	-75.8863	53.5968	0.1704	-186.87
CB	**WA**	-159.77	41.1413	0.0005	-243.09
CB	**WB**	-147.94	41.4020	0.0011	-232.09
ST	**WA**	-83.8870	52.0245	0.1197	-191.17
ST	**WB**	-72.0541	52.4553	0.1812	-179.85
WA	**WB**	11.8329	26.9835	0.6614	-41.2917

[a]Least squares mean. Pairwise mean differences and associated statistics from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

Table 4.6.4: Sprint distance: Display of least squares means and summary of pairwise comparisons.

Playing position	Least Squares Mean[a]	Significance of pairwise comparison of playing position[b]
WA	267.13	A
WB	255.30	A

CAM	208.93	B	A	
ST	183.25	B	A	C
CM	142.50	B		C
CB	107.36			C

[a]Least squares mean estimates from linear mixed linear model, fitting playing position as fixed effect and match and (individual) player as random effect.

[b]Means sharing the same letter are not statistically different from each other at 0.05 significance level; pairs of means that do not share a letter differ statistically significantly.

Table 4.6.3 and 4.6.4 show the results of a statistical comparison of the various playing positions in regard to total sprint distance. The distance covered by WA, WB and CAM is statistically, significantly higher ($p<0.05$) when compared to the CM and CB.

CHAPTER 5:

DISCUSSION OF RESULTS

5.1. INTRODUCTION

Time motion analysis is a study on the physical and physiological demands of sport, and it has been the centre of focus in modern sport around the world. This study, to the knowledge of the researcher is the first to explore the physical characteristics of players in the South African PSL over the 2018-2019 season. The team was simultaneously competing in the League, Champions League, Telkom Knockout, Nedbank Cup and MTN8 and playing a total of two games per week. Outfield positions investigated were divided into six groups: Central Attacking Midfielders (CAM), Central Midfielders (CM), Wing Attack (WA), Wing Back (WB), Defender (CB), Strikers (ST) and goalkeepers (GK) were excluded in this study.

Twenty-six (26) participants were investigated in this study and all participants were from Mamelodi Sundowns. The medical team advised on the players available for a match and the technical team chose a team and some players were utilised in a different position during a match and the season. Time motion analysis was investigated for only a full match; this data gave us a full overview of PSL in South Africa in various playing positions. Additionally, the participants played in their specialist positions in some matches CB (5), WB (3), WA (5) CM (6), CAM (4), and ST (3). Parameters measured were total distance (TD), Runs, Run Distance, Run Distance per run, Sprints, Sprint Distance and Sprint Distance per sprint. Modric *et al.* (2019) and Bradley *et al*. (2011) cited that both running performance and game performance indicators are significant determinants of success in soccer and emphasised how various playing styles are crucial in the analysis and interpretation of performance data.

5.2 TOTAL DISTANCE COVERED

During a soccer match, players cover distance over varied speed intensities. These intensities could be anything from walking and jogging to running and sprinting. There are numerous variables that can affect most of the above-mentioned intensities, such as playing positions, playing style, type of competition, score and most importantly, environmental factors. Di Salvo *et al.* (2013) indicated that, at some point in a soccer match, a player can cover at least a total distance of 10.8 ± 1.0 km. However, Table 2.2 summarise all the positional total distance covered by different leagues. Mallo *et al.* (2015) report in friendly matches a total distance of 10.772 m, Di Salvo *et al*. (2007) in the Spanish & Champions League games, 11.612m, Bradley *et al.* (2009) in English FA, 10.778m, and 4 years later Bradley *et al*. (2013) 10.784m, Dellal *et al.* (2011) in English FA 11.095m, Barros *et al*. (2007) in first division 10.071m, Andrzejewski *et al.* (2014) in UEFA European League, 11.680m, Djaoui *et al.* (2013) in the French First League 11.044m. It is interesting to note that in a recent study by Modric *et al*. (2019) on professional soccer players a total distance of 10.180m was reported, which is very similar to all the other studies. Time motion analysis is a feasible tool that is commonly used in soccer to quantify such match activities/variables and give aid to the medical teams, sport scientist, and the technical team in relation to match demands and programme designs. However, our study found an mean total distance of only 8.494m It is clear that the mean total distance cover in the PSL (8.494m) is much lower than the French First League (Djaoui *et al*., 2013; 11.044m) and First Division Brazilian (Barros *et al.,* 2007; 10.071m). Alarmingly, when comparing to International counterparts the difference is in most cases more than 1.5 - 2 Km in mean total distance (Di Salvo *et al*., 2007; Mallo *et al.,* 2015; Bradley *et al.,* 2009; Dellal *et al.,* 2011; Andrzejewski *et al.,* 2014).

Due to the non-availability of such data in South African soccer, we cannot compare this study to any other study in South Africa. With the positional differences in mind, it is important to note that in this current study, the team would shift formations from a 1-4-4-2, 1-4-2-3-1; 1-4-3-3; 1-4-4-1-1. In this study we found that CAM covers the most mean distance (9200m) in a single match. A possible reason for that is because most of the play happens in the midfield, and a number of teams build out from the back and that entails a separation of CBs (7741m) and a CM (8621m) coming down to collect the ball a bit deeper than usual, as a result leaving a CAM lots of space/distance to cover from one half of the field to another (Figure 5.1). They connect the defence and the offence in build-up and their role in possession is to play in front (in the pocket) (see numbers 8 & 10, Figure 5.1) of the CM when they are in their defensive third while building up from the back and in a matter of seconds the demands of the game require this position to support the ST or extend the game and play as a ST. Out of position a CAM is expected to press one of the CB and share the load with a ST (see Figure 5.3) hence this position has to cover mean (9200.63 ± 314.50m) and the second highest max total distance (11646m) in this study. Dellal *et al*. (2011) in the study of the English FA (11.779m) and Djaoui *et al*. (2013) in the study of the French First League (12.784m) (in Chapter 2) confirmed the work rate of CAM in relation to total distance. However, it is clear that the PSL players covers much less distance than the international counterparts do. Alarmingly, is that these differences are more than 2 km.

The WB (8724m) covered the second highest mean total distance in PSL match play. WB position has been one of the most favourable positions in modern soccer. Most teams and coaches prefer using this position as an extra offensive player in a match (tactical overload), by overlapping and underlapping the WA (8301m). It is no surprise that they cover the second highest mean distance (8724.37m) and the highest max total distance (11693m), superior to the ST (7197) who covered the lowest possible mean distance (7197m), CB (7741.36m) and WA (8301m), but cover comparable distances with CM (8621,51m). The discoveries from this study in all the positions in total distance correlate poorly with the English Premier League, Spanish & Champions League, German League, Brazil, Netherlands and Argentina as reported in Chapter 2 (Table 2.1, Table 2.2, Table 2.5,Table 2.6 and Table 2.7) .

The relationship between WB and CM is of overloading certain areas and making numerical superiority both in attack and in defence. Both positions are required to anticipate and cover most of the players that are out of position, resulting in lower average of recovery between activities. With that being said, this position has to be in motion all the time in different intensities both aerobically and anaerobically. Di Salvo *et al.* (2007) reaffirmed the reason that (CM) midfielders cover more total distance than defenders is because of their “linking” role in the match.

One of the several studies discussed in Chapter 2 (table 2.1), the Brazilian First Division, the combined Spanish La Liga and Champions League, and the European National League, where CB also covered less distance have highlighted that CB cover the least distance in a match play (Suarez-Arrones *et al.,* 2014). However, it must be highlighted that these CB players cover still more than 1.5-2.5 km more than PSL CB players. On the contrary, the findings in this study show that the ST (7197m) covers less distance compared to any other position on the field. The main reason for this is possible that when teams do not have the ball; they stay compact and do not allow the opposing teams to pass through them with a forward pass. Once the ball goes wide, a CAM will go out to go press the ball and the ST drops into a CAM position. Furthermore, in transition, WA plays between the opponents WB and CB, thus leaving a ST with short distance to travel to get to the ball. However, WA cover significantly more total distance than the ST and the CB; the findings of this study correlate with other studies previously mentioned in Chapter 2, although PSL distances are much lower as reported in the literature.

Generally, the least square means are covered by the defenders and strikers in the South African PSL, these positions vary from CB (7741m) and a ST (7197m). Both these positions cover the least mean total distance covered by any other positions. This investigation correlates with reports from English FA (Bradley *et al.*, 2009). Both sets of wingers (WB- 8724m and WA- 8301) cover mean distances to each other, where Bradley *et al*. (2009) reported WB (10.710) and WA (11535m). However, Bradley *et al.* (2013; WB=10.649m) and Mallo *et al*. (2015; WB= 10.452m) agreed in both studies with this current study’s results that the WB covers more total distance in that position. In the midfield positions, the CAM (9200m) and the CM (8621m) cover both ends of field and CAM covers the most distance in all the positions on the field.

Figure 5.1 Illustrates how building from the back and tactical flexibility is applied in soccer.

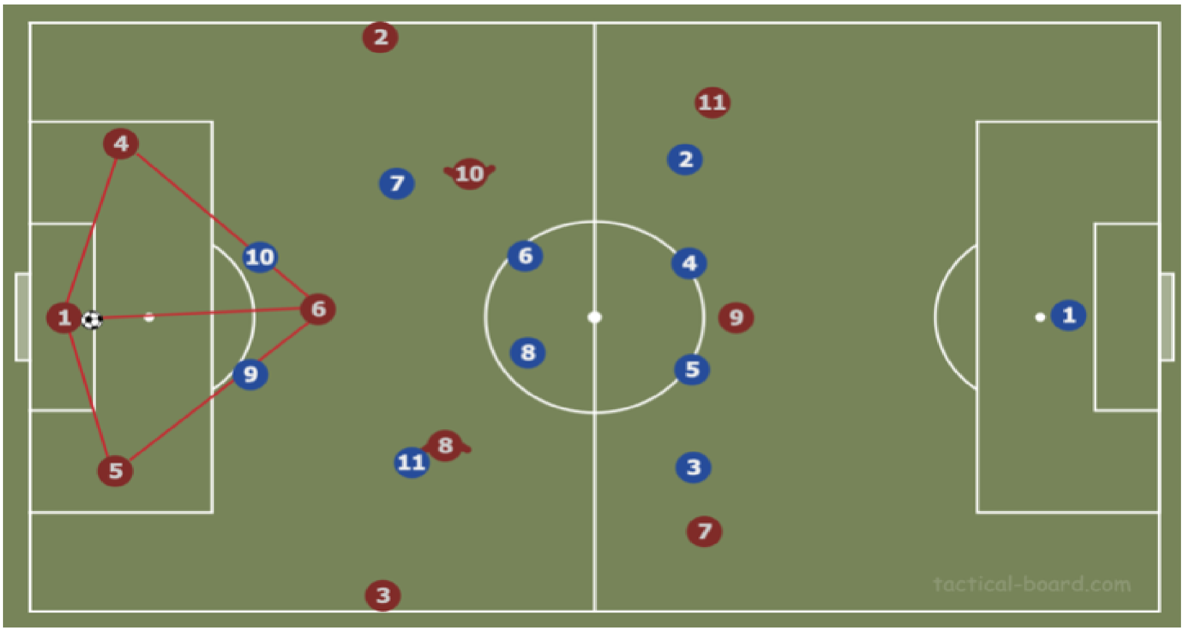
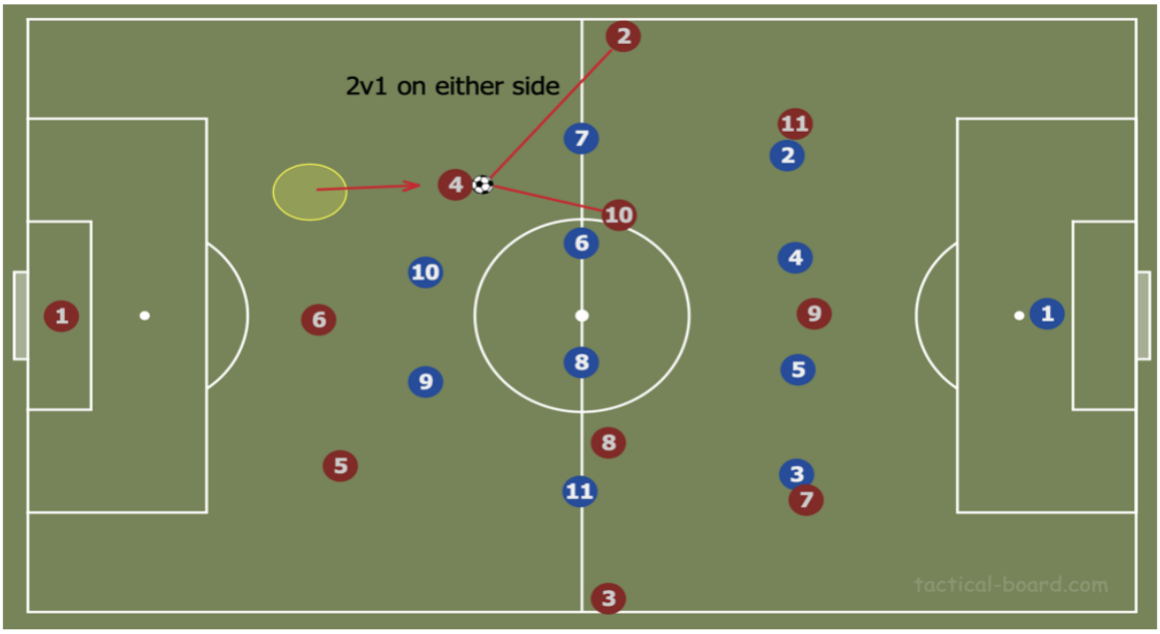


Figure 5.1. Back three using the GK (van James, 2019).

Figure 5.1. Demonstrates the tactical flexibility, and this explains why the CAM (number 10 and 8 on the diagram) get to cover a greater amount of total mean distance in a match. On the other hand, it also shows how the WB (2 & 3) are high and wide to provide the team with width and an option to play out from the back. This relationship between the CAM, WB and the WA (11 & 7) who is converted, comes to the inside as a second ST, is to open a channel for a WB (2 & 3) to overlap or under lap (when WA decides to stay wide). Their second role is to support a Striker (9) and form a 1-3-4-3 formation.

Figure 5.2. Illustrates the middle to offensive third.



Using a 3-4-3 with aggressive CBs to create 2v1s in the midfield

Figure 5.2: Using a 1-3-4-3 with aggressive CBS, "to create 2v1 in the midfield (van James, 2019).

Figure 5.2. Illustrates the end of the build-up phase into the middle offensive third. Take note of the CB (5) and ST (9) which have not moved that much compared to other positions like WB, WA and CAM. This illustration is evidence why CB and ST would cover less distance in a match based on the tactical play employed by teams of late. Teams keep the ball and are patient in trying to break lines and play forward passes. Once they break the first line of defence, which is the opponent's (blue) ST and a CAM, the defenders move forward to minimise the space between them and midfielders (see Figure 5.3).

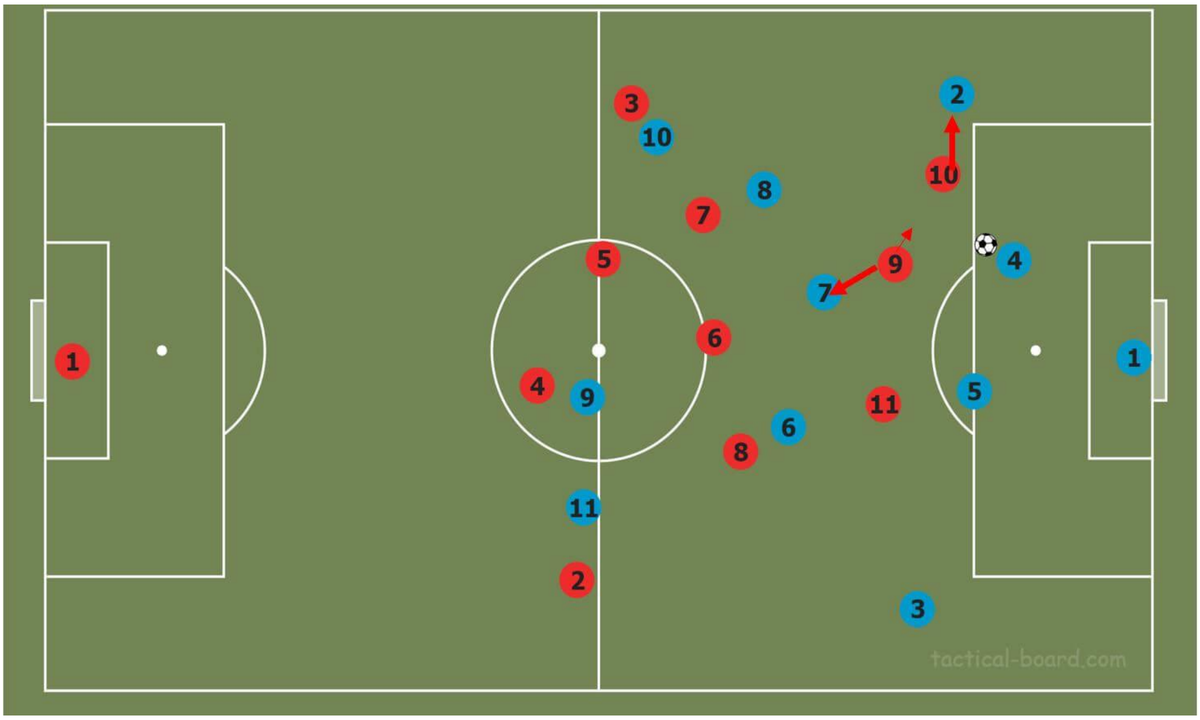


Figure 5.3: Explanation of total distance covered by ST and CB (van James, 2019).

This in turn means that if the ball is lost, the ST (9) and CB (4 & 5) does not have to cover that much ground to get it back. This tactic we call the “High Press”. The defenders can push up high and compress the space in a half field (see diagram 5.3). This is easily executed because of the offside rule that teams can employ. These illustrations demonstrate the significant statistical ($p<0.05$) difference between the CAM and ST.

The findings in this study demonstrate that aerobic activities play an imperative role in soccer. The mean total distance covered by all outfield-playing positions over the 90 minutes of the match suggests that aerobic fitness may be an important factor in soccer conditioning. It also appears that aerobic endurance may be even more important for the midfield positions as compared to the defensive positions (Clark, 2014).

5.3 DISTANCE OF RUNS AND SPRINTS

Running and sprinting forms a paramount part of total distance covered in a match. Clark (2014) noted that, on average, total distance covered by all the players in terms of running during match play is 1580.5 ± 463.7m and distance covered by sprinting 134.7 ± 67.2m. Clark's (2014) study further investigated various positions and the results showed that WA 2022.2 ± 297.4m covered the most distance when compared to CM 1805.1 ± 288.8m. These two positions showed superiority when compared to WD 1607.5 ± 341.0m, ST 1213.0 ± 207.4m and lastly 1000.4 ± 231.6m for CB.

In this South African study, the results demonstrate that CAM and WB cover the most distance in runs: CAM 1106.26m and WB 1074.17m when comparing the least square means. This would make sense as the attacking midfielders are in control of the creativity and making the team play, they collect the balls deep and try to combine with the strikers. Amani (2018) confirmed that midfield players covered the highest distance during the game, because they are the link between defenders and forward players during the matches. Beenham *et al.* (2017) reiterated that midfielders revealed the greatest physical loads during match play, proving further support to their considerably more prominent work rate demands of this positional role. The position that covers the least possible distance is CB 587.32m. As a result, there is a significant difference ($p<0.05$) between CM and CB in terms of run distance in a match.

In reference to sprint distance, Clark (2014) mentioned that the mean sprint distance for the team was 134.7 ± 67.2m and the most distance covered by a single position was by CM 159.9 ± 85.5m followed by WB 142.6 ± 51.2m, ST 137.3 ± 36.2m, CB 108 ± 36.3 and WA 103 ± 50.2m recorded the lowest sprint distance in the team. However, our study shows a strong correlation of wing play from Mamelodi Sundowns. Sundowns wings (WA and WB) cover the most distance across the team. WA covered 267.13 m and WB 255.30m respectively. With these results from this study, it shows the tactical plan of third man sprint (number 2 & 3, Diagram 5.4) on the outside channels from one side of the field to the middle then coming out on the other side. The more central positions covered less distance in sprints CAM 208.93m, ST 183.25m and CM 142.50m. As mentioned before, these intensities could be influenced by different tactical roles, playing styles and playing positions within a team and could be the reason there are similarities and differences between leagues.

Various studies on TMA have been conducted around the globe in different climates and conditions but there has not been a study conducted in South Africa or Africa about TMA. A study by Tuo *et al*. (2019) reflected players coming from AFC, CAF, and CONCACAF covered the least amount of total distance, spent less time playing, and covered least distance in jogging and low-speed running, whereas they spent greater time walking, in contrast with players from UEFA and CONMEBOL. The differences could be because of other environmental factors that we have no control of, and we should take that into account.

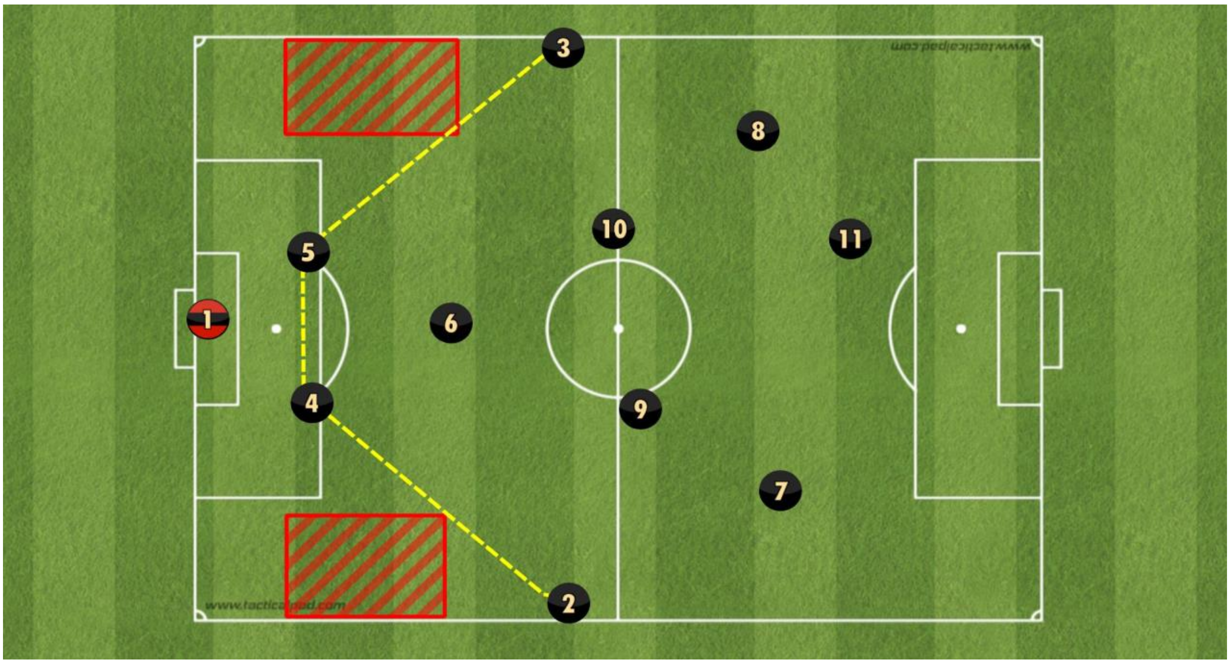


Figure 5.4: An explanation of the relationship between WA and WB

This study is in line with Di Salvo *et al.* (2010) who stated that wide midfielders (WA & WB) executed a higher number of sprints in all five distance categories when compared to other positions (see Figure 5.4). Both this study and that of Di Salvo *et al*. (2010) displayed that sprinting traits are influenced by position. The sprint results from this study demonstrates superiority over the study from Clark (2014).

Overall, the aim of this study in terms of match motion analysis characteristics of South African Premier League players were shown to be remarkably similar to other leagues from around the world regarding positional play. This study confirms that the attacking positions and wing positions in soccer cover the most total distance in the match in terms of runs and sprints and is greater than central midfielders and defenders which is similar with a study from Bush *et al.* (2015). However, to conclude, this study suggest much lower total distance covered in the PSL than International counterparts. Alarmingly, these lower total distances reported in this study range from 1-2 Km less than our counterparts.

CHAPTER 6:

CONCLUSION, RECOMMENDATIONS LIMITATIONS AND FUTURE RESEARCH

6.1 INTRODUCTION

In order to improve player performance in soccer, it is critical to know the physical requirements of the sport when developing sport specific exercise programmes. It is clear from the literature review that various researchers have previously investigated the physical demands of soccer and match play, (Di Salvo *et al*., 2007; Barros *et al.,* 2007; Bradley *et al.,* 2009; Penas *et al.,* 2009; Rampinini *et al*., 2007; Andrzejewski *et al*., 2014; Mallo *et al.,* 2015). Therefore, the aim of this dissertation was to determine the physical requirements of different playing positions in the South African PSL.

With the number of games taking place in the elite or professional leagues, TMA has sparked interest around the world in terms of monitoring players' workload and recovery. A relatively small amount of published literature exists for elite soccer players in South Africa. Therefore, this study was motivated by the lack of studies on African soccer, and specifically South African soccer. The current research studies a team competing in the South African PSL, the CAF Champions League and various competitions within the PSL. A total number of forty-six (46) matches were recorded between the PSL completions and CAF Champions League. The focus was to determine, for the various playing positions, (1) the Total distance covered, (2) Runs, (3) Run distance, (4) Run Distance per run, (4) Sprints, (5) Sprint Distance, and (6) Sprint distance per sprint. , The findings were compared to their counterparts from other leagues, to inform sport scientists and coaches in terms of training and match practices.

The TMA from the present study and the literature review have highlighted a greater understanding of the current running demands of PSL in South Africa versus their international counterparts.

6.2 CONCLUSION AND RECOMMENDATIONS

Numerous studies have attested to the fact that various playing positions in soccer have different physiological and physical requirements (see literature review) and this study confirms these findings. This study can also help aspiring soccer players from club level to understand the physiological demands to play at PSL level and the physical demands at International level.

Chapter 4 presents a detailed TMA of a South African PSL team. The study suggested that:

- All playing positions combined covered a mean total distance of 8494m (7197m-9200m) during a match which is notably lower than total distances reported from international soccer leagues which range from 10.180m-11.680m (Di Salvo *et al*., 2007; Barros *et al.,* 2007; Bradley *et al.,* 2009; Penas *et al.,* 2009; Rampinini *et al*., 2007:b; Andrzejewski *et al*., 2014; Mallo *et al.,* 2015).
- This 1.5-3km difference in total distance covered between PSL players and their international counterparts is alarmingly high. We acknowledge that factors such as climate, game plan, ground surface, height above sea level and level of competition can pay a significant role in total distance, and not only the aerobic basis of the players.

Furthermore, more detailed analysis has shown differences from previous studies conducted in other countries, in terms of total distance covered by various playing positions. This study determined that:

- The physical demands of PSL players differ between the different player positions.
- The lowest distance covered was by ST (7197m), followed by the CB (7741m), which is in contrast to the findings of other studies from Brazil, English premier league and Spanish and Champions League (Bradley *et al.*, 2009; Bradley *et al*., 2013; Dellal *et al*., 2011). In these studies the CB covered the smallest total distance of all playing positions. However, in our study the CAM, WB and CM

cover higher distances than the WA, CB and ST, which finding is similar to the results of Dellal *et al.* (2011).

- The CAM and WB covered the highest run distance of (11646m) and (11252m) respectively; consistently, the same positions made the highest number of runs, namely CAM (78m) and WB (72m). The WA covered the highest sprinting distance (299m), narrowly followed by the WB (278m). The lowest sprint distance was registered by the CM (99m) and CB (101m). The WA performed a greater number of sprints (19) closely followed by the WB with a total of 17 CM and CB listed the lowest number of sprints in a match 7.
- Again, the total distance covered by players in the different playing positions in this study, is consistently lower by 1-2km than the distances covered by their international counterparts.

With the information presented by the study, sport scientists, strength and conditioning coaches and coaches should be motivated to adapt their training and periodization plans. Coaches should be able to manage a periodization plan and most importantly an individual periodization plan. With the technology that is available in modern day sports, coaches can use the information from these technologies to;

- Periodize the season
- Prescribe individualised programs
- Plan day to day sessions
- Load management strategies
- Recovery strategies
- Overall substitution system of the team

As mentioned before, different positions require different physiological and physical requirements. Sport specific programs should be designed based on the individual player and the position they are playing. For example, a CB's programme would include more strength training, vertical jumps, acceleration whereas WB would focus on both aerobic and anaerobic training, power training, speed 0-20 and change of direction. Strength & Conditioning coaches should analyse the position and the demands of the formation the team is more accustomed to play. Using HR data would also provide information when examining activity patterns in substitution box.

In conclusion, this study revealed compelling differences with international counterparts' in regards to TMA analysis, especially in total distance running and between the different positions. With that being said, coaches should adopt a holistic approach when they plan for the season, this would help in eliminating or minimizing risk of injuries and most importantly help players to perform at their best.

6.3 LIMITATIONS AND FUTURE RESEARCH

Using an elite player group during the PSL competition may provide the most representative data for elite South African soccer players, but it also poses some challenges. As this is the first study in South African PSL there is no comparison to any other study in South Africa. Due to the reluctance of clubs (teams) to share data, the findings of this study had to be compared to findings of studies outside the African continent. However, there might be significant differences in performance due to uncontrollable circumstances such as environmental factors, social aspects, cultural differences, historical backgrounds and geographical differences (Tuo *et al*., 2019).

Furthermore, injuries to players during matches in the PLS competition may influence coaching tactics, and also the different style of refereeing by referees can confound results. Furthermore, the effect of the opposition team on physical and technical performance is not measured. Climate, ground surface, and height above sea level may differ between countries. Therefore, comparing the results of the current study with overseas counterparts has some challenges. However, this study suggests that South African soccer can improve by more intense aerobic conditioning of players in all the different positions, or by a more fast-paced playing style, or both.

A further challenge were the various definitions for the different movement classifications used in different studies in the literature. As discussed in the aforementioned literature (literature on TMA ion International soccer teams), the discrepancies found with regard to "maximal velocities and time spent per speed band" could be due to pre-determined speed bands being used instead of individualized speed bands.

It must be mentioned that the effect of home versus away play in South Africa, in particular for teams that do not own their own stadiums, is not that relevant. With the busy schedule of soccer these days, players are affected by injuries and some are monitored and protected from any risk of getting injured; this means we do not have continuous data for all these players.

Financial implications can be a significant limitation in terms of travelling arrangements, nutritional intake, recovery strategies and sleeping arrangements; lastly, there is not enough capital to even employ (GPS) TMA in the financially constrained teams.

For future research in South Africa and around the continent, to the effect of travel could be investigated, seeing that successful teams play in a large country and continent. These teams could be studied from the point of view of playing in a different province in your own country, or having to travel to other countries like Morocco (7,622 km) or in Egypt (6,405km). The question that could be explored is how the distance travelled affects performance.

One could also investigate TMA based on the status of the game (winning, draw or losing) and the output of variables it will present. Various studies in Europe indicated teams winning the match tend to cover the greater distances.

Seeing that in South Africa players like to express themselves with the ball and run with the ball, the findings would provide valuable information based on the technical, tactical and physical attributes required in the match. Furthermore, differences between the first and second half of a match should be investigated. There seems to be a decline in intensity from the first to the second half, in modern soccer. A study in this regard could be vital for improvement of match performance.

Some components measured by the Catapult Minimax X4 not investigated in the current study include the following:

- Number of times a player executes the various movement classifications during match play,

- Work-to-rest ratio,
- Total number of accelerations,
- Total number of jumps,
- Player load in the three different axes (frontal, sagittal and transverse),
- Distances covered in different velocity bands, and
- Heart rate response.

To conclude, the question remains whether the availability of TMA data will make a significant difference in performance and the outcome of the match. The researcher recommends that future research should investigate whether TMA analysis has any influence on the performance of soccer teams. Ideally, all PSL teams are analysed and documented, to compile a comprehensive database of GPS data on soccer players in South Africa. Going even further, similar studies could be conducted on different levels of soccer in South Africa, including at junior (school) level.

CHAPTER 7:

REFLECTION OF THE STUDY

7.1 INTRODUCTION

In this last chapter, I reflect on my journey in concluding this study. Research can be an overwhelming process that can make you question yourself; you ask, “whether you really want to do this”. The world of sport and science is an ever-changing world and my enthusiasm to learn and the risk or opportunity to be at a forefront of changing the world or maybe inspiring a mind (thought) that will change the world was enough to spur me on to continue with this study. Lewis and Williams (1994 p.1) once said “Experimental learning means learning from experience or learning by doing”— what better way for me to learn than to dive in headfirst.

7.2 REFLECTING ON THE PROCESS

After my honours programme, I thought I had an idea of what I was getting myself into, but I soon realised my background is inadequate. Therefore, I researched the process on how to keep your study going and on time when you have to submit. I wracked my brain trying to figure it out until I decided to go to the ‘NET’ and stumbled on these simple 6 steps:

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

STEP 1: FIND THE RIGHT SUPERVISOR AND THE RIGHT TEAM.

This was the easiest part of my research. For me it was a no-brainer as I have been working with the world class Prof. F.F. Coetzee, who has had an impressive career with the South African Rugby team in 2004, 2007 and 2011. He has been my mentor from my entire undergraduate degree and he was always eager to feed my enthusiasm to learn, what a way to pick his brain one last time - "the last supper". The difficult part was what I actually wanted to investigate in South African soccer; the idea of what I wanted to investigate was there but I could not put it into a research question and that is where you need a supervisor. If I had any doubt before, at that particular moment I knew I had picked the right supervisor and most of all an expert in his field.
Everything started falling into place and we became a moving train once he brought in two other exceptional colleagues and professionals in their fields. Dr R. Schoeman (who had just finished his PHD in Time-motion Analysis in rugby union) was approached to become a co-supervisor since we had decided what we are doing. Last but not least, Prof R. Schall was the final key to this team, who is a Biostatistician. "They say two heads are better than one, now imagine four!

STEP 2: DON'T BE SHY, ASK!

At this stage I had picked a team and I was sticking to it, they had been in the industry for the longest time and any question that I had in my mind I knew it was going to be met by an astute answer. Oprah Winfrey said, "You get in life what you have the courage to ask for," as I had mentioned before, about my enthusiasm to learn. And I asked to get clarity and gain knowledge at the same time and that is what I received.

STEP 3: SELECT THE RIGHT TOPIC

With my background of soccer in South Africa, I knew what I was interested in, and what I wanted to find out in terms of my research project. I pitched the idea to Prof. Coetzee after one of my travels with the national teams. We went to visit one of the big European teams and they emphasised the importance of time motion analysis and that is when it hit me that, even if we do it in South Africa, there is no data on it. This was enough for me to take on this task because of “an opportunity to be at a forefront of changing the world soccer in South Africa or maybe inspire a mind (thought) that will change it”.

STEP 4: KEEP YOUR PLAN REALISTIC

When I saw this, I chuckled a bit because I thought how can I try to change or spark a mindset that will change soccer in South Africa if I were to keep my plans realistic? This thought came to my head because I was not in the PSL environment. I had to find a big team in the country that was dominating our local league and continental soccer.

STEP 5: PREPARE A PROJECT TIMELINE

The aim of this research was to investigate “Motion Analysis in the South African Premier Soccer League using GPS Technology” by using retrospective data on specific variables over a three-year span. Inclusion criteria meant that the participants needed to be part of Mamelodi Sundowns FC. Data was collected and analysed from 2017, 2018 and 2019. Dates were projected so we could finish the research protocol within the allocated time frame.

STEP 6: WRITE, WRITE, WRITE…

With the schedule that we tend to have, it seems almost impossible to sit down and write. That is what I used to say but I soon found out that is just a procrastination mechanism, because as I am typing this out, I have been writing for the past four weeks, religiously, every day. All I needed was to get past those times where the going felt tough and I did not feel like writing. **If you have decided to commit to anything, do it religiously until it is completed. Never make a mistake of waking up every day to decide on that commitment.**

Like the heading said, ‘write, write, write’ and one day your own findings could be compared to previous research and you will have contributed to the field in some way.

7.3 PERSONAL REMARKS

If you had asked me a year ago if I was thinking of doing my PhD, I would have said "NO" but through this process, mistakes were made, and I learned immensely about myself through this process. I have grown as an individual and in my field of practice. My writing skills have improved, and I learned that this process takes time and patience.

Along the way during this project mentors became colleagues and I am looking forward to continue in nurturing these relationships long after this research is done. I respect these three gentlemen, Prof. Derik Coetzee, Prof. Robert Schall and Dr. Riaan Schoeman even more after this process because they do this year in year out, which shows their abundance of knowledge, experience, patience and dedication to their profession and helping me and inspiring me to sit at that same table with them one day.

Lastly, every story has an end but in life every ending presents a new beginning.

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Appendix A

Approval: Health Science Research Ethics Committee

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Dear **Mr Kopano Melesi**

Health Sciences Research Ethics Committee

19-Mar-2019

Ethics Clearance: **Time Motion Analysis in the South African Premier Football League using GPS Technology**

Principal Investigator: **Mr Kopano Melesi**

Department: **Exercise and Sport Sciences Department (Bloemfontein Campus)**

APPLICATION APPROVED

Please ensure that you read the whole document

With reference to your application for ethical clearance with the Faculty of Health Sciences, I am pleased to inform you on behalf of the Health Sciences Research Ethics Committee that you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2019/0170/2603**

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the HSREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

A progress report should be submitted within one year of approval, and annually for long term studies. A final report should be submitted at the completion of the study.

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.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research. Yours Sincerely

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
IRB 00006240; REC 230408-011; IORG0005187; FWA00012784
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 B

PERMISSION LETTER (SUNDOWNS)

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

1118 Molokoane Street

Batho location

Bloemfontein

9300

20 September 2018

Research title: Time Motion Analysis in South African Premier Soccer League using GPS Technology

Dear Mr. Kabelo Rangoaga

Head of Sport Science (Mamelodi Sundowns)

I, K.Z. Melesi and the Department of Exercise and Sport Sciences of the University of the Free State, are doing research on the physical demands in South African Premier Soccer League using GPS Technology. 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 Mamelodi Sundowns in the premier soccer league season. Data from every player who wore the GPS unit will be used. Data will be downloaded to a personal computer and further analysis will be carried out using system software provided by the manufacturer.

The Aim of this study is:

1) To determine the physical demands of elite soccer players.
2) To implement time motion analysis to ascertain the movement activities of elite soccer players and to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain tri-axial accelerometer data from the participating Soccer players on:

The following variables will be investigated:

(1) total distance covered

(2) sprint distance

(3) Run distance

(4) Number of runs

(5) Number of sprints.

The data collected will be invaluable for future use by all involved and serve as a sport specific tool for developing conditioning and training programmes. The study will only commence once ethical approval has been obtained from the Health Sciences Research Ethics Committee.

Contact details of Secretariat and Chair: 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– for reporting of complaints/problems

Kopano Z Melesi 0817479968
kmelesi@yahoo.com

With this letter I would like to request permission from you to conduct my research on the team for the season of 2017-2018.

I, Kabelo Rangoaga hereby give permission to K.Melesi to collect and analyze accelerometer data from Mamelodi Sundowns players, who meet the inclusion criteria, and to publish the results for his study.

____
Signature

APPENDIX C

PERMISSION LETTER (SAFA)

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

1118 Molokoane Street
Batho location
Bloemfontein
9300
20 September 2018

Research title: Time Motion Analysis in South African Premier Soccer League using GPS Technology

Chief medical officer South African Football Association (SAFA)

I, K.Z. Melesi and the Department of Exercise and Sport Sciences of the University of the Free State, are doing research on the physical demands in South African Premier

Soccer League using GPS Technology. In this study we want to learn more about what actually happens in a Soccer match using GPS as a measuring tool.

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The Aim of this study is:

1) To determine the physical demands of elite soccer players.
2) To implement time motion analysis to ascertain the movement activities of elite soccer players and to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain tri-axial accelerometer data from the participating Soccer players on:

The following variables will be investigated:

(1) total distance covered
(2) sprint distance
(3) Run distance
(4) Number of runs
(5) Number of sprints.

The data collected will be invaluable for future use by all involved and serve as a sport specific tool for developing conditioning and training programmes. The study will only commence once ethical approval has been obtained from the Health Sciences Research Ethics Committee.

Contact details of Secretariat and Chair: 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– for reporting of complaints/problems

Kopano Z Melesi
0817479968
kmelesi@yahoo.com

With this letter I would like to request permission from you to conduct my research on the team for the season of 2017-2018.

I, Dr Thulani Ngwenya, hereby give permission to K.Melesi to collect and analyze accelerometer data from Mamelodi Sundowns players, who meet the inclusion criteria, and to publish the results for his study.

Yours sincerely,

....

Signature

Dr. Thulani Ngwenya
Head of Department
SAFA Medical Department

APPENDIX D

INFORMATION DOCUMENT

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

Research title: Time Motion Analysis in South African Premier Soccer League using GPS Technology

Dear Participant

I, K.Z. Melesi am doing research on the physical demands in South African Premier Soccer League. This research wishes to evaluate real-time measurements of 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 soccer teams during the Premier soccer league season.

What is involved in the study - Data will be collected from all matches played by Sundowns, during the Premier Soccer league Season. Every player's 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: distances covered, velocities achieved, direction changes, body impacts, work to rest ratios and the implications for fitness training. Results will be published in relevant sports performance journals.

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.

Costs Involved: There is no payment for your involvement in this study and no “out of pocket” expenses will be expected of you.

Possible Risks: Participation in soccer association carries with it an inherent risk due to the physical contact that is part of the game. Participants will not be placed under additional risk from participating in the study. There may be a small risk of injury associated with the unlikely event of receiving direct contact on the GPS unit itself.

Possible Benefits: The information gathered during this study will provide a better knowledge and understanding of the game which will assist coaches and conditioning staff to improve training and fitness programmes 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 any ensuing publication. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.

Contact details of researcher:

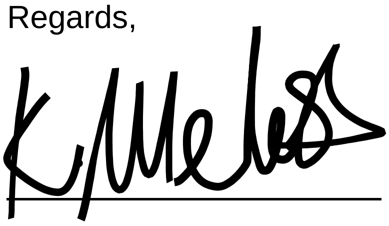
Kopano Zabulon Melesi
Tel: 0817479968

Email: kmelesi@yahoo.com

Contact details of Secretariat and Chair: Health Sciences Research Ethics committee of the University of the Free State – for reporting of complaints/problems: Telephone number (051) 405 2812

Thank you for participating in this research project.

Regards,



Kopano Melesi

Principal researcher

APPENDIX E

INFORMED CONSENT FORM

Research title: Time Motion Analysis of in South African Premier Soccer League using GPS Technology

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 Mamelodi Sundowns Team. This research will investigate the physical demands placed on soccer players during the South African Premier Soccer League matches. It is hoped that the findings of this study will assist your coaches and conditioning staff to improve your training and fitness programmes 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 need 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.

Contact details of researchers:

Kopano Zabulon Melesi
Tel: 0817479968
Email: kmelesi@yahoo.com

Prof Derik Coetzee
Tel: 051 401 2944
Email: coetzeef@ufs.ac.za

You may contact the Secretariat of the Health Sciences Research Ethics committee of the 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.

____

Name and surname

____

ID Number

__________________________	______________________
Signature of Participant	Date
__________________________	______________________
Signature of Witness	Date

APPENDIX F

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